WATER AVAILABILITY AS A CONSTRAINT ON CHINA'S FUTURE GROWTH

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ABSTRACT

Recent writings on China’s water situation often portray China’s water problems as severe and suggest that water availability could threaten the sustainability of China’s future growth. However, China’s high growth of the last 20 years or more has been obtained with relatively little increase in the physical volume of water. In this paper, we use a growth accounting approach to investigate both the contribution played in the past by water availability in constraining China’s growth performance, and what would be involved in the future. We use a modified version of Solow growth accounting in which water in efficiency units enters the production technology, and investment in water management assets raises efficiency of water use. Our results suggest that if investments in water assets in the future were lower than they were in the past, growth might slightly increase by about 0.1 percentage points if non-water capital and water in efficiency units are close substitutes but growth rates could decrease by as much as 0.2-3.9 percentage points if investments in water assets were small, and if the elasticities of substitution were low. On the other hand, our experiments suggest that with faster growth of investments in water assets than in the past and a low elasticity of substitution growth rates could increase. But if non-water capital and water in efficiency units are close substitutes growth rates could even decrease, as in other cases.

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1. Introduction

There has been considerable discussion in popular writings on China's potential to continue high growth performance at rates comparable to those prevailing before the 2008 financial crisis of water availability as a constraint on future growth prospects (Naughton, 2007; Shalizi, 2008; Gleick, 2009; Jiang 2009; World Bank, 2009). In agriculture growing consumption of grains, the grain requirements of sharply increased meat consumption, falling water tables in the North China plain and rising water demands from increased agricultural output have all attracted attention. And in urban areas sharply increasing water demand from rapid urbanization and industrialization are thought to play a similar role.

Over the past 20 years, however, China has been able to experience continued high growth with relatively small increase in the physical volume of water used. Since 1990 China's GDP growth has been around 10% per year while water use increased by only 14.8% in total between 1993 and 2009. Agricultural water use, which is the largest user of water in 2009 accounting for about 63% of total water use, decreased by 8% between 1993 and 2009. Agricultural water use increased until the mid 1990s but decreased later as agricultural water use efficiency increased (Jin and Young, 2001; Shalizi, 2006). This has been achieved through increased investment in water treatment plants, improved irrigation and water management, and water diversion and other infrastructure projects. The throughput of water volume in the economy has grown much more slowly than the economy in general, since through investment in water management assets the speed and ease of reuse has increased. Thus, water use per capita in China differs by only small amounts from much higher income per capita economies in Europe and North America, and has changed far less over time than GDP, suggesting water availability need not be a serious impediment to future higher growth.

Here we investigate water availability as a potential constraint on Chinese growth using a growth accounting framework in which water enters the aggregate production function along with capital and labour, but in efficiency terms reflecting speed and quality of water treatment. The efficiency of water use can be raised through investment in water management and so Chinese investment is differentiated between water management assets and all other assets. Using calibration procedures we calibrate a water efficiency function which relates increments in efficiency units of water to investment in water assets in each period using a power function. We then perform growth accounting analysis for the period 1998-2009 using this structure, and forward project growth rates using various assumed investment rates in water and other assets over a 10 year period.

Our results suggest that if water asset investment occurs at similar rates as for other assets, water availability need not constrain future high growth in China. The extent of any such constraint depends on the elasticity of substitution in technology. Water constraints also depend on elasticities of substitution between water and other inputs in production.

2. China’s Water Situation

Recent writings on China’s water situation often portray China’s water problems as severe and suggest that water availability could threaten the sustainability of China’s future growth (Shalizi, 2008; Gleick, 2009; Jiang 2009; World Bank, 2009). Gleick (2009) reports that China’s water problems are poor water quality, water-related environmental disasters, water availability and quantity, groundwater overdraft, floods and droughts, climate change and water, water and politics and growing regional conflicts over water. Since 1980 China’s water quality[2] decreased due to rapid industrialization, urbanization and intensive use of agricultural pesticides and fertilizers. Water in China is severely contaminated with pollutants from untreated industrial and municipal wastewater and from agricultural pesticides and fertilizers. It is estimated that 40% of surface water can be used only for industrial or agricultural use (Gleick, 2009) and that water quality in 20.7% of China’s river length in below class V, which means that it is not safe for human contact or appropriate even for irrigation (Naughton, 2007). The World Bank (2009) estimates that water that is below class V is used to irrigate about 7.4% of China’s irrigated land especially in North China plain. This type of water is essentially wastewater that lowers harvests and reduces the quality of crops.

In addition to water quality deterioration, water shortage is another major source of concern. Water is unevenly distributed between Southern and Northern China, with Northern China having far less water per capita than Southern China. This uneven distribution of water has led to reliance on groundwater in the North China Plain which is unsustainable. Water is extracted from underground faster than the natural capability of reload and this has caused the water table to fall especially in Hebei province. In the Hai River basin water tables fall by 0.5 m per year and in Beijing groundwater tables fell by 100-300 m (Jiang, 2009).

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[2] As measured by biological oxygen demand and chemical oxygen demand. Water quality decreases as it is depleted of oxygen and the increasing presence of heavy metals and chlorinated hydrocarbons in the water also decreases its quality (see Naughton, 2007).

Climate change compounds China’s water problems because rising temperatures accelerate the melting of glaciers (Gleick, 2009). China is one of the largest countries in the world covered by glaciers. However, due to climate change it is estimated that glaciers decreased by about a third in the past century. In many regions in China, water is obtained from glaciers melting and the loss of glaciers leads to fewer water resources.

Another recent study by Jiang (2009) suggests that the severity of China’s water problems could threaten China’s food security and extends China’s water problems to a global scale. If China had to rely on global markets to feed its population it could have major impacts on the global economy through increasing demand of food and increasing prices for food products. Brown (1996) goes even further and says that “China’s water scarcity will become the world’s water scarcity”. He suggests that China’s rapid industrialization and increasing incomes will increase the demand for food and combined with water scarcity could led China to rely heavily on food imports.

Despite all of the problems related to water availability, while China’s economic growth over the last 2 decades was high this growth was achieved with little increase in physical water use. Table 1 reports data on China’s water use and real GDP growth from 1997 to 2009. The data show that water use increased very little. In 1997 water use (measured in 100 million cu.m.) was 5,566 and it increased to 5,965 in 2009, a 7.2% increase. In contrast, real GDP (measured in 100 million 1995 yuan) increased from 72,493 to 204,251, a 181% increase, over the same period.

The slow growth in water use over the last decade was achieved by increased investment in water treatment plants, improved irrigation and water management, and water diversion and other infrastructure projects. Table 1 reports growth rates of investments in non-water assets and growth rates of investments in water assets. Investments in water assets grew 3-4 times faster than investments in non-water assets in the period 1997-2000. In 2001 the growth rate of investments in water assets was almost zero and picked up again in 2002-2004 when it was almost the same at the growth of investments in non-water assets. In 2009 the growth rate of investment in water assets reached 58%, the highest since 1997.

Table 1: Water Use, Real GDP, Growth Rates of Water Use, Growth Rates of Real GDP, Growth Rates of Investments in Non-Water Assets and Growth Rates of Investments in Water Assets, China, 1997-2009

Year	Water Use (in 100 mill. cu.m)	Real GDP (in 100 mill 1995 yuan)	Growth Rates of Water Use (%)	Growth Rates of Real GDP (%)	Real Growth Rates of Investments in Non-Water Assets (%)	Real Growth Rates of Investments In Water Assets (%)
1997	5,566.03	72,493.33	n/a	8.80	6.02	14.97
1998	5,435.39	78,147.81	-2.35	7.80	9.70	41.01
1999	5,590.88	83,696.30	2.86	7.10	6.76	30.02
2000	5,497.59	90,392.00	-1.67	8.00	9.18	26.68
2001	5,567.43	96,990.62	1.27	7.30	11.44	0.89
2002	5,497.28	104,749.87	-1.26	8.00	15.21	19.56
2003	5,320.40	114,491.61	-3.22	9.30	20.07	16.11
2004	5,547.80	125,368.31	4.27	9.50	15.16	19.48
2005	5,633.00	138,155.88	1.54	10.20	12.32	8.54
2006	5,795.00	153,491.18	2.88	11.10	17.12	3.64
2007	5,818.70	171,756.63	0.41	11.90	13.79	12.30
2008	5,910.00	187,214.73	1.57	9.00	13.14	13.43
2009	5,965.20	204,251.27	0.93	9.10	24.46	58.85

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

Table 2 shows that nominal investments in water assets increased 17 fold in the last 14 years from 29 to 503 billion yuan (nominal investments in non-water assets increased 7.5 fold over the same period). Investments in the period 2006-2009 totaled 1,314 billion yuan and surpassed the investments for the period 1995-2005 which totaled 1,168 billion yuan. Moreover, the Chinese government announced that investments in water assets would amount to 4 trillion renminbi over the next 10 years[3] which is twice as high as investments made in the last 10 years. The largest investments are in management of water conservancy which account, on average, for 53% of total investments and investments in production and supply of water which account for 27% of total investments. Data on investments in drainage works and treatment in wastewater are not available before 2000 or there were no investments in these, but

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[3] See Xinhua, (2012), 'Water shortage, pollution threaten China's growth: official', available at http://news.xinhuanet.com/english/china/2012-02/16/c_131414176.htm.

after 2000 investments in drainage works account for 17% of total investments and investments in treatment of wastewater account for 6.5%.

Table 2: Nominal Investments in Water Assets by Sector (in 100 mill. Yuan) China, 1995-2009

Year	Nominal Investment in Water Assets	Nominal Investment in				
		Production and Supply of Water	Geologic Prospecting	Management of Water Conservancy	Drainage Works	Treatment of Wastewater
1995	297.16	123.10	25.30	148.70	n/a	n/a
1996	391.32	152.50	23.20	215.70	n/a	n/a
1997	457.53	155.00	19.70	282.80	n/a	n/a
1998	643.86	177.20	23.80	442.80	n/a	n/a
1999	833.82	177.90	20.90	566.20	n/a	68.80
2000	1,067.90	187.50	18.20	603.40	149.30	109.60
2001	1,081.71	188.80	11.60	583.90	224.50	72.90
2002	1,295.89	197.90	18.20	733.40	275.00	71.50
2003	1,537.77	337.20	25.70	712.30	375.20	87.40
2004	1,940.18	460.90	25.30	996.00	352.30	105.60
2005	2,139.52	508.70	61.50	1,067.60	368.00	133.70
2006	2,250.59	654.90	59.80	1,053.20	331.50	151.10
2007	2,625.96	835.70	78.60	1,105.60	410.00	196.10
2008	3,243.71	1,045.40	87.30	1,420.40	496.00	194.60
2009	5,028.92	1,755.70	176.00	2,217.90	729.80	149.50

Source: China Statistical Yearbook (1996-2009)

Even though water quality is still below national standards in many rivers, China made significant progress at improving the treatment rate of wastewater through investments in wastewater treatment facilities. Wastewater treatment is a relatively recent phenomenon as can be seen from the data. In 1980 China had only about 20 wastewater treatment plants which were small with low capacity of water treatment. Through increased investment, in 2000 the number of wastewater treatment facilities increased to 400. The urban wastewater treatment rate increased from 16.2% to 35% in 2000.[4] In 2005 the municipal wastewater treatment rate was 45%. The 11th Five Year Plan set a target to increase the municipal wastewater treatment rate to 70% by 2010. However, in small cities, towns and rural areas the wastewater treatment rate is still

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[4] See OECD (2004), "Financing Strategy of the Urban Wastewater Sector in Selected Municipalities of the Sichuan Province in China", available at http://www.oecd.org/dataoecd/44/23/2408767.pdf.

much lower and overall in China it seems that wastewater treatment rate is as low as 20%. In 2002, 500 municipal treatment facilities operated in 310 of the 660 of cities, but 17,000 towns had no municipal wastewater treatment facilities (OECD, 2007). Compared to the OECD, the share of China's urban population connected to wastewater treatment plants in the early 2000s was about 33%, while in the OECD on average it was 64% and in some countries such as Germany and UK it was as high as 90-95%.

Industrial wastewater treatment has also improved in the last 10-15 years. According to the OECD (2007) there were more than 60,000 industrial wastewater treatment plants built in China and about 90% of industrial discharge complies with national standards. The building of so many wastewater treatment plants came as a result of Chinese policy that required industries that are heavy polluters to treat the water or to close the enterprise if water treatment was not feasible.

In the agricultural sector, which is the largest user of water, water saving technologies have also been expanded in recent years (see Blanke et al, 2007) which increases the efficiency of water use[5]. Blanke et al. conducted two surveys in Northern China provinces covering more than 400 villages and found that the most benefit in water saving came from water saving technologies adopted at the household level. In the early 1990s the rates of use of household water saving technologies accelerated. In 1995 surface pipe use was 23% and in 2004 it increased to 48%. The use of other water saving technologies at household level have also increased such as drought resistant technologies, plastic sheeting and retaining stubble. On the other hand, traditional technologies (such as border irrigation, furrow irrigation, level fields) and saving technologies at community level (such as underground pipe, lined canal and sprinkler) grew more slowly. For example, the adoption rate of lined canals increased between the early 1990s and 2004 but the adoption is still low at only 25% in Northern China. The water saving technologies that expanded more slowly require high fixed investments. But even though water saving technologies in agriculture expanded in recent years in

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[5] Water use efficiency is defined as crop production at the field level per unit of water input (see Blanke et al (2007).

China increasing water use efficiency, the efficiency of irrigation is still low (40-50% in China and 55-65% in North China Plain) (see Blanke et al. 2007; Hubacek and Sun, 2007).

China has also undertaken major investments in projects to transfer water from the South to water scarce Northern China. A South-North water transfer project is being built to transfer 45 billion cubic meters per year to the North China Plain from the Yangtze River basin by 2020 and it was approved in 2002 (OECD, 2007; Gleick, 2009). The construction of a western route was expected to begin in 2010 and will transfer 17 billion cubic meters per year at a cost of around USD 37 billion. The central route will transfer 14.6 billion cubic meters by 2020. The eastern route already transfers 9 billion cubic meters and this will increase by 2020 to 13 billion cubic meters. The costs for the eastern and central routes will be USD 14.5 billion and USD 3 billion in resettlement costs. However, even all this may not be enough to meet China's growing demands for water. According to the Ministry of Water Resources (2007) additional investments in key water projects were 96 billion yuan to harness 717 large rivers and lakes which were under construction in 2007, 63 billion yuan accumulative investment in reservoir projects including completion of Phase-III of the Three Gorges Project, investments in irrigation, drainage and rural water supply, rural hydropower and electrification, soil and water conservation and ecology restoration and capacity building.

3. China’s Growth and Water Constraints: A Growth Accounting Approach

We use a growth accounting framework to assess both the past and potential future effects of water availability on China’s real output growth. Unlike in traditional growth accounting exercises which use only two factors of production (capital and labour) and total factor productivity, here we add a third factor of production, water. This, however, enters the production function in efficiency units to also reflect water treatment and recycling as well as physical volume. Thus if investment in recycling occurs, water in physical volume terms need not expand for water in efficiency units to increase. We distinguish between Chinese investments in water assets and investments in all other assets. Investments in water assets increase the efficiency of water use, but the resources shifted to improve water use efficiency cannot be used in other productive activities.

Growth accounting exercises decompose the growth rate of output into a growth rate of factors of production (capital, labour and water) and a growth rate of total factor productivity (TFP). Thus, it is possible to find what portion of China’s growth is attributable to the growth in capital stock, labour and improved water use efficiency. Total factor productivity in the growth accounting exercise is a “residual” and it accounts for the growth in output that is not explained by the growth in factor inputs weighted by their respective shares in national output. Essentially, the growth of total factor productivity accounts for the efficiency change in the combined use of capital and labour but because it is “residual” total factor productivity can embody many other things in addition to efficiency change such as technological progress and omitted variables.

Growth accounting originates with Solow (1957) who ran an experiment on the US economy for the period 1909-1949 using 2 factor inputs (capital and labour). Solow wanted to find out how much of the increase in output per man hour was attributable to technical change (shifts in the production function) and how much was attributable to the increase in capital per man hour (movements along the production function). His results showed that 87.5% of the increase in output per man hour in the US was due to technical change and 12.5% of the increase was due to an increase of capital per man hour. His initial calculations were modified and extended in various ways in Kendrick (1961), Denison (1962), and Jorgenson and Griliches (1967).

More recently, Wang and Yao (2003) and Whalley and Zhao (2010) have used a growth accounting framework to find the contribution of total factor productivity and factor input growth to China's economic growth. They also incorporate human capital accumulation into the growth accounting exercise. They find that human capital accumulation played an important role in the growth of Chinese economy. They use a Cobb-Douglas production function.

Here, we assume that China's production function can be characterized by the following three factor input function, with capital, labour and water as inputs

$$Y_t = A_t F(K_t, L_t, e_t \overline{W}) \tag{1}$$

where Y is the output, A is total factor productivity, K is the capital stock in non-water assets, L is the quantity of labour, $\overline{W}$ is the quantity of water used and e is the efficiency of water use. The quantity of water use changes little over time, which is represented by the bar sign on $\overline{W}$. The e_t that we use in the production function allows for water management-augmenting technological progress which is the result of investments in water assets; that is, even though the growth of water use remains constant, if water-augmenting technological progress through investments in water assets increases it is as if water inputs would grow with unchanged technology[6]. Thus water use does not have to increase in order to increase output; water use could remain constant and if China invests in more water management assets, water is used more efficiently and water is not a constraint.

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[6] See Solow (1978) for discussion on resources and economic growth.

Here, we use a two-level, three factor CES production function with non-water capital and water in efficiency units in the nested function and labour as a substitute[7] to the composite of non-water capital plus water in efficiency units (see Kemfert, 1998[8]):

$$Y_t = A_t \left[a\{(bK_t^{\frac{\gamma-1}{\gamma}} + (1-b)(e_t W_t)^{\frac{\gamma-1}{\gamma}})^{\frac{\gamma}{\gamma-1}}\}^{\frac{\sigma-1}{\sigma}} + (1-a)L_t^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

where A_t is Hicksian neutral technological progress, γ is the elasticity of substitution between non-water capital and water, σ is the elasticity of substitution between labour and the composite of capital and water and a and b are share parameters.

The elasticity of substitution, γ, shows how easily water and non-water capital can be substituted for each other, and the elasticity of substitution, σ, shows how easily labour and the composite of non-water capital and water can be substituted for each other. With an aggregate production function that has an elasticity of substitution less than one the diminishing returns to the faster growing factor occur faster than otherwise. For given water augmenting technological progress, and a given elasticity of substitution between water and non-water capital, as the implicit price of water increases, the share of water in the production also increases.

Taking natural logarithms, equation (1) becomes:

$$\ln(Y_t) = \ln(A_t) + \frac{\sigma}{\sigma-1} \ln\left[a\{(bK_t^{\frac{\gamma-1}{\gamma}} + (1-b)(e_t W_t)^{\frac{\gamma-1}{\gamma}})^{\frac{\gamma}{\gamma-1}}\}^{\frac{\sigma-1}{\sigma}} + (1-a)L_t^{\frac{\sigma-1}{\sigma}} \right] \tag{3}$$

From equation (3) we can estimate $\ln(A_t)$, the value of total factor productivity as:

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[7] It is common to argue that water and capital are pairwise complements. In this function, substitutability only occurs between the composite of capital and water and labour, and so there is no calibration for the pairwise capital-water substitution possibilities. Kemfert (1998) discusses this also.

[8] Kemfert (1998) investigates the substitution elasticities between capital, energy and labour for West Germany industry using three approaches of a two-level CES production function.

$$\ln(A_t) = \ln(Y_t) - \frac{\sigma}{\sigma - 1}\ln\left[a\{(bK_t^{\frac{\gamma-1}{\gamma}} + (1-b)(e_t W_t)^{\frac{\gamma-1}{\gamma}})^{\frac{\gamma}{\gamma-1}}\}^{\frac{\sigma-1}{\sigma}} + (1-a)L_t^{\frac{\sigma-1}{\sigma}} \right] \qquad (4)$$

where $(1-a)$ is the share of national income attributed to labour, a is the share of national income attributed to a composite of non-water capital and water, $(1-b)$ is the share attributed to water and b is the share attributed to non-water capital[9]. The shares of factors of production in output are the factor social marginal products multiplied by factor inputs and divided by output. We assume that factors are paid their marginal products with the exception of water. The production function is a constant returns to scale production function.

Using calibration procedures we next calibrate a water efficiency function which relates increments in efficiency units of water to investment in water assets in each period using a power function of the following form:

$$\hat{e} = g(I^w) = a(I^w)^b \text{ ; } b < 1 \qquad (5)$$

where $\hat{e}$ is the increment in the period in efficiency units of water use, I^w is investment in water assets and a and b are positive numbers with $b < 1$. The expectation is that b will be a positive number but less than 1 due to diminishing incremental efficiency returns to investments in water assets.

Here, we investigate the degree to which water availability could constrain China's growth under the different assumptions on elasticities of substitution. The elasticticy of substitution between labour and the composite of non-water capital and water in efficiency units is held constant at unity. The assumptions on the elasticity of

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[9] If the elasticties of substitution are unity, the production function is Cobb-Douglas and factor shares are constant. If the elasticity of substitution between non-water capital and water in efficiency units is greater or less than 1 non-water capital and water shares will change over time if the non-water capital-water in efficiency units ratio changes. For example, if the elasticity of substitution is less than 1, an increase in non-water capital-water in efficiency units ratio will result in an increase in the water share over time.

substitution between non-water capital and water in efficiency units are 1.1 (strong substitutes), 0.75, 0.5 and 0.025 (when they become almost perfect complements).[10]

4. Data Sources

4.1 Output

GDP data is from China Statistical Yearbook various years and covers the period 1995-2009. Because GDP data reported in China Statistical Yearbooks is in nominal terms (at current prices) we construct a GDP deflator to convert nominal GDP data into the real terms which are actually used in our growth accounting exercise. We choose 1995 as the base year. Following Zheng et al. (2009), we first calculate a year-on-year GDP deflator and calculate the GDP deflator and real GDP using the following:

$$P_t = \frac{GDP_t^{\text{Nominal}}}{(GDP_{t-1}^{\text{Nominal}} \cdot GDP_t^{\text{Growth}})/100} x100 \tag{6}$$

$$(GDPdeflator)_t = \frac{(GDPdeflator)_{t-1} \cdot P_t}{100} \tag{7}$$

$$GDP_t^{\text{Real}} = \frac{GDP_t^{\text{Nominal}}}{(GDPdeflator)_t} \tag{8}$$

where P_t is the year-on-year GDP deflator and GDP_t^{Growth} is the index of GDP in year t. Indices of GDP that are reported in China Statistical Yearbook are calculated at comparable constant prices with the previous year as the base year (ie 100). Table 3 reports our calculation of real GDP and real GDP growth for the period 1995-2009.

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[10] Grebenstein and Field (1979) argue that water and labour inputs are substitutes and that water and capital are complements.

Table 3: Nominal and Real Chinese GDP 1995-2009 (in 100 million yuan)

Year	Nominal GDP	Indices of GDP	Year-on-year GDP deflator	GDP deflator	Real GDP	Real GDP Growth (%)
1995	60,793.7	110.5	100.00	100.00	60,793.70	n/a
1996	71,176.6	109.6	106.82	106.82	66,629.90	9.60
1997	78,973.0	108.8	101.98	108.94	72,493.33	8.80
1998	84,402.3	107.8	99.14	108.00	78,147.81	7.80
1999	89,677.1	107.1	99.21	107.15	83,696.30	7.10
2000	99,214.6	108.0	102.44	109.76	90,392.00	8.00
2001	109,655.2	107.3	103.00	113.06	96,990.62	7.30
2002	120,332.7	108.0	101.61	114.88	104,749.87	8.00
2003	135,822.8	109.3	103.27	118.63	114,491.61	9.30
2004	159,878.3	109.5	107.50	127.53	125,368.31	9.50
2005	184,937.4	110.2	104.97	133.86	138,155.88	10.20
2006	216,314.4	111.1	105.28	140.93	153,491.18	11.10
2007	265,810.3	111.9	109.81	154.76	171,756.63	11.90
2008	314,045.4	109.0	108.39	167.75	187,214.73	9.00
2009	340,902.8	109.1	99.50	166.90	204,251.27	9.10

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

4.2 Capital Stock Data

Capital stock data for non-water assets is not directly available in the China Statistical Yearbook. To construct capital stock data we use an initial real capital stock for year 1995 calculated by Wang and Yao (2003) (from which we deduct the initial capital stock in water assets) and gross fixed capital formation from the Chinese Statistical Yearbook (2010). Wang and Yao (2003) estimate capital stock based on investment data from Hsueh-Li for the period 1952-1995 and from CSY for 1996-1999. They use total social fixed investment to measure gross fixed capital formation.

Our chosen series to construct the capital stock is gross fixed capital formation because this is a more accurate measure of the change in reproducible capital stock (see Bai et al, 2006). We observed that investment in fixed assets to GDP ratio increased from 32% of GDP in 1995 to 65% in 2009. NBS includes in investment in fixed assets the value of land purchases and expenditure on used machinery and preexisting structures. These should not be included in the calculation of the capital stock. On the other hand, NBS does not count expenditures on small-scale investment projects. Liang (2006) note that China's real estate development expanded fast in recent years which led to an overstatement of investment if land purchases are included in investment spending.

For gross fixed capital formation we rely on Table 2-18 [CSY, 2010] from national accounts which provides data on components of GDP by expenditure approach for the period 1978-2009 at current prices. Gross fixed capital formation is defined by [CSY, 2010] as "the value of acquisitions less those disposals of fixed assets during a given period. Fixed assets are the assets produced through production activities with unit value above a specified amount and which could be used for over one year….Total tangible fixed capital formation includes the value of the construction projects and installation projects completed and the equipment, apparatus and instruments purchased (less those disposed) as well as the value of land improved… Total intangible fixed capital formation includes the prospecting of minerals and the acquisition of computer software minus the disposal of them".

Therefore, this series does not include the land purchases and expenditure on used machinery and preexisting structures but it includes the expenditures on small-scale investment projects. Gross fixed capital formation (in nominal terms) grew at a much slower rate after 2003 compared with investment in fixed assets and its share in GDP in 2009 was 45% as opposed to 65% for investment in fixed assets. Between 2003 and 2009 gross fixed capital formation grew at 20% per year while investment in fixed assets grew at 26.4% per year. Between 1995 and 2002 the levels and growth rates for both series are almost the same.

We use the price index for investment in fixed assets reported in Table 9-1 [CSY, 2010] to calculate the real investment in fixed assets (see Table 4) and the real capital stock is then calculated via a perpetual inventory method using

$$K_t = I_t + (1-\delta)K_{t-1} \tag{9}$$

where the real capital stock at time t is equal to the sum of investment in fixed assets at time t and the balance of the depreciated capital stock from the previous period; and δ is the depreciation rate. Here we use a depreciation rate of 5% as in Wang and Yao (2003) and Zheng et al. (2009).

Table 4: Real Investment in Non-Water Assets and Real Capital Stock in Non-Water Assets 1995-2009 (in 100 million yuan)

Year	Nominal Investment in Non-Water Assets*	Price index of investment in fixed assets	Investment deflator at time t	Real Investment in Non-Water Assets	Growth Rate of Real Investment in Non-Water Assets (%)	Real capital stock in Non-Water Assets	Growth Rate of Real capital stock in Non-Water Assets (%)
1995	20,587.84		100.00	20,587.84		124,823.53	
1996	23,656.78	104.00	104.00	22,746.90	10.49	141,329.26	13.22
1997	25,507.47	101.70	105.77	24,116.43	6.02	158,379.23	12.06
1998	27,925.14	99.80	105.56	26,455.17	9.70	176,915.44	11.70
1999	29,693.48	99.60	105.13	28,243.40	6.76	196,313.06	10.96
2000	32,776.50	101.10	106.29	30,836.65	9.18	217,334.06	10.71
2001	36,672.79	100.40	106.72	34,364.89	11.44	240,832.25	10.81
2002	42,336.21	100.20	106.93	39,592.71	15.21	268,383.34	11.44
2003	51,952.93	102.20	109.28	47,540.35	20.07	302,504.53	12.71
2004	63,177.52	105.60	115.40	54,745.82	15.16	342,125.12	13.10
2005	72,093.38	101.60	117.25	61,487.96	12.32	386,506.83	12.97
2006	85,703.51	101.50	119.01	72,015.72	17.12	439,197.20	13.63
2007	101,322.64	103.90	123.65	81,944.46	13.79	499,181.81	13.66
2008	124,840.69	108.90	134.65	92,713.16	13.14	566,935.88	13.57
2009	151,650.88	97.60	131.42	115,393.24	24.46	653,982.33	15.35

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)
*Nominal investment is based on Gross Fixed Capital Formation data

The price index is important in the calculation of the growth of real output, the growth of real capital stock in non-water assets and the growth of real capital stock in water assets. Literature on China argues that the rate of inflation is often underestimated and therefore, real output growth is overestimated (Bosworth and Collins, 2007). The same argument also applies to the calculation of the growth rate of the real capital stock. If the price index is underestimated, the growth rate of real capital stock is overestimated. As a result of this problem with the data, alternative price indexes have been constructed by Young (2003) and other researchers.

Here, we calculate the real variables based on Chinese prices indices. These Chinese indices show that the inflation rate was faster for GDP in general than for investments in fixed assets. Indices of GDP are higher than the price indices of investment in fixed assets. These calculations show that the growth in real capital stock in non-water assets accelerated especially after 2002 from 10-11% per year to 13-15% per year in 2008-2009 (see Table 4).

In our calculations, we assume that there is no idle capacity for the capital stock. If there is idle capacity the calculation needs adjustments for the capital stock that is not in use. Because there is a lack of data on the utilization of capital, this could be approximated by the labour force unemployed. Capital stock in use in each year would be equal to the capital in place multiplied by the percentage of the labor force unemployed under the assumption that idle capital stock and labour unemployed are equal with the same percentage (Solow, 1957). China's unemployment rates are not high; in 2008-2009 these were in the range of 3-4% depending on the region. Thus, taking into calculation the idle capacity of the capital stock would thus likely not significantly change our calculations.

Investments in water assets refer to investments in the production and supply of water, investments in geologic prospecting, investments in management of water conservancy, investments in drainage works and investments in treatment of wastewater. The data is denominated in 100 million yuan and is taken from CSY various years and covers the period 1995-2009. In 2004 the National Bureau of Statistics of China changed the format for reporting these investments. Between 1995 and 2003, investments in fixed assets were reported as investment in capital construction and investment in innovation by type of construction and sector. Since 2004 data on investments in fixed assets is reported as investments in fixed assets, and in both urban and rural areas. CSY reports data by sector only for investments in urban areas. For nominal investment in fixed assets in production and supply of water, geologic prospecting and management of water conservancy (investment in capital construction and investment in innovation) we rely on Tables 5-14 and 5-19 [CSY, 1996], Tables 5-16 and 5-21 [CSY, 1997], Tables 6-16 and 6-21 [CSY, 1998, 1999], Tables 6-16 and 6-20 [CSY, 2000, 2001, 2002,], Tables 6-9 and 6-22 [CSY, 2004], Table 6-13 [CSY, 2005-2007] and Table 5-13 [CSY, 2008-2010].

Investments in drainage works and treatment of wastewater data is taken from Table 12-47 [CSY, 2010] "Investment in the Treatment of Environmental Pollution" and Table 12-49 [CSY, 2010] "Investment Completed in the Treatment of Industrial Pollution" from the Resources and Environment section of the China Statistical Yearbook. Table 12-47 "Investment in the Treatment of Environmental Pollution" reports data on Investment in Urban Environmental Infrastructure (Gas Supply, Centralized Heating, Drainage Works, Gardening and Greening, Environmental Sanitation), Investment in the Treatment of Industrial Pollution (Treatment of Waste Water, Treatment of Waste Gas, Treatment of Solid Waste, Treatment of Noise Pollution and Treatment of Other Pollution) and the "Three Simultaneities" Environmental Investment for New Projects. Here we use only data that is related directly to water treatment such as drainage works and treatment of waste water. The data on investment in drainage works is available starting in the year 2000 and investment in treatment of wastewater is available starting in the year 1999.

The initial capital stock in water assets in year 1995 is not directly available in the China Statistical Yearbook nor is it calculated in previous research studies. Thus we rely on a method of calculation of the initial capital stock reported by Nehru and Dhareshwar (1993). We calculate the capital stock in water assets each year via a perpetual inventory method initially assuming that the initial capital stock in water assets is zero. Then we calculate the average of the capital-output ratio for the years 2005-2009 and apply this ratio to find the initial capital stock in the year 1995. The average capital-output ratio in the last 5 years is 0.071 and the initial water asset capital stock in year 1995 is 4,338.13 (100 million yuan).

When the initial capital stock is estimated, the real capital stock calculated in the first 2-3 years is sensitive to the initial capital stock estimate (Barro and Sala-i-Martin, 2004). This can be seen from Table 5 where the growth rates of the real water capital stock between 1996 and 1998 are lower (3-7% per year) than in subsequent years, suggesting that the initial capital stock could be overestimated and real investments are low relative to the real capital stock in water assets. But as the real capital stock in water assets depreciates, the capital stock becomes more accurate, especially from 1999 on, when growth rates remain in the range of 10-13% per year.

Table 5: Real Investment in Water Assets and Real Water Capital Stock, China, 1995-2009 (in 100 million yuan)

Year	Nominal Investment in Water Assets	Price index of investment in fixed assets	Investment deflator at time t	Real Investment in Water Assets	Growth Rate of Real Investment in Water Assets (%)	Real Water capital stock	Growth Rate of Real Water capital stock (%)
1995	297.16		100.00	297.16		4,338.13	
1996	391.32	104.00	104.00	376.27	26.62	4,497.49	3.67
1997	457.53	101.70	105.77	432.58	14.97	4,705.20	4.62
1998	643.86	99.80	105.56	609.97	41.01	5,079.90	7.96
1999	833.82	99.60	105.13	793.10	30.02	5,619.01	10.61
2000	1,067.90	101.10	106.29	1,004.70	26.68	6,342.76	12.88
2001	1,081.71	100.40	106.72	1,013.64	0.89	7,039.25	10.98
2002	1,295.89	100.20	106.93	1,211.91	19.56	7,899.20	12.22
2003	1,537.77	102.20	109.28	1,407.16	16.11	8,911.40	12.81
2004	1,940.18	105.60	115.40	1,681.24	19.48	10,147.08	13.87
2005	2,139.52	101.60	117.25	1,824.78	8.54	11,464.51	12.98
2006	2,250.59	101.50	119.01	1,891.15	3.64	12,782.43	11.50
2007	2,625.96	103.90	123.65	2,123.74	12.30	14,267.04	11.61
2008	3,243.71	108.90	134.65	2,408.95	13.43	15,962.64	11.88
2009	5,028.92	97.60	131.42	3,826.57	58.85	18,991.08	18.97

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

4.3 Labor Data

Labor force data is from World Bank Development Indicators database and is for the years 1995 to 2009. The total labor force consists of economically active population of age 15 or older as reported by the International Labour Organization criteria. We assume that average hours per worker do not change over the period.[11]

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[11] We take the labor input in production as the number of hours worked in a year under the assumption that each worker worked 2,080 hours per year.

4.4 Factor Shares

The shares of factors of production in output are the factor social marginal products multiplied by factor inputs and divided by output. In order to compute factor shares we need to have estimates for the social marginal products of labour, capital and water. These are not directly available from the data but the assumption used in the research literature is that the social marginal products are equal to their input prices (Barro and Sala-i-Martin, 2004). Therefore, the social marginal product of capital is equal to the rental rate of capital and the social marginal product of labour is equal to the wage rate.

Labour factor shares are calculated using data from China's National Accounts. We use Table 2-16 [CSY, 2008-2010], Table 3-10 [CSY, 1998-2003, 2006], Table 3-12 [CSY, 2004, 2005], Table 2-17 [CSY, 1997] and Table 2-18 [CSY, 1996] which report data for 31 regions based on an income approach to components of gross regional product. The data is calculated at current prices. We obtain labour shares as the ratio of compensation of employees to the sum of gross regional product. The NBS defines the compensation of employees as "the total payment of various forms to employees for the productive activities they are engaged in… includes wages, bonuses and allowances, which the employees earn in cash or in kind… includes the free medical services provided to the employees and the medicine expenses, transport subsidies and social insurance, and housing fund paid by the employers". Between 1995 and 2004 the labour share is stable in the range of 0.50-0.53. In 2005 it decreased to 0.41 and remained at this value until 2008. In 2009 the labour share increased again to 0.47. On average for the entire period labour share it was 0.48. This is almost the same as the labour share used by Wang and Yao (2003) but is smaller than the labour share computed by Young (2003) who found an average labour share of 0.6 for the period 1978-1997.

In the case of China, the assumption that social marginal product of water is equal to the water price is not realistic. It is common in developing countries that water prices are usually significantly lower than their marginal product. Wang and Lall (2002) estimated the marginal productivity of water using a production function for the industrial sector with 5 inputs (capital, labour, water, energy and other raw materials) and data for about 2,000 Chinese industrial firms. They obtained data from China's State Environmental Protection Administration (SEPA) for 1993, and found that the industry average marginal productivity of water was 2.45 yuan per cubic meter of water while the price of water in 1996 was in the range of 0.70 and 1.20 yuan in cities in Hebei Province. This suggests that the water price was about 2 to 3.5 times lower than the marginal product. Giving that the comparison data is for year 1996 and the study uses data for year 1993, the gap between water price and marginal product could be even larger. The authors also note that their sample consists of large and medium sized enterprises and that the marginal value product of water could be as high as 3.92 yuan per cubic meter of water if small-scale industries were included.

Also, World Bank (1997) noted that the willingness to pay was about 1.8 yuan per cubic meter in some coastal cities and 4.3 yuan per cubic meter in a representative city for water-scarce Hai River Basin. The industries' economic value of water in Shanxi and Hai River Basin was about 24 yuan per cubic meter; in sharp contrast with the average price in the region which was in the range of 0.5-0.9 yuan per cubic meter.

Because the marginal product of water is higher than the price charged for water, we calculate the share parameter of water $(1-b)$ under different assumptions. These are if the marginal product of water is 4 times higher than the average price of water reported by the Ministry of Water Resources 2006 and 2007, and if the marginal product of water is 8 times higher and 12 times higher. The implied values for distribution parameters in the aggregate production function are reported in Table 6.

Table 6: Distribution Parameters in Production for Different Water Pricing Assumptions

	Distribution Parameter	Assumed Ratio of Water Marginal Product to Price		
		$\lambda = 4$	$\lambda = 8$	$\lambda = 12$
Non-water capital	b	0.9867	0.9734	0.9601
Water in efficiency units	$1-b$	0.0133	0.0266	0.0399
Composite of Non-water capital and water in efficiency units	a	0.5173	0.5173	0.5173
Labour	$1-a$	0.4827	0.4827	0.4827

Source: Authors' calculations based on Ministry of Water Resources (2006-2007) and China Statistical Yearbook (1996-2009)

4.5 e-function

To calibrate the e function, we find the values for the positive parameters a and b by constructing a system of two equations and solving for the two parameters. Our system of equations takes the efficiency of water use at time t, denoted by e_t as equal to the efficiency of water use at time $t-1$, denoted by e_{t-1} plus the water efficiency increment function, denoted by $\hat{e}$.

$$e_t = e_{t-1} + \hat{e} = e_{t-1} + a(I_t^w)^b \qquad (10)$$

Using data for 1998 and 2008 in Table 7 , and assuming that the efficiency of water use at time t is equal to real GDP at time t divided by water use at time t, we can solve for the values of parameters in equations (4) and (5) as

$$14.38 = 13.02 + a(609.97)^b$$
$$31.68 = 29.52 + a(2,408.95)^b$$

Solving these equations for the parameters a and b yields values 0.1526648 and 0.3402391, and substituting these values into the water efficiency function yields

$$\hat{e} = 0.1526648(I^w)^{0.3402391} \qquad (11)$$

Equation 11 implies that the function $\hat{e}$ exhibits positive and diminishing returns to investment in water assets. For $I^w > 0$, $\frac{\partial \hat{e}}{\partial I^w} > 0$ suggesting that there are positive marginal products with respect to investments in water assets and $\frac{\partial^2 \hat{e}}{\partial^2 I^w} < 0$ suggesting that the marginal product is diminishing. Each additional unit of investment in water assets increases $\hat{e}$ but the increase falls as investment in water assets increases.

Table 7 reports in column D the actual efficiency of water use (Real GDP/Water Use) and in column G the calculation of efficiency of water use (e_t) using the calibrated e function. Using the calibrated function yields slightly higher efficiency of water use (column G) than in reality (column D) in most of the years.

Table 7: Efficiency of water use China, 1998-2009

A	B	C	D	E	F	G	H
Year	Real GDP (in 100 mill 1995 yuan)	Water Use (in 100 mill cu.m)	Efficiency of water use (Real GDP/Water Use)	Real Investment in Water Capital	$\hat{e}$	e_t	e_tW
1995	60,793.70	n/a	n/a	297.16	1.06	n/a	n/a
1996	66,629.90	n/a	n/a	376.27	1.15	n/a	n/a
1997	72,493.33	5,566.03	13.02	432.58	1.20	13.02	72,493.33
1998	78,147.81	5,435.39	14.38	609.97	1.35	14.38	78,147.81
1999	83,696.30	5,590.88	14.97	793.10	1.48	15.86	88,656.77
2000	90,392.00	5,497.59	16.44	1,004.70	1.60	17.46	95,994.44
2001	96,990.62	5,567.43	17.42	1,013.64	1.61	19.07	106,169.89
2002	104,749.87	5,497.28	19.05	1,211.91	1.71	20.78	114,229.46
2003	114,491.61	5,320.40	21.52	1,407.16	1.80	22.58	120,123.16
2004	125,368.31	5,547.80	22.60	1,681.24	1.91	24.49	135,858.32
2005	138,155.88	5,633.00	24.53	1,824.78	1.96	26.45	149,012.78
2006	153,491.18	5,795.00	26.49	1,891.15	1.99	28.44	164,823.82
2007	171,756.63	5,818.70	29.52	2,123.74	2.07	30.51	177,536.47
2008	187,214.73	5,910.00	31.68	2,408.95	2.16	32.67	193,085.26
2009	204,251.27	5,965.20	34.24	3,826.57	2.53	35.20	209,967.81

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

We perform sensitivity analysis on the parameters used in the e-function. Table 8 reports our calculations for the calibration of e function using data for 7 different pairs of years which are taken randomly. The calculations show that there are significant differences for the values of parameters a and b suggesting that the results of the counterfactuals could change if the calculations are performed using the values from other rows (the values from row 6 are used in our counterfactual analysis). For all pairs of years reported (see Table 8, rows 1, 2, 3, 4, 5, 6, 7) the value of parameter b is less than 1 and greater than 0; the e function exhibits positive and diminishing marginal products with respect to investment in water assets.

Table 8: Sensitivity Analysis for e-function

Row #	Data for years	a	b	$\hat{e}$	$\frac{\partial \hat{e}}{\partial I^{w}}$	$\frac{\partial^2 \hat{e}}{\partial^2 I^{w}}$
1	1998 / 2003	0.0136196	0.7170643	$=0.0136196\,(I^{w})^{0.7170643}$	> 0	< 0
2	2005 / 2008	0.0901988	0.4078173	$=0.0901988\,(I^{w})^{0.4078173}$	> 0	< 0
3	2002 / 2009	0.1013375	0.3915791	$=0.1013375\,(I^{w})^{0.3915791}$	> 0	< 0
4	2000 / 2007	0.0018649	0.9650913	$=0.0018649\,(I^{w})^{0.9650913}$	> 0	< 0
5	1999 / 2009	0.0011881	0.9305185	$=0.0011881\,(I^{w})^{0.9305185}$	> 0	< 0
6	1998 / 2008	0.1526648	0.3402391	$=0.1526648\,(I^{w})^{0.3402391}$	> 0	< 0
7	2005 / 2006	0.0584134	0.4656757	$=0.0584134\,(I^{w})^{0.4656757}$	> 0	< 0

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

5. Results

Here we report the results of growth accounting calculations on the significance of water availability for China's growth for a number of counterfactual cases. We use values for parameters a and b as reported in row 6 from the Table 8 for the e function. The marginal product of water is calculated as the average price of water reported by Ministry of Water Resources for years 2006 and 2007 and multiplied by a factor λ which can take the alternative values of 4, 8 and 12. The elasticity of substitution between the composite of non-water capital and water, and labour is assumed to be unity and this value does not change during the experiments.

Table 9 reports the results of change in growth rates under the hypothesis that investments in water assets grew at zero after 1997 and under the assumption of different elasticities of substitution between water and non-water capital and different marginal products for water. The results show that if there was no growth in investments in water assets, output growth rates would have been changed only a little when compared with actual output growth rates if elasticity of substitution between water and non-water capital was 1.1 or 0.75.

Larger changes in output growth rates occur if the elasticity of substitution approaches zero and water and non-water capital become almost perfect complements. If elasticity of substitution was 0.25 or 0.025 output growth rates would have been decreased in 2009 by as much as 1.3-1.8 percentage points. In the first years of the experiment, the magnitude of growth decrease when compared with actual growth rates is not so large but as diminishing returns to non-water capital, the faster growing factor, occurs faster than otherwise the decrease in output growth rates becomes larger and larger. When the elasticity of substitution is 0.025 the diminishing returns sets in much faster and growth rates fall earlier than when the elasticity of substitution is 0.25 (see Table 9).

The actual average growth rate of real non-water capital for the period 1998-2009 was around 12.5% per year and the growth rate of water in efficiency units was 9.29%. If there was no growth in investments in water assets the efficiency of water use would have increased from 13.02 in 1997 to 27.09 in 2009 (20.8% lower than the actual efficiency of water use) and water efficiency increments would have been around 1.17 unit per year. The growth rate of water in efficiency units falls from 9.29% to 6.93% per year (around 25% lower) and because there is more investment available for non-water capital assets, the growth rate of real non-water capital raises a little to 12.7% per year. Therefore with a very low elasticity of substitution, a faster growth of non-water capital input relative to water in efficiency units indicates that the implicit share of non-water capital would decrease and the share of water would increase over time. As a result the growth rate of output would decrease because of the larger share on the growth rate of water in efficiency units which was lower than the growth rate of non-water capital.

Table 9: Change in Growth Rates under the Hypothesis that there was No Growth in Investments in Water Assets 1998-2009 (percentage point change)

	$\gamma = 1.1$			$\gamma = 0.75$			$\gamma = 0.25$			$\gamma = 0.025$		
	Marginal Product of Water = P_wx λ											
Year	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$
1998	0.05	0.04	0.03	0.04	0.03	0.02	-0.03	-0.10	-0.15	-0.58	-0.58	-0.58
1999	0.08	0.07	0.06	0.08	0.06	0.04	-0.04	-0.14	-0.23	-0.91	-0.91	-0.91
2000	0.11	0.09	0.08	0.10	0.08	0.06	-0.09	-0.24	-0.36	-1.19	-1.19	-1.19
2001	0.08	0.07	0.05	0.08	0.06	0.04	-0.09	-0.22	-0.32	-1.02	-1.02	-1.02
2002	0.09	0.08	0.06	0.08	0.06	0.04	-0.18	-0.38	-0.51	-1.15	-1.15	-1.15
2003	0.09	0.07	0.06	0.08	0.05	0.02	-0.38	-0.65	-0.82	-1.26	-1.26	-1.26
2004	0.10	0.08	0.06	0.09	0.06	0.03	-0.26	-0.49	-0.65	-1.41	-1.41	-1.41
2005	0.08	0.06	0.04	0.07	0.04	0.01	-0.44	-0.72	-0.88	-1.38	-1.38	-1.38
2006	0.05	0.03	0.01	0.03	0.01	-0.02	-0.50	-0.77	-0.92	-1.29	-1.29	-1.29
2007	0.04	0.02	0.01	0.02	-0.01	-0.04	-0.81	-1.13	-1.28	-1.33	-1.33	-1.33
2008	0.04	0.02	0.00	0.02	-0.01	-0.04	-0.88	-1.18	-1.31	-1.39	-1.39	-1.39
2009	0.10	0.08	0.06	0.08	0.03	-0.01	-1.35	-1.73	-1.87	-1.81	-1.81	-1.81

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

Table 10 reports the results of change in growth rates under the strong hypothesis that there were no investments in water assets (they were set at zero) between 1997 and 2009. We assume that the savings rate in the economy was the same between 1997 and 2009 and instead of investing in water assets, investments took place in non-water assets. Under these assumptions the change in growth rates is negative. When elasticity of substitution is 1.1 or 0.75 the change in output growth rates is small (but larger than in the case of no growth of investments in water assets). As the elasticity of substitution decreases, growth is lowered to a larger extent.

The major changes in output growth occur when the elasticity of substitution is 0.25 and 0.025. In 2009 growth rates would be reduced by 4.1 to 5.5 percentage points. This is because with no investments in water assets the efficiency of water use remains constant at 13.02 and water in efficiency units changes very little (grows at 0.6% per year). On the other hand, the capital stock in non-water assets grows at the rate of 12.7% per year. With a higher growth rate of the capital stock and almost no growth in water in efficiency units and an elasticity of substitution less than 1, the share of water (the slow growth factor) increases and the share of the faster growing input decreases leading to a fall in output growth which gets larger every year.

Table 10: Change in Growth Rates under the Hypothesis that there were No Investments in Water Assets 1998-2009 (percentage point change)

	$\gamma=1.1$			$\gamma=0.75$			$\gamma=0.25$			$\gamma=0.025$		
	Marginal Product of Water = P_wx λ											
Year	$\lambda=4$	$\lambda=8$	$\lambda=12$	$\lambda=4$	$\lambda=8$	$\lambda=12$	$\lambda=4$	$\lambda=8$	$\lambda=12$	$\lambda=4$	$\lambda=8$	$\lambda=12$
1998	0.10	0.03	-0.04	0.07	-0.03	-0.13	-0.71	-1.37	-1.87	-5.37	-5.37	-5.37
1999	0.11	0.04	-0.03	0.08	-0.02	-0.12	-0.83	-1.54	-2.06	-5.29	-5.29	-5.29
2000	0.12	0.05	-0.02	0.08	-0.03	-0.13	-1.32	-2.21	-2.80	-5.25	-5.25	-5.25
2001	0.07	0.01	-0.05	0.04	-0.06	-0.16	-1.43	-2.26	-2.77	-4.78	-4.78	-4.78
2002	0.07	0.01	-0.04	0.02	-0.08	-0.18	-2.21	-3.17	-3.67	-4.69	-4.69	-4.69
2003	0.05	0.00	-0.05	-0.01	-0.12	-0.23	-3.43	-4.41	-4.80	-4.59	-4.59	-4.59
2004	0.05	-0.01	-0.06	0.00	-0.10	-0.20	-2.56	-3.29	-3.62	-4.51	-4.51	-4.51
2005	0.03	-0.02	-0.07	-0.03	-0.14	-0.24	-3.51	-4.14	-4.36	-4.31	-4.31	-4.31
2006	-0.01	-0.06	-0.10	-0.07	-0.17	-0.28	-3.68	-4.15	-4.29	-4.09	-4.09	-4.09
2007	-0.02	-0.06	-0.10	-0.09	-0.20	-0.32	-4.77	-5.03	-5.00	-3.99	-3.99	-3.99
2008	-0.02	-0.06	-0.10	-0.09	-0.20	-0.31	-4.53	-4.65	-4.59	-3.79	-3.79	-3.79
2009	0.05	0.00	-0.04	-0.05	-0.18	-0.31	-5.54	-5.46	-5.29	-4.13	-4.13	-4.13

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

Table 11 reports our results under the hypothesis that investments in water assets grew twice the rate actually observed between 1997 and 2009. In this case, investments in non-water assets would have been smaller than they were in the period considered. In this case growth rates would have decreased by 0.03 to 1.38 percentage points if the elasticity of substitution was 1.1 or 0.75. But output and growth rates would increase if elasticity of substitution was 0.25 or 0.025. The biggest increase in output and growth rates occurs if the elasticity of substitution was 0.025. With double the growth rate for investments in water assets the efficiency of water use increases from 13.02 in 1997 to 45.87 in 2009, 33.9% higher in 2009 when compared to the actual efficiency of water use of 34 in 2009. Along with this increase in efficiency, water use in efficiency units also increases at an average rate of about 11.73% per year. On the other hand, the growth rate of the real capital stock falls a little to 11.7% per year. Therefore, water in efficiency units contributes positively to growth of output in this case.

Table 11: Change in Growth Rates under the Hypothesis that there was Double the Growth Rate of Investments in Water Assets 1998-2009 (percentage point change)

	$\gamma = 1.1$			$\gamma = 0.75$			$\gamma = 0.25$			$\gamma = 0.025$		
	Marginal Product of Water = P_wx λ											
Year	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$
1998	-0.05	-0.04	-0.04	-0.05	-0.04	-0.03	0.01	0.07	0.11	0.47	0.47	0.47
1999	-0.11	-0.10	-0.09	-0.11	-0.09	-0.07	-0.01	0.08	0.15	0.82	0.82	0.82
2000	-0.20	-0.18	-0.17	-0.19	-0.17	-0.15	-0.04	0.10	0.21	1.13	1.13	1.13
2001	-0.15	-0.14	-0.13	-0.15	-0.13	-0.11	-0.04	0.07	0.15	0.95	0.95	0.95
2002	-0.23	-0.21	-0.19	-0.22	-0.19	-0.17	-0.03	0.13	0.25	1.12	1.12	1.12
2003	-0.29	-0.27	-0.25	-0.28	-0.25	-0.22	0.04	0.28	0.45	1.27	1.27	1.27
2004	-0.41	-0.39	-0.37	-0.41	-0.37	-0.34	-0.20	-0.01	0.14	1.48	1.48	1.48
2005	-0.41	-0.39	-0.36	-0.40	-0.37	-0.33	-0.10	0.13	0.31	1.45	1.45	1.45
2006	-0.32	-0.30	-0.28	-0.31	-0.28	-0.25	-0.02	0.20	0.36	1.33	1.33	1.33
2007	-0.39	-0.37	-0.35	-0.38	-0.34	-0.31	0.10	0.42	0.63	1.41	1.41	1.41
2008	-0.52	-0.49	-0.47	-0.50	-0.46	-0.43	0.00	0.33	0.55	1.52	1.52	1.52
2009	-1.38	-1.34	-1.29	-1.35	-1.29	-1.22	-0.50	0.05	0.41	2.10	2.10	2.10

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

In Table 12 we also report a sensitivity analysis of the change in growth rates using a Cobb-Douglas production function where the elasticity of substitution is unity and factors shares are constant over time. The results obtained are close to the results reported in Tables 8, 10 and 11 under the hypothesis that the elasticity of substitution is 1.1.

Table 12: Sensitivity Analysis of Change in Growth Rates Using Cobb-Douglas Production Function Under Different Hypotheses (percentage point change)

Year	No Growth of Investments in Water Assets			No Investments in Water Assets			Double Growth of Investments in Water Assets		
	Marginal Product of Water = P_wx λ								
	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$	$\lambda = 4$	$\lambda = 8$	$\lambda = 12$
1998	0.04	0.03	0.01	0.04	-0.10	-0.24	-0.04	-0.03	-0.02
1999	0.07	0.04	0.01	0.04	-0.11	-0.25	-0.10	-0.08	-0.05
2000	0.10	0.06	0.03	0.05	-0.08	-0.22	-0.19	-0.15	-0.12
2001	0.07	0.04	0.01	0.01	-0.12	-0.24	-0.14	-0.11	-0.08
2002	0.08	0.05	0.01	0.01	-0.11	-0.23	-0.21	-0.18	-0.14
2003	0.08	0.04	0.01	0.00	-0.12	-0.23	-0.28	-0.24	-0.20
2004	0.08	0.04	0.00	-0.01	-0.13	-0.25	-0.40	-0.35	-0.30
2005	0.06	0.02	-0.01	-0.03	-0.14	-0.25	-0.39	-0.35	-0.30
2006	0.03	-0.01	-0.04	-0.07	-0.17	-0.27	-0.31	-0.26	-0.22
2007	0.02	-0.01	-0.05	-0.07	-0.17	-0.27	-0.37	-0.33	-0.28
2008	0.02	-0.02	-0.05	-0.07	-0.17	-0.26	-0.51	-0.46	-0.40
2009	0.08	0.03	-0.02	-0.01	-0.12	-0.22	-1.40	-1.31	-1.21

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

We also report sensitivity analysis of change in growth rates using the CES production function under different assumptions of values of parameters a and b that are calculated in Table 8. The sensitivity analysis shows that the results of the counterfactual experiments are almost the same in all cases if non-water capital and water are close substitutes. On the other hand the results show larger variations in counterfactual experiments if non-water capital and water are poor substitutes. If the power of e-function, parameter b , takes higher values closer to 1, a one unit increase in investments in water assets increases the efficiency of water use by larger amounts then if the parameter b is closer to 0.

Table 13: Sensitivity Analysis of Change in Growth Rates Using CES Production Functions Under Different Parameterizations (percentage point change)

Year	No Growth of Investments in Water Assets													
	$\gamma = 1.1$							$\gamma = 0.025$						
	$a = 0.013$ $b = 0.717$	$a = 0.090$ $b = 0.407$	$a = 0.101$ $b = 0.391$	$a = 0.001$ $b = 0.965$	$a = 0.001$ $b = 0.930$	$a = 0.152$ $b = 0.340$	$a = 0.058$ $b = 0.465$	$a = 0.013$ $b = 0.717$	$a = 0.090$ $b = 0.407$	$a = 0.101$ $b = 0.391$	$a = 0.001$ $b = 0.965$	$a = 0.001$ $b = 0.930$	$a = 0.152$ $b = 0.340$	$a = 0.058$ $b = 0.465$
1998	0.03	0.04	0.04	0.03	0.04	0.04	0.04	-1.15	-0.63	-0.61	-1.03	-0.52	-0.58	-0.67
1999	0.04	0.07	0.07	0.04	0.07	0.07	0.06	-1.92	-1.02	-0.99	-1.86	-0.99	-0.91	-1.10
2000	0.06	0.09	0.09	0.06	0.09	0.09	0.09	-2.59	-1.34	-1.30	-2.69	-1.49	-1.19	-1.47
2001	0.04	0.06	0.07	0.03	0.06	0.07	0.06	-2.21	-1.17	-1.13	-2.39	-1.41	-1.02	-1.29
2002	0.04	0.07	0.07	0.03	0.06	0.08	0.07	-2.57	-1.33	-1.29	-2.90	-1.77	-1.15	-1.48
2003	0.04	0.07	0.07	0.03	0.06	0.07	0.07	-2.83	-1.46	-1.41	-3.32	-2.11	-1.26	-1.64
2004	0.03	0.07	0.07	0.02	0.05	0.08	0.07	-3.22	-1.65	-1.59	-3.90	-2.55	-1.41	-1.86
2005	0.02	0.06	0.06	0.00	0.03	0.06	0.05	-3.13	-1.62	-1.56	-3.88	-2.65	-1.38	-1.83
2006	-0.01	0.02	0.03	-0.03	0.00	0.03	0.02	-2.90	-1.52	-1.46	-3.64	-2.58	-1.29	-1.72
2007	-0.02	0.02	0.02	-0.04	-0.01	0.02	0.01	-3.02	-1.58	-1.52	-3.86	-2.82	-1.33	-1.80
2008	-0.02	0.01	0.02	-0.04	-0.02	0.02	0.01	-3.14	-1.65	-1.58	-4.05	-3.02	-1.39	-1.87
2009	0.02	0.07	0.07	-0.02	0.02	0.08	0.06	-4.48	-2.19	-2.09	-6.14	-4.60	-1.81	-2.52

Source: Authors' calculations based on China Statistical Yearbook (1996-2009); * Marginal Product of Water = P_wx λ ; $\lambda = 8$

Given the results obtained under the assumption of different elasticities of substitution and investments in water assets, one could also ask what would be the optimal value of investments in water assets which minimize the reduction in output in the year? The response to this question depends on the elasticity of substitution between non-water capital and water in efficiency units. If the elasticity of substitution is high and the share of water in production is low then it is optimal to invest more in non-water capital assets instead of water assets because the share in production is higher. The growth in output is about 0.1 if there would be no growth of investments in water assets. If the elasticity of substitution between non-water capital and water in efficiency units is low then by investing more in water assets would also benefit growth (see Table 14).

Table 14 reports some projections of future changes in real GDP growth rates for the period 2010-2022 if there is no growth of investments in water assets, no investments in water assets and double the growth rate of investments in water assets. We compare the growth rates of real GDP under counterfactual analyses with projected growth rates of real GDP if real GDP, real investments in non-water assets and real investments in water assets continue to grow at the average annual growth rates from the last 10 years. If the elasticity of substitution between non-water capital and water in efficiency units, γ, is 1.1 then GDP growth rates would slightly increase by 0.1 percentage points per year if there is no growth of investments in water assets. If the growth rates of investments in water assets were twice the growth rate from the past, the GDP growth rates would decrease by 0.05 to 2.13 percentage points per year between 2010 and 2022.

If non-water capital and water in efficiency units are poor substitutes, γ is 0.025, GDP growth rates would increase by 0.2 to 1.89 percentage points per year if investments in water assets would increase at twice the rate from the past. The growth would decrease by 0.2 to 1.5 percentage points per year if there would be no growth of investments in water assets and by 3.6 to 4.1 if there would be no investments in water assets.

Table 14: Future Projections of Change in Growth Rates under Different Hypotheses of Growth in Investments in Water Assets 2009-2022 (percentage point change)

Year	No Growth of Investments in Water Assets				No Investments in Water Assets				Double Growth of Investments in Water Assets			
	$\lambda = 8^*$				$\lambda = 8^*$				$\lambda = 8^*$			
	$\gamma = 1.1$	$\gamma = 0.75$	$\gamma = 0.25$	$\gamma = 0.025$	$\gamma = 1.1$	$\gamma = 0.75$	$\gamma = 0.25$	$\gamma = 0.025$	$\gamma = 1.1$	$\gamma = 0.75$	$\gamma = 0.25$	$\gamma = 0.025$
2010	0.05	0.04	-0.10	-0.24	0.23	0.16	-2.16	-4.18	-0.05	-0.04	0.08	0.21
2011	0.08	0.07	-0.22	-0.44	0.19	0.10	-2.78	-4.11	-0.10	-0.09	0.19	0.41
2012	0.11	0.09	-0.37	-0.61	0.15	0.05	-3.29	-4.06	-0.16	-0.14	0.31	0.60
2013	0.12	0.10	-0.53	-0.76	0.12	0.01	-3.68	-4.00	-0.23	-0.21	0.45	0.77
2014	0.13	0.11	-0.70	-0.89	0.10	-0.02	-3.95	-3.95	-0.31	-0.28	0.60	0.94
2015	0.14	0.11	-0.86	-1.01	0.09	-0.05	-4.11	-3.91	-0.40	-0.37	0.74	1.09
2016	0.14	0.11	-1.02	-1.12	0.08	-0.07	-4.19	-3.87	-0.52	-0.48	0.88	1.23
2017	0.14	0.10	-1.16	-1.21	0.07	-0.10	-4.21	-3.83	-0.66	-0.61	1.01	1.37
2018	0.14	0.10	-1.29	-1.29	0.06	-0.12	-4.19	-3.79	-0.84	-0.78	1.13	1.49
2019	0.14	0.09	-1.41	-1.37	0.06	-0.13	-4.15	-3.76	-1.06	-0.99	1.23	1.60
2020	0.14	0.08	-1.50	-1.44	0.05	-0.15	-4.10	-3.73	-1.33	-1.25	1.30	1.71
2021	0.14	0.07	-1.59	-1.50	0.05	-0.17	-4.04	-3.70	-1.68	-1.59	1.35	1.80
2022	0.13	0.06	-1.66	-1.56	0.05	-0.19	-3.98	-3.68	-2.13	-2.03	1.34	1.89

Source: Authors' calculations based on China Statistical Yearbook (1996-2009)

* Marginal Product of Water = P_wx λ

6. Concluding Remarks

In this paper, we use a growth accounting approach to investigate both the contribution played in the past by water availability in constraining China's growth performance, and what would be involved in the future. We use a modified version of Solow growth accounting in which water in efficiency units enters the production technology, and investment in water management assets raises efficiency of water use. We note that China's high growth of the last 20 years or more has been obtained with relatively little increase in the physical volume of water. We adopt various assumptions on the relationship between the price of water and marginal product, and on substitution elasticities in making our calculations.

Our counterfactual experiments suggest that water affects China's growth rates and will affect growth in the future but at uncertain rates. The degree depends on the elasticity of substitution between non-water capital and water in efficiency units and on the size of investments in water assets. If investments in water assets in the future were lower than they were in the past, growth might slightly increase by about 0.1 percentage points if non-water capital and water in efficiency units are close substitutes but growth rates could decrease by as much as 0.2-3.9 percentage points if investments in water assets were very small or small, and if the elasticities of substitution were low.

On the other hand, our experiments suggest that with faster growth of investments in water assets than in the past and low elasticity of substitution growth could increase. But if non-water capital and water in efficiency units are close substitutes growth rates could even decrease.

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