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Summary

Water resources are unevenly spread in China. Especially the basins of the Yellow, Hui and Hai rivers in the North are rather dry. To increase the supply of water in these basins, the South-to-North Water Transfer project (SNWT) was launched. Using a computable general equilibrium model this study estimates the impact of the project on the economy of China and the rest of the world. We contrast three alternative groups of scenarios. All are directly concerned with the South-to-North water transfer project to increase water supply. In the first group of scenarios additional supply implies productivity gains. We call it the “non-market” solution. The second group of scenarios is called “market solution”. The market price for water adjusts such that supply and demand are equated again. In the third group of simulations the economic implications of China’s capital investment in infrastructure for the water South-North water transfer project is analyzed. Finally, the investment is combined with the increased capacity of water. If an increase in water supply in China leads to an increase in productivity of their water-intensive goods and services (non-market solution) this would result in a huge positive welfare effect from increased production and export. The effect on China’s welfare would still be positive, if a market for water would exist (market solution), but the world as a whole would lose. The negative effect for the rest of the world is largely explained by a deterioration of its terms-of-trade. Well functioning water markets in China are unlikely to exist.

Keywords: Computable General Equilibrium, South-North Water Transfer Project, Water Policy, Water Scarcity

JEL Classification: D58, R13, Q25, Q28

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1 Introduction

Total water resources in China amount to about 2,897 bln m^3 per year, the fifth largest in the world (FAO AQUASTAT). However, with a population of about 1.28 bln in 2000, water availability is limited to an annual average of 2,259 m^3 per capita, compared to the world average of about 8,036 m^3 per capita; the UN defines this as slightly scarce. The uneven distribution of water resources and population aggravates the problem of scarcity. While the South is relatively water abundant, the Huang-Huai-Hai (3-H) river basins in the North are rather dry. More than a third of China's population is living in this densely populated region, which includes the mega-cities Beijing and Tianjin. In this area, more than 30% of China's cultivated land and GDP depends on less than 10% of the country's water resources (MWR, 2004a). Water availability is restricted to 500 m^3 per capita on average, and falls below 400 m^3 in the Hai river basin, which includes Beijing and Tianjin (MWR, 2004a). According to the UN, this is severe and most severe scarcity, respectively. Another reason for concern is the quality of the water. The shortage of wastewater treatment capacity, has led to problems of water pollution; wastewater is partly released untreated (WWC, 2003). The uneven distribution of water over time aggravates the problem further. The monsoon climate with its varied rainfall leads to serious droughts and floods. The 2002 drought reduced the amount of water resources in the Hai river basin by more than 60% to less than 150 m^3 per capita (MWR, 2002). As a consequence, people in this area suffer from relatively severe water shortage. Estimates show a current water shortage in the 3-H river basins of 14.5 to 21.0 bln m^3 per year (MWR, 2004a).[1] Governments officials estimate an annual damage of $16 bln for the economy as a whole (Cernetig, 2000).

The management and distribution of the limited water resources are major issues for China's social and economic development. Population growth and increasing urbanization makes the problem even more imminent. Water demand in the 3-H river basins is projected to increase while water shortage will reach up to 28 bln m^3 by 2010 per year and up to 40 bln m^3 by 2030 (MWR, 2004a). For comparison, the total annual flow of the Huang (Yellow) river amounts to about 60 bln m^3 (MWR, 2004b). An additional reason for concern is climate change. For China climate change models predict an overall increase in temperature but a substantial decline in rainfall over most parts of the country. Higher temperatures would imply larger water demand and higher evaporation (IPCC, 1997).

The Chinese government has identified several options for a sustainable water resource development strategy, including increasing efficiency of water use, protecting and developing water resources, and expanding the capacity of water supply (WWC, 2003). Zhou and Tol (2005) propose desalination. To increase the supply of water in the 3-H river basins the South-to-North Water Transfer (SNWT) project was launched. The idea dates back to 1952 but implementation did not start until the end of 2002. The project contains three alignments, the eastern, western and middle route. It will divert water from the lower, middle and upper reaches of the Yangtze river and build a network with the 3-H rivers. The total amount of water transferred to the North is projected to 44.8 bln m^3 by 2050. The total amount of water supply will increase by 34.5% in the 3-H river basins (MWR, 2004b). Total investment is estimated at about $60 bln (US Embassy, 2003); compared to the annual damage of $16 bln quoted above, this implies a payback time of less than four years and a rate of return on investment of 36%.

An increase in water supply in China would increase the water use in all sectors including the agricultural sector. Although the primary recipients of the transferred water will be households and industry, it is very likely that part of the transferred water will be allocated to

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[1] Given the large uncertainties in future water demand other studies arrive at different numbers. WB (2001), for example, shows a shortage of 37 bln m^3 in the 3-H basins for 2000.

the agricultural sector.[2] In the 3-H river basins this sector uses currently about 70% of the total water supplied (MWR, 2004b). An increase in water supply and agricultural output would affect national and international markets of agricultural products and food supply. The water embedded in commodities is also known as virtual water (Allan, 1992 and 1993). Therefore, changes in water supply would affect virtual water trade as well. To our knowledge, this implication of the SNWT project has yet to be investigated. The appropriate tool is a multi-region, multi-sector general equilibrium model.

The CGE approach allows for a rich set of economic feedbacks and for a complete assessment of the welfare implications. The analysis is based on regions' total renewable water resources and differences in water productivity. Growing wheat in North Africa requires more water than growing it in Germany. Also, different crop types have different crop water requirements; and regions grow different crop varieties. The production of a ton of rice is e.g. more water intensive than the production of a ton of wheat. Berrittella *et al.* (2005a) use GTAP-W, a computable general equilibrium (CGE) model including water resources, to analyze the economic impact of restricted water supply for water short regions. Using the same model Berrittella *et al.* (2005b) analyze the economic impact of water pricing policies. In contrast, this study is concerned with increased capacity of water supply and the implications of the related capital investment in China as well as consequences for the world economy.

In this paper, we present the GTAP-W model and apply it to water supply management in China. Section 2 reviews the literature on water management, the SNWT project and economic models of water use. Section 3 presents the model used and the data on water resources and water use. The basic model and the corresponding data can be purchased from the Global Trade and Analysis Project (http://www.gtap.agecon.purdue.edu/). Section 4 lays down the base simulation scenarios and discusses the results. Section 5 presents the results of a sensitivity analysis. Section 6 concludes.

2 Previous studies

2.1 Water use in China and the North-South Transfer

As the supply of water is limited, attempts have been made to economize on the consumption of water. One way to address the problem is to reduce the inefficiencies in irrigation and urban water systems. In urban water systems, water is wasted through leakage. About 70% of all water supply in the 3-H river basin is used for agriculture but water use efficiency is generally low (MWR, 2004b). The current level and structure of water charges mostly do not encourage farmers to use water more efficiently. An increase in water price, for instance by a tax, would lead to the adoption of improved irrigation technology (e.g., Dinar and Yaron, 1992). The water saved could be used in other sectors, for which the value is much higher. In this paper, we do not look at a reallocation of water, but we do look at a reallocation of water-intensive products.

If countries increase irrigation water prices their agricultural production might become less competitive on the world market and food supply would decreases. Of course, food demand could be met by importing more water-intensive food from water abundant countries, and producing and exporting commodities that are more water-extensive. Yang and Zehnder (2001) suggest this for China to reduce the problem of water scarcity. So far, few studies provide estimates of global virtual water trade (see e.g. Chapagain and Hoekstra, 2004) or analyze this kind of water management strategy (Kumar and Singh, 2005). However, in China

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[2] This is further discussed in section 2.

more than 60% of the population is engaged in agriculture (WWC, 2003) and price increases will have social implications as well. Jin and Young (2001) suggest compensation of farmers by other users for reallocation of water out of agriculture.

An alternative to alleviate the problem is to increase the supply of water as suggested by the SNWT project.[3] Construction of the project was officially launched in 2002 and work started at the eastern route. This is the easiest to construct as it builds upon the existing irrigation and water transportation network of the Grand Canal. Water will be diverted from the lower Yangtze river and will be lifted 65m by pump stations to flow north and supply water for Tianjin. For a total investment of \$8-10 bln the eastern route will transfer 14.8 bln m^3 per year (MWR, 2004a; US Embassy, 2003). A major concern is the low quality of the transferred water, due to the influx of untreated wastewater along the route (Yang and Zehnder, 2005).

Constructions of the slightly longer middle route (1,267 km) started recently (China Daily, 2005). Water will be diverted from the Han, a major tributary of the middle Yangtze river, to Beijing through canals. No pumping stations are needed for the project as the water can be conveyed by gravity. Investment costs are estimated at \$10 bln (US Embassy, 2003). Annual total water transfer capacity will be 13 bln m^3 (MWR, 2004a). A major concern is the limited availability of water resources at the origin of the route (Yang and Zehnder, 2005). Also, the construction involves the relocation of about 320,000 people mostly because of an increase in an existing reservoir at the intake for the route (US Embassy, 2003).

Specific details about the western route are still to be finished and work is not likely to start before 2010. For this project water will be diverted from three upstream tributaries of the Yangtze river into the upper Yellow river. The route runs through a remote and mountainous area in western China at altitude above 4,000 meters which are frozen most of the year. Therefore, if ever built, it will be the most difficult route and the most expensive one too. Investment costs are likely to exceed \$37 bln for a total annual capacity of 17 bln m^3 (MWR, 2004a; US Embassy, 2003). The total financial investment of about \$60 bln for the SNWT project will be only partly provided by the government (20%). A special water fee in the benefiting areas of 35% and bank loans of 45% will supply the rest (US Embassy, 2003).

Figure 1 about here

There are a number of studies debating the rationale, the feasibility and economic, environmental and social implications of the project (see e.g. Liu, 1998; Liu and Zheng, 2002; Ma *et al.*, 2006; Shang *et al.*, 2003; Shao *et al.*, 2003; Yang and Zehnder, 2001). Yang and Zehnder (2005), for example, state that an important reason for implementing the project was related to the environmental benefits arising from the water transfer. The increasing water shortage has led to severely degraded ecosystems and the environment. To prevent the ecosystem from further deterioration or allow for restoration of degraded systems about 23 bln m^3 would be needed. Even if all available water conservation measures were implemented in the economic sector it would be insufficient to meet the projected ecosystem water requirements. However, they conclude that water supply to the environment is likely to be limited since all the economic sectors are served first and the environment is unlikely to recover if water prices continue to be to low to reduce demand significantly.

Two studies have especially looked at the economic implication of the project in relaxing water constraints in the future. The World Bank (2001) study uses a detailed optimization model including a variety of constraints; hydrological, physical and agronomic. The results

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[3] For a detailed description of the decision making process of the project see, for example, Yang and Zehnder (2005).

indicate that even if the government’s management plan to improve irrigation efficiency, reduce unaccounted water supplies, increase water prices and treat waste water, together it will not be sufficient to meet future demand. Supply must be increased as well. Using a discount rate of 12% they conclude that the SNWT project, especially the east route, is highly profitable. They include information of the next stage of the SNWT project for the east and the middle route only and assume that these projects can deliver an annual water transfer of 19.4 bln m^3 by 2020. The WWF (2001) adopts a less detailed cost-benefit approach. They assume a much higher potential for water savings due to increases in water use efficiency and conclude that the project should not be implemented. Similar, Jin and Young (2001) see a high potential for increasing water use efficiency in agriculture. They suggest that farmers should be compensated for reallocation of water out of agriculture.

Berkoff (2003) analyzes the implications of the project in an agricultural development context focusing on the role of water in the rural economy. Reallocation of water from agriculture to municipal and industrial use is economically rational, but socially divisive. Employment in agriculture in that region is high. And despite the enduring water shortage, grain yields have been rising. One reason is groundwater mining. However, income levels of most farmers are still low. To mitigate the transition for the rural population, Berkhoff concludes that despite the large direct cost, environmental and socio-political arguments support the implementation of the project.

2.2 Economic models of water use

In order to obtain insights from alternative water policy scenarios on the allocation of water resources, partial and general equilibrium models have been used. While partial equilibrium analysis focus on the sector affected by a policy measure assuming that the rest of the economy is not affected, general equilibrium models consider other sectors or regions as well to determine the economy-wide effect; partial equilibrium models tend to have more detail. Most of the studies using either of the two approaches analyze pricing of irrigation water only (for an overview of this literature see Johannson *et al*., 2002). Rosegrant *et al*. (2002) use the IMPACT-Water model to estimate demand and supply of food and water to 2025. Fraiture et al. (2004) extend this to include virtual water trade, using cereals as an indicator. Their results suggest that the role of virtual water trade is modest. While the IMPACT-Water model covers a wide range of agricultural products and regions, other sectors are excluded; it is a partial equilibrium model.

Studies using general equilibrium approaches are generally based on data for a single country or region assuming no effects for the rest of the world of the implemented policy. Decaluwe *et al.* (1999) analyze the effect of water pricing policies on demand and supply of water in Morocco. Daio and Roe (2003) use an intertemporal CGE model for Morocco focusing on water and trade policies. Seung *et al*. (2000) use a dynamic CGE model to estimate the welfare gains of reallocating water from agriculture to recreational use for the Stillwater National Wildlife Refuge in Nevada. For the Arkansas River Basin, Goodman (2000) shows that temporary water transfers are less costly than building new dams. Gómez *et al*. (2004) analyze the welfare gains by improved allocation of water rights for the Balearic Islands.

Berrittella *et al.* (2005a) are an exception. They use a global CGE model including water resources (GTAP-W) to analyze the economic impact of restricted water supply for water-short regions. They contrast a market solution, where water owners can capitalize their water rent, to a non-market solution, where supply restrictions imply productivity losses. They show that water supply constrains could improve allocative efficiency, as agricultural markets are heavily distorted. The welfare gain may more than offset the welfare losses due to the resource constraint. Berrittella *et al.* (2005b) use the same model investigating the economic implications of water pricing policies. They find that water taxes reduce water use, and lead to shifts in production, consumption and international trade patterns. Countries that do not levy water taxes are nonetheless affected by other countries' taxes.

Feng *et al*. (in press) is an interesting study for China using a recursive dynamic general equilibrium approach based on the GREEN model (Lee *et al*., 1994) to assess the economic implications of the SNWT project. In their model China is divided into two regions; Beijing is chosen as the water recipient while the rest of China is treated as Beijing's national trading partner. The rest of the world acts as the international trading partner. The model comprises of 36 sectors with a detailed disaggregation of the industry and service sector, but no further disaggregation of the agricultural sector. Water is included as a production factor available at different quality. For the implementation of the SNWT project the authors assume a maximum transfer of about $1x10^8m^3$ from 2008. They compare four simulation scenarios; two sustainable water utilization scenarios (one with the SNWT project and one without) and two sustainable ones (one with the SNWT project and one without). The simulation results indicate that between 2010 and 2020 Beijing's GDP growth would be lower without the SNWT project and would be lowest under the sustainable water use scenario (and no water transfer). However, investment costs of the SNWT project are not considered.

In contrast to Feng *et al.* (in press), our analysis offers less regional detail but focuses in particular on the international implications of the SNWT project. Also, Feng *et al.* (in press) consider only part of the water transfer project relevant for Bejing (assuming an annual transfer of about $1x10^8m^3$) and not taking into account capital investment explicitly. We present results for the implementation of the complete SNWT project (water transfer of 44.8 $x10^8m^3$ per year) and the completion of the first two routes only (27.8 $x10^8m^3$ per year). Capital investment is explicitly taken into account. In contrast to Berrittella *et al.* (2005a and 2005b), this study is concerned with supply management and the effects of the SNWT project on China and the world economy.

3 Modeling framework and data

As in all CGE models, the GTAP-W model makes use of the Walrasian perfect competition paradigm to simulate adjustment processes.[4] Industries are modeled through a representative firm, which maximizes profits in perfectly competitive markets. The production functions are specified via a series of nested CES functions (*Figure A1 in the Annex*). Domestic and foreign inputs are not perfect substitutes, according to the so-called "Armington assumption", which accounts for product heterogeneity.

A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labour and capital). Capital and labour are perfectly mobile domestically, but immobile internationally. Land (imperfectly mobile) and natural resources are industry-specific. The national income is allocated between aggregate household consumption, public consumption and savings (*Figure A2 in the Annex*). The expenditure shares are generally fixed, which amounts to saying that the top level utility function has a Cobb-Douglas specification. Private consumption is split in a series of alternative composite Armington aggregates. The functional specification used at this level is the Constant Difference in Elasticities (CDE) form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods.

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[4] The model is a refinement of the GTAP model in the version modified by Burniaux and Truong (2002). The GTAP model is a standard CGE static model distributed with the GTAP database of the world economy (www.gtap.org). For detailed information see Hertel (1997) and the technical references and papers available on the GTAP website.

A money metric measure of economic welfare, the equivalent variation, can be computed from the model output.

In our modeling framework, water is combined with the value-added-energy nest and the intermediate inputs as displayed in *Figure A1 (Annex)*. As in the original GTAP model, there is no substitutability between intermediate inputs and value-added for the production function of tradeable goods and services. In the benchmark equilibrium, water supply is supposed to be unconstrained, so that water demand is lower than water supply, and the price for water is zero. Water is supplied to the agricultural industry, which includes primary crop production and livestock, and to the water distribution services sector, which delivers water to the rest of the economic sectors. Note that *distributed* water can have a price, even if primary water resources are in excess supply. Furthermore, water is mobile between the different agricultural sectors. However, water is immobile between agriculture and the water distribution services sector, because the water treatment and distribution is very different between agricultural and other uses.

The key parameter for the determination of regional water use is the water intensity coefficient. This is defined as the amount of water necessary for a sector to produce one unit of commodity. This refers to water directly used in the production process, not to the water indirectly needed to produce other input factors. To estimate water intensity coefficients, we first calculated total water use by commodity and country for the year 1997. For the agricultural sector the FAOSTAT database provided information on production of primary crops and livestock. This includes detailed information on different crop types and animal categories. Information on water requirements for crop growth and animal feeding was taken from Chapagain and Hoekstra (2004). This information is provided as an average over the period from 1997 to 2001. The CGE is calibrated for 1997. The water requirement includes both the use of blue water (ground and surface water) as well as green water (moisture stored in soil strata). For crops it is defined as sum of water needed for evapotranspiration, from planting to harvest, and depends on crop type and region. This procedure assumes that water is not short and no water is lost by irrigation inefficiencies. For animals, the virtual water content is mainly the sum of water needed for feeding and drinking. The water intensity parameter for the water distribution sector is based on the country’s industrial and domestic water use data provided by AQUASTAT. This information is based on data for 2000. By making use of this data we assume that domestic and industrial water uses in 2000 are the same as in 1997.

The mechanism through which water transfer is introduced into the model is the potential emergence of economic rents associated with water resources. If supply falls short of demand, consumers would be rationed, and willing to pay a price to access to water, because water has an economic value, as it is needed in production. The opposite happens if supply is greater than demand. If water resources are privately or collectively owned, the owners receive an economic rent, which becomes a component of disposable income. The price for water is then set by the market at the level that makes water demand compatible with supply. In this setting, water supply is assumed to be completely inelastic (vertical). By introducing technologies for “effective” water production, the supply function could, however, be positively sloped. Therefore, we introduce a constraint on water amounts, in our model, which entails the creation of a new market and a new exchangeable commodity.

Finally, we make the link between output levels and water demand sensitive to water prices. In other words, we assume that more expensive water brings about rationalization in usage and substitution with other factors. The opposite happens if more water would be available. The actual capability of reducing the relative intensity of water demand is industry-specific, and captured by a price elasticity (*Table A3 in the Annex*), or rather the production cost elasticity to water demand. Note that the elasticities are little more than informed guesses, derived from Rosegrant *et al.* (2002).

4 The economic consequences of the SNWT project

4.1 Design of model experiments

To assess the economic impacts and the international trade implications of the SNWT project for China and the rest of the world, we design three base scenarios. In the first scenario, we exclusively investigate implications of the increased water supply due to the construction of the SNWT project, not considering the capital investment necessary to make the additional supply available. In the second scenario, we consider the implications of capital investments in China without linking the investment to additional water supply. In the third scenario, we combine the first two scenarios to analyze the interrelation between increases in water supply through capital investment.

In the first scenario (called 'base' scenario), we increase the water supply in China by about 7%. This is equivalent to an increase of 44.8 bln m^3 of water. It is the maximum amount of water that could be transferred if all routes would be implemented. The water transfer is implemented in the model by increasing the productivity in the water demanding industries. We interpret the water transfer as an improvement of production for the same level of non-water factor inputs. Although more water is available, current water users do not experience a drop in the value of that asset, or rather, they cannot capitalize the change in value. This reflects China's underdeveloped property and capital markets. Nonetheless, in section 5, we report the results of a scenario in which the existing water rents changes.

In the second scenario (called 'investment' scenario), we account for the fact that capital investments are necessary to implement the SNWT project. In the standard GTAP framework, regional investments are endogenous variables. Furthermore, savings and investments are not equalized domestically, but only at the global scale. A hypothetical "world bank" collects savings and allocates investments, realizing the equalization of regional expected returns. We modified this procedure by defining regional investment exogenously for China. Following Bosello *et al.* (2004), we set the investment level in China augmenting the calibration value by the percentage change, due to the additional investment expenditure for the SNWT project. To ensure the equalization of global saving and investment, we then allowed for an endogenous adjustment of regional savings by assuming that all regional investments increase by the same percentage. In this way, the GTAP assumption of perfect international mobility of capital is respected. More specifically, in scenario 2 we simulate a total capital investment of about bln \$60, at a 10% discount rate, for the construction of all three routes by 2050.[5] This is equivalent to an annuity of about \$7 bln.[6] Finally, in the third scenario (called 'base + investment' scenario), we jointly simulate the capital investment of scenario 2 and the increase of available water as in scenario 1 for the case that the whole SNWT project would be constructed.

4.2 Simulation results

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[5] 2050 is the year when construction of all three routes is supposed to be completed.

[6] Alternatively, we could have kept global investment at its initial level, and allocated more investment to China. As \$7 bln is small compared to global investment, the results would have been very similar.

Results for the scenarios described in section 4.1 are presented in Tables 1 to 4. The first three tables report values for some key economic variables including water demand, virtual water trade balance, trade balance and welfare indices on a regional level. Table 4 compares changes in prices and production levels in China.

The additional water supply, scenario 1 (base), increases water productivity in China. The resulting change differs between agriculture and water distribution services: productivity increases faster in more water-intensive sectors; the water distribution service sector, for example, needs more water to produce $1 of output. More water supply leads to a decrease of virtual water imports in China. Furthermore, the shift in the production to more water-intensive goods and services in China leads to a decrease in exports of other goods and services. Overall, the change in China's trade balance is negative as prices for agricultural products on the world markets fall. The other regions reduce their demand for water due to the decrease in imports of water-intensive goods and services in China and increase the production as well as exports of non-water intensive goods and services. This leads to gains in terms of trade. Global welfare and GDP increase. On the regional level, China gains substantially, but most other regions are worse off. The changes in welfare are mostly a consequence of the changes of a region's terms-of-trade effect on welfare (compare Table 1). JPK is one of the regions that is better off. The main contribution to welfare in JPK comes from increased imports of agricultural products (especially cereals and other crops) at lower prices from China and to a much lower extend from higher exports of products of other industries to China. For China the largest contribution to the positive change in welfare comes from the technological change due to increased productivity in the water-intensive industries. The Hicksian equivalent variation increases by $3.3 bln a year, for 44.8 mln m^3 (75 $/$m^3$). This is rather smaller than the $16.0 bln for 17.8 mln m^3 (900 $/$m^3$) estimated by governments officials (Cernetig, 2000).[7]

Table 1 about here

In scenario 2 (investment), reported in Table 2, we simulate the capital investment necessary to build the western, eastern and middle Routes of the SNWT project. The increase of the investment demand leads to an increase in production of capital goods, but to a decrease in production in most other sectors in China, including water-intensive goods and services. Prices increase. Therefore, the demand for water decreases. As the production of water-intensive goods and services decreases, the virtual water exports decrease as well. In terms of international trade, China loses too as less goods and services are produced for the international markets. On the opposite, China gains in terms of welfare and GDP. The investment of $7 bln leads to an increase in welfare of $1 bln. The opposite effects occur for most other regions. The increase in investment in China is offset by a decrease in investment elsewhere. Water demand and agricultural production increase leading to a positive change in the virtual water trade balance in most regions. However, the change in trade balance is generally less positive compared to scenario 1. Although the production of most goods and services increases, the price changes are mostly negative and the overall effect on terms of trade is negative. Exceptions are JPK and SEA. The effect on welfare is more mixed. For countries like the US and CAN the change in welfare is less negative. For others, for example WEU and JPK, changes are more negative. For Japan this is most pronounced. One reason is that compared to scenario 1, no cheap imports of agricultural products from China are on the market. In addition, the increase in value of exports of products from 'other industries' and

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[7] We used the average shortage in the 3-H river per year (MWR, 2004a).

energy-intensive products is not enough to compensate for the loss originating from imports of commodities belonging to other industries of that sector from China. Again, changes in welfare are mostly a consequence of the changes of a region's terms-of-trade effect (compare Table 1). In scenario 2, this is also true for China. Global welfare decreases by \$0.5 bln.

Table 2 about here

Finally, in scenario 3 (base + investment), we jointly simulate the capital investment of \$60 bln (as in scenario 2) as well as the increase in the capacity of water. Consider also that in this scenario, we take into account the endogenous change in the capital investment (about 3.56%) due to the change in water supply of the base scenario.[8] The results are reported in Table 3. Like in scenario 1, we assume a non-market solution where additional water supplied leads to increases in water productivity. Compared to scenario 1, the increase in productivity is slightly more pronounced in the agricultural sector, and less so in the water distribution services for the same increase in water availability. The water demand in most other regions decreases less. In terms of virtual water trade balance, the increase in exports from China and decrease in exports from elsewhere are slightly smaller. The change in trade balance is more substantial and for most regions more positive. This is particularly pronounced for the USA, JPK and WEU; for EEU changes are turning from positive to negative. For China, the trade balance is negatively affected in scenarios 1 and 2; in scenario 3, the negative effects is somewhat higher than the sum of the two compounding scenarios. Changes in regions' welfare are generally more negative. This is, again, a consequence of the changes in a region's terms-of-trade. The largest contribution to welfare improvements in China is caused by increased productivity in the water using sectors. Changes in global welfare are slightly less positive compared to scenario 1. This is caused by the more pronounced negative changes in regional terms-of-trade. For China, changes in welfare are more positive. However, the positive change in welfare is slightly smaller than the sum of scenarios 1 and 2.

Table 3 about here

Table 4 compares changes in prices and production levels in China as a consequence of the above scenarios. Increasing the supply of water in China (scenario 1) leads to higher production levels and supply of most water-intensive products. To clear the market prices fall. The investment scenario leads to only small changes in production levels and prices in China. The biggest percentage change is the increased production of capital goods due to the increased investment. In scenario 3, compared to scenario 1, market prices for products from water intensive sectors decrease less, but prices for all other goods and services increase more.

Table 4 about here

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[8] The total change in investment in China implemented in the model is 3.56% (base scenario) + 1.85% (investment scenario).

5 Sensitivity analysis

5.1 Design of model experiments

In the previous section, we assumed that the extra water would be shared between all water-users, that all three routes would be implemented, that no market for water would exist in China, and that the discount rate for the capital investment would be 10%. In this section, these assumptions are altered.

The purpose of the SNWT project is the supply of water to high value users, like households and industries rather than to the agricultural sector, in scenario 4 (‘preferred allocation’), we simulate an uneven distribution of water transfer amongst the water-intensive industries. In particular, the water supply increases by 16.8% for water distribution services and only by 3.0% for agriculture. The additional water supplied to the agricultural sectors is equivalent to the amount transferred by the construction of the eastern route. As discussed above, a major concern is the low quality of the transferred water which might make it less valuable for other users. In this scenario (called ‘reduced’) we consider the fact that the western route is unlikely to be constructed. Additional capacity would drop from 44.8 bln m^3 per year to 27.8 bln m^3 (increase of 4%). This would occur if only the middle and the eastern routes would be constructed.

The second set of sensitivity simulations is based on the water quantities of scenario 1 (base scenario), but we now assume there is a water market in China; we refer to this scenario as the ‘market scenario’. The water transfer is introduced into the model through the economic rents associated with water resources. As the water supply increases, the price of water falls and water owners lose part of their income. The positive effects of an increased water supply are partly offset by the decreased value of water. In the base scenario, water users are de facto subsidized (per unit). In the water scenario, this subsidy is clawed back (lump-sum).

The last set of sensitivity scenarios refers to the investment scenario (scenario 2 above). In the first alternative investment scenario, called ‘investment 15%’, we set the discount rate equal to 15% to reveal how sensitive the results are in terms of welfare and trade. The capital investment increases to an annuity of about $9 bln. Furthermore, in the second alternative investment scenario, called ‘investment reduced’, we restrict the capital investment to the construction of the middle and eastern routes by 2050. As discussed above, the western route is particularly difficult to construct. Capital investment would be reduced to bln $20. China’s annuity decreases to about $3 bln. In neither scenario additional water is supplied to water using sectors in China. The focus of those experiments is on the economic consequences of the investment.

5.2 Simulation results

Figure 2 compares the changes in welfare in China and the rest of the world for the different non-market scenarios.[9] Also displayed is the contribution of the changes in terms-of-trade to changes in welfare for the respective scenario for the rest of the world. Omitted are the results for China as they would just mirror the above showing the opposite sign. It is evident that China’s welfare would be higher if all three routes would be implemented and the water would be given to the sectors more equally (left-most three scenarios of Figure 2). The pattern is similar for the terms-of trade effects although relative small in size. Including the investment to the first three scenarios (middle three scenarios) shows a similar picture with comparable numbers. The change in welfare is higher compared to the sum of the left-most three scenarios and the respective investment scenario individually indicating multiplicative

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[9] Rest of the world (ROW) refers to all regions except China and not to the specification used in previous tables.

effects. The investment scenarios (right-most three scenarios) have only a limited influence on China's welfare, but always positive.

The changes in welfare for the rest of the world are measured on the right axis of Figure 2 and always negative; although an order of magnitude smaller for most scenarios compared to the impact on China's welfare.[10] The left-most three scenarios indicate that welfare losses for the rest of the world would be smaller if all three routes would be implemented and the water would be given to the sectors more equally. The investment scenarios (right-most three scenarios) lead to much higher negative impacts on welfare for the rest of the world. This is caused by the transfer of investment to China reducing investments elsewhere. Changes in terms-of trade dominate the welfare impact. The welfare effect falls and rises with the annual investment in China. Again, combined scenarios (middle three scenarios) show more pronounced impacts on welfare and terms-of-trade compared to the individual ones (right-most three and investment scenarios) and the terms-of –trade effects dominate the welfare impacts. The welfare change is particularly pronounced in the scenario 'preferred + investment'. This is due to high negative changes in welfare in USA, WEU and JPK. For those regions the negative terms-of-trade effects are extremely pronounced.

Figure 2 about here

In the second set of simulations (Figure 3) we consider the existence of a water market (market scenarios). With extra water supply, the water price falls, and, hence, the water rent. As in the other scenarios, due to cheaper production of water intensive goods and services, more water supply leads to an increase in virtual water exports from China and to a decrease in virtual water exports to China. The change in the water trade balance is less pronounced than in the non-market scenarios. The changes in welfare for China and the rest of the world are generally smaller in size but all positive. These results come from two effects. First, the water rent falls, which is a loss of welfare. This is zero in the non-market scenario. Second, the output augmenting technology change is zero in the market scenario. This is positive in the non-market scenario. As in the non-market scenarios, China would benefit from the capital investments necessary to implement the SNWT project. This increase in welfare comes mainly from the positive terms-of-trade effects. If investment increases, the imports of the other goods and services decreases, leading to higher welfare.[11]

Because there is now a negative welfare effect through the decrease in water rent, more water does not imply more welfare, as it does in the non-market-scenarios. An unequal allocation of the additional water would now increase welfare. Although China's agricultural production is lowest in the 'preferred allocation' scenario, prices are highest. Therefore, China's terms-of-trade deteriorate if there is more water available. This further reduces water rents.

Comparing the 'base' and the 'investment' scenarios to the 'base + investment' scenario indicates that the sum of the welfare changes is higher than the joint change. In the joint scenario, the production of agricultural goods and capital goods is higher, but prices are lower. As prices for water decrease more, the income from water rent is smaller as well.

If least water is directed to the agricultural sector (preferred + investment) welfare gains are highest. As less additional agricultural products are produced, prices fall less compared to the other two scenarios. This dampens the loss in water rents. Although the fall in water rents is

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[10] Please note that the scale of the two axis are different.

[11] Note that the results of the investment scenarios (right-most three scenarios) are identical in Figures 2 and 3. The only difference is that of scale.

largest in the ‘base + investment’ scenario, the higher investment leads to welfare improvements compared to scenario ‘reduced + investment’.

Comparing figures 2 and 3, welfare losses for the rest of the world are smallest in the non-market scenario if we consider only the increase in water supply. If water supply increases, the import of water-intensive goods and services in the rest of the world increases more in the non-market scenario compared to the market scenario. World prices for agricultural goods are lower. But, if we add the investment, the rest of the world is better off in the market solution. If investments in China increase, the previous increase of imports (mainly agricultural goods) is counterbalanced by an increase of exports (investment) to China, which are higher in the non-market scenario.[12]

Figure 3 about here

6 Discussion and conclusion

In this study, we estimate the impact of the South-North Water Transfer (SNWT) project on the economy of China and the rest of the world using a computable general equilibrium model called GTAP-W. We find that the SNWT would stimulate China’s economy and increase welfare. In our base case, the payback period of the SNWT would be slightly less than two years. For the eastern and middle route, the payback period would be just over a year; for the western route, a bit more than 3 years. Previous estimates find a range of economic damage of $0.8 to $1.1 per cubic metre of water shortage. We find benefits of $\$0.7/m^3$ for additional water supply. If, as we assume, the SNWT project is (implicitly) financed at the international capital market, benefits slightly increase with the influx of investment. If, as the Chinese government plans, the water transferred is preferably allocated to industry and households, the benefits are halved.

These conclusions change drastically if we account for the current value of water. Additional water supply would reduce the implicit price of water, and hurt the “owners” of informal water rights. Then, the benefits of the SNWT are minimal – the difficult eastern route of the SNWT would reduce welfare – and water should be preferentially allocated to industry and households.

The economic and welfare impacts of the SNWT on the rest of the world are small but negative. The size of the effect may cast doubt on our choice of a *global* computable general equilibrium model. However, the negative effect for the rest of the world is largely explained by a deterioration of its terms-of-trade. This implies that the terms-of-trade of China would improve, which justifies that we embedded the Chinese economy in the world economy. The welfare gains of China far outweigh the welfare losses elsewhere – if we disregard the reduction in water rents. If that is included, global welfare falls due to the implementation ot the SNWT project.

This analysis needs to be extended in several ways and a number of limitations apply. First, we consider regional water supply, implicitly assuming that there is a perfect water market and costless water transport within each region. Sector-specific water resources allow for sub-

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[12] As indicated in Section 4, the changes in investment levels resulting from the ‘base’ scenarios are taken into account in the ‘base + investment’ scenarios. For the market solution the base scenario resulted in an increase in investment of about 3.56% (compare Table 4). In the non-market solution the changes was only 1.20%.

regional differentiation of water resources, but only to a limited extent. Second, we have not been able to allocate industrial water use to its different users. We rather used a simplifying assumption that water for domestic and industry use is supplied by the water service sector. Third, we were not able to differentiate between the different qualities of water supplied. Some of the difference is captured by defining sector-specific water, but not all. Fourth, in our model we assume that water is used efficiently and no water is wasted. The water intensity coefficient captures some differences, but these differences do not respond to price or other signals, except to the price of water. Fifth, for the agricultural sector, we used irrigation water plus rainfall, without distinction; water use is gross water use, ignoring evapotranspiration by crops. Sixth, we nested water at the upper level in the production function of the water intensive goods and services, so that water cannot be substituted with specific inputs in the production processes. Seventh, we used a single data set for water use and water resources, ignoring the uncertainties in the data. All this is deferred to future research. These caveats hold for the model. For its application to the South-North Water Transfer in China, we note the following problems. First, we do not take into account secondary benefits of increases in water supply to water scarce regions including health effects (including higher productivity of labour force), sanitation, peoples life-satisfaction assuming less water stress, functioning ecosystems. Second, we use data for China as a whole without dividing the country at least in two parts, the 3-H-river basin and the rest of the country. Disaggregating the data for China would require a new social accounting matrix and re-calibration. Third, we use a static CGE model based on 1997 data to analyse investment decisions.

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Annex

Table A1. Aggregations in GTAP-W

A. Regional Aggregation

1. USA – United States

2. CAN – Canada

3. WEU – Western Europe

4. JPK – Japan and Korea

5. ANZ – Australia and New Zealand

6. EEU – Eastern Europe

7. FSU – Former Soviet Union

8. MDE – Middle East

9. CAM – Central America

10. SAM – South America

11. SAS – South Asia

12. SEA – Southeast Asia

13. CHI – China

14. NAF – North Africa

15. SSA – Sub-Saharan Africa

16. ROW – Rest of the world

B. Endowments

1. Land

2. Labour

3. Capital

4. Natural Resource

C. Sectoral Aggregation

1. Rice – Rice

2. Wheat – Wheat

3. CerCrops – Other cereals and crops

4. VegFruits – Vegetable, Fruits

5. Animals – Animals

6. Forestry – Forestry

7. Fishing – Fishing

8. Coal – Coal Mining

9. Oil – Oil

10. Gas – Natural Gas Extraction

11. Oil_Pcts – Refined Oil Products

12. Electricity – Electricity

13. Water – Water collection, purification and distribution services

14. En_Int_ind – Energy Intensive Industries

15. Oth_ind – Other industry and services

16. MServ – Market Services

17. NMServ – Non-Market Services

Table A2. Regional characteristics

	Population	GDP/cap	Renewable water resource[a]		Water use	Water intensity in agriculture[c]	Water intensity other[d]	Water imports	Water exports
	mln	$	$10^9 \mathrm{m}^3$ per year	M^3/person[b]	$10^9 \mathrm{m}^3$ per year	$\mathrm{M}^3/\$$	$\mathrm{m}^3/\$$	$10^9 \mathrm{m}^3$	$10^9 \mathrm{m}^3$
USA	276	28786	3069	11120	479	2.9	3.7	57	125
CAN	30	20572	2902	96733	46	4.3	5.2	8	51
WEU	388	24433	2227	5740	227	2.6	3.5	256	96
JPK	172	35603	500	2907	107	1.4	1.6	82	0
ANZ	22	21052	819	37227	26	4.1	1.2	3	30
CEE	121	2996	494	4083	60	3.3	13.6	19	6
FSU	291	1556	4730	16254	284	9.1	28.0	27	61
MDE	227	3150	483	2128	206	4.9	6.8	35	19
CAM	128	2938	1183	9242	101	5.2	13.6	25	31
LAM	332	4830	12246	36886	164	3.9	5.9	35	68
SAS	1289	416	3685	2859	918	9.8	47.5	21	25
SEA	638	4592	5266	8254	279	10.1	12.8	58	35
CHI	1274	790	2897	2274	630	3.6	38.5	33	16
NAF	135	1284	107	793	95	8.5	39.5	27	4
SSA	605	563	4175	6901	113	11.4	6.4	14	132
ROW	42	3338	2984	71048	75	4.7	2.7	6	8

[a] 2001 estimates taken from Aquastat.

[b] UN criterion for water resource scarcity degree: slightly scarce (1700-3000), middle scarce (1000-1700), severe scarcity (500-1000) and most severe scarcity (<500).

[c] Average water intensity covering crop/plant growth and animal production measured in water use/$ output. Numbers differ considerably between countries and sectors. Note that water use includes the use of different kind of sources; rain, soil moisture and irrigation water. However, farmers pay for irrigation water only.

[d] Note that in some countries only a low number of persons is connected to a distribution network. In others a number of self-supplied industries are not connected. However, both are included as users of the services the water distribution network provides. As a consequence, water use per $ of output is overstated in the above table.

Table A3. Water price elasticities

	Agricultural sectors	**Water distribution services**
1 USA	-0.14	-0.72
2 CAN	-0.08	-0.53
3 WEU	-0.04	-0.45
4 JPK	-0.06	-0.45
5 ANZ	-0.11	-0.67
6 EEU	-0.06	-0.44
7 FSU	-0.09	-0.67
8 MDE	-0.11	-0.77
9 CAM	-0.08	-0.53
10 SAM	-0.12	-0.80
11 SAS	-0.11	-0.75
12 SEA	-0.12	-0.80
13 CHI	-0.16	-0.80
14 NAF	-0.07	-0.60
15 SSA	-0.15	-0.80
16 ROW	-0.20	-0.85

Source: Our elaboration from Rosegrant et al.(2002).

Figure A1 – Nested tree structure for industrial production process

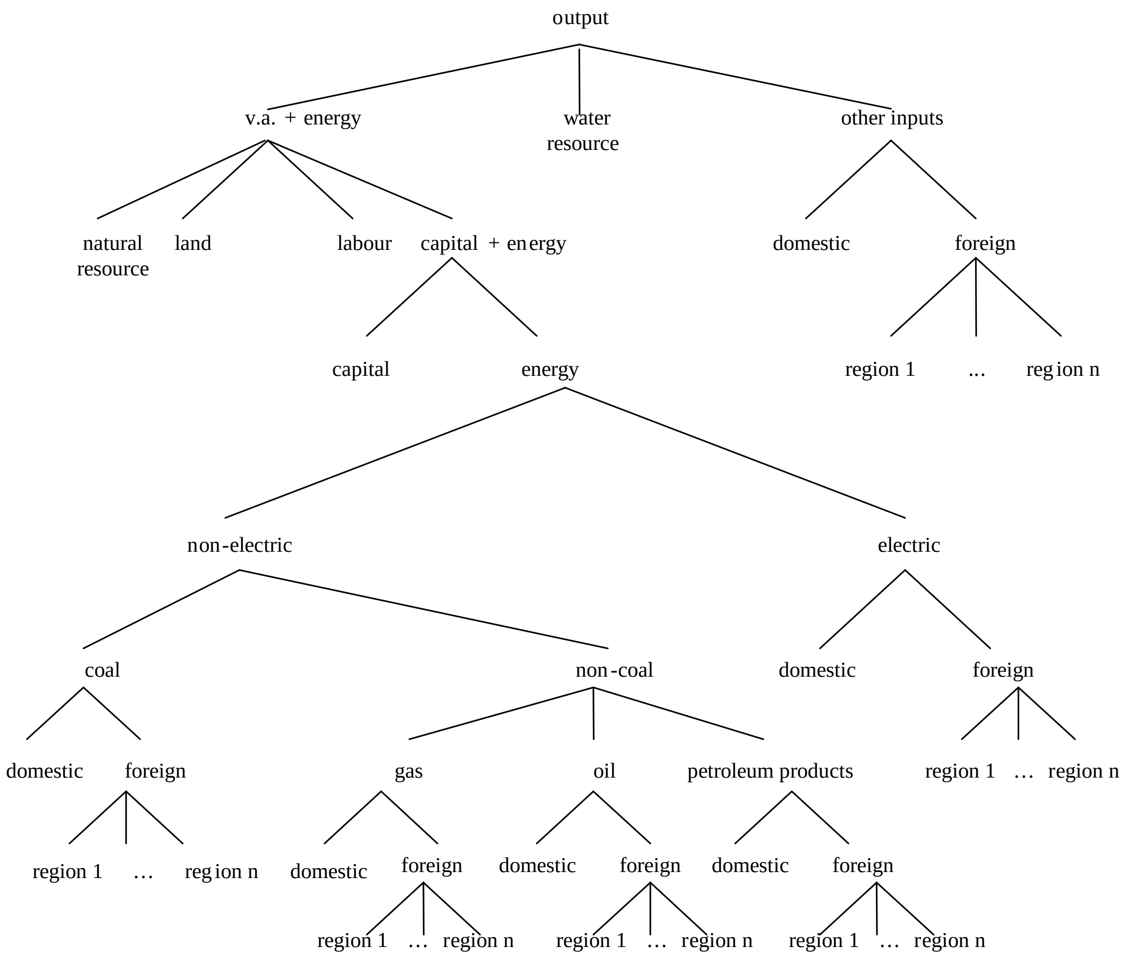
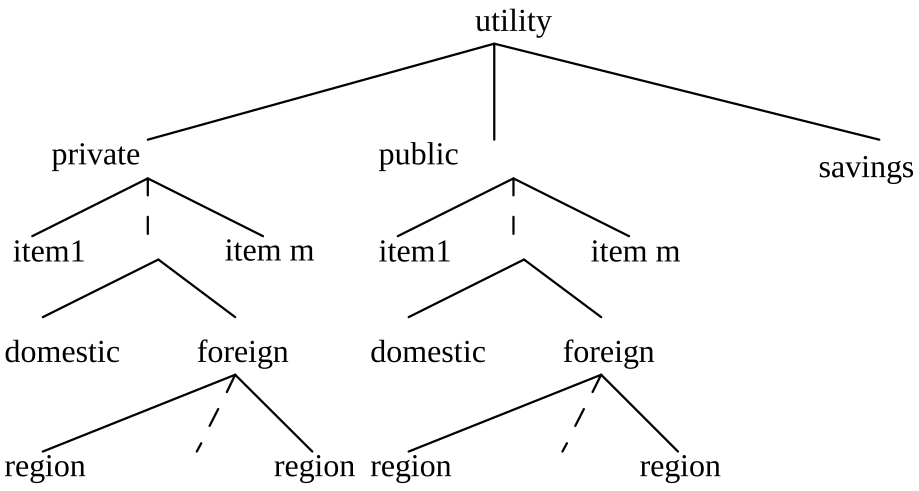
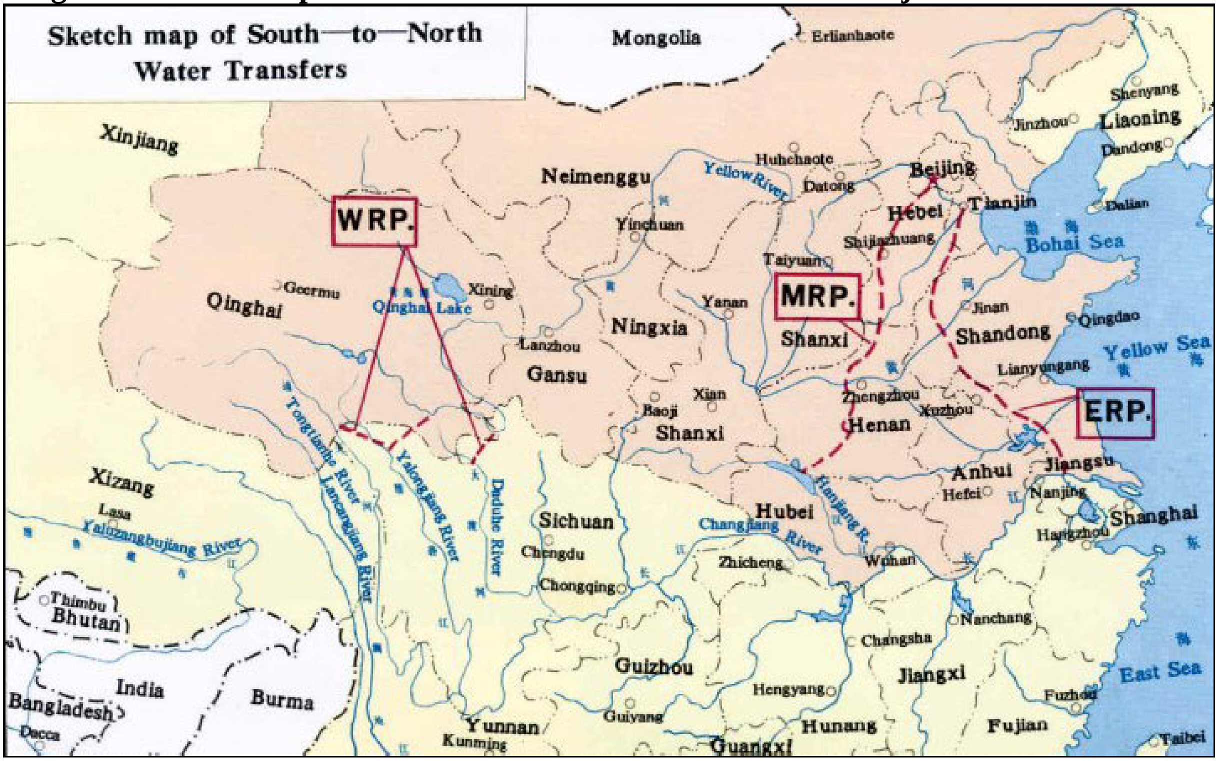


Figure A2 – Nested tree structure for final demand



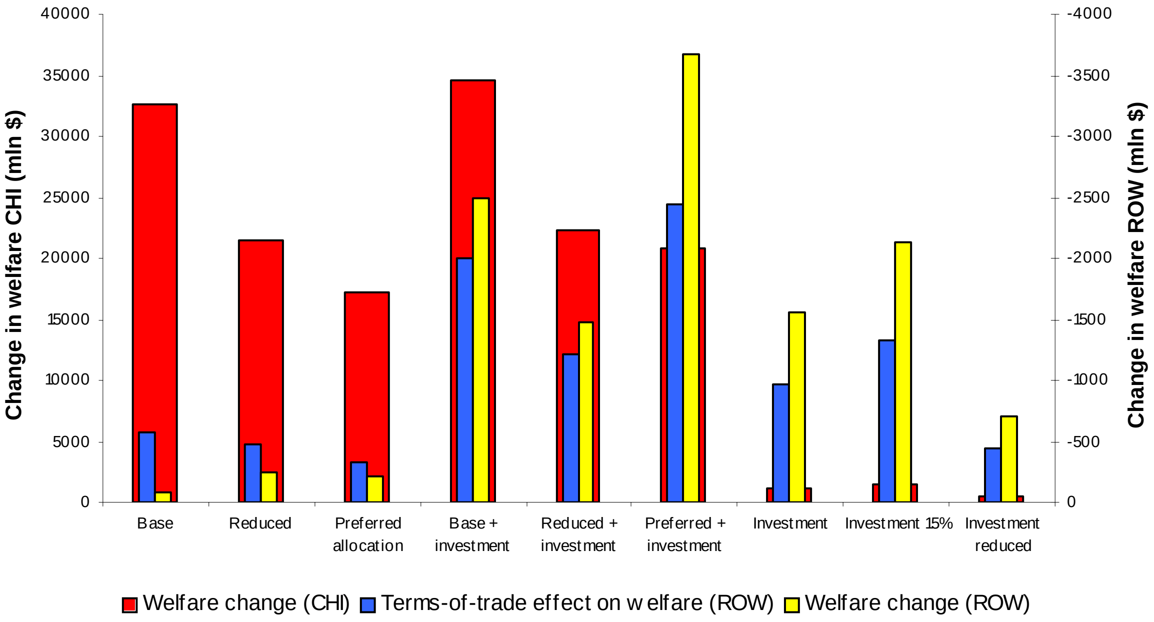
Figures and Tables

Figure 1: Sketch map of the South-to-North Water Transfer Project



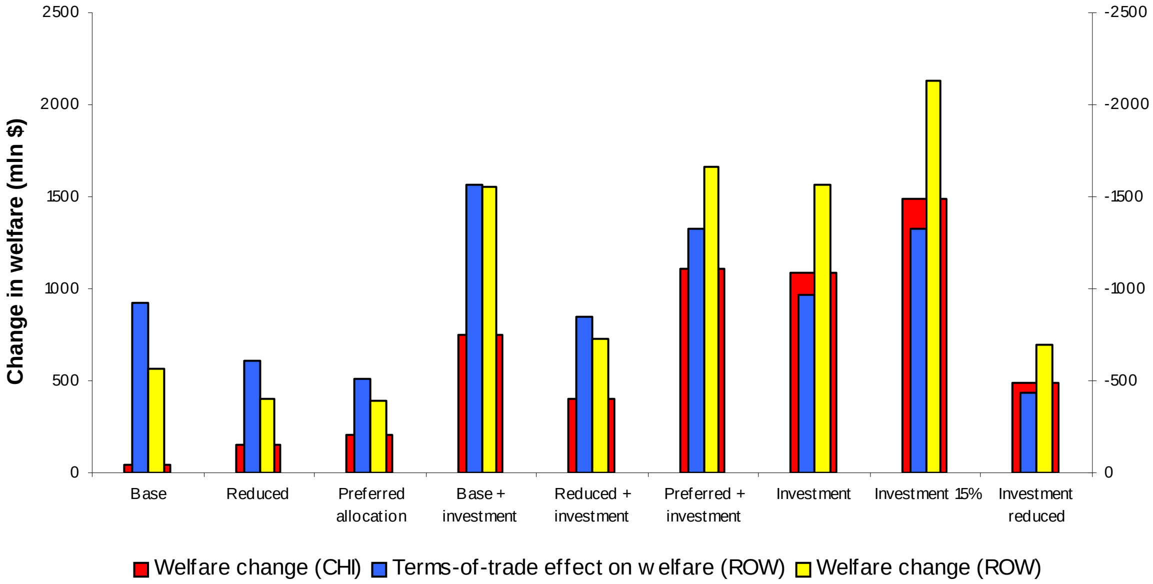
Source: MWR.

Figure 2: Welfare changes in China for the non-market scenarios[1]



[1] ROW refers to all regions except China and not the definition used in table A1. "Change" indicates a gain for China and a loss for "ROW".

Figure 3: Changes in welfare for the market scenarios[1]



[1] ROW refers to all regions except China and not the definition used in table A1. "Change" indicates a gain for China and a loss for "ROW".

Table 1. Construction of the western, middle and eastern routes (Scenario 1)

	Water demand (%)	Technical augmenting change (%)		Virtual water trade balance (change in billion m^3)	GDP (%)	Trade balance (change in mln $)	Contribution of ToT to EV (change in mln $)	EV welfare (change in mln $)
		Agricultural sector	Water distribution					
USA	-0.88	0	0	-5.55	0.000	2542	-790	-862
CAN	-1.70	0	0	-1.55	0.000	211	-55	-53
WEU	-0.63	0	0	-3.26	-0.002	3323	-300	-448
JPK	-0.48	0	0	0.72	0.018	1678	234	990
ANZ	-1.43	0	0	-0.95	-0.001	132	-43	-51
EEU	-0.33	0	0	-0.19	0.000	114	-6	-7
FSU	-0.83	0	0	-1.76	0.002	146	80	91
MDE	-0.59	0	0	-0.44	0.010	220	308	383
CAM	-0.43	0	0	-0.60	0.002	125	-9	-3
SAM	-0.35	0	0	-1.70	-0.007	575	-119	-258
SAS	-0.10	0	0	-1.39	0.000	147	-79	-84
SEA	-0.40	0	0	-1.03	0.006	-119	317	352
CHI	6.58	14.84	41.80	22.49	3.198	-9353	579	32646
NAF	-0.41	0	0	-0.29	0.004	99	39	46
SSA	-0.57	0	0	-3.93	-0.008	129	-189	-217
ROW	-0.31	0	0	-0.56	-0.001	32	34	34

Table 2. Capital investment for the construction of all three routes (Scenario 2)

	Water demand (%)	Investment (%)	Virtual water trade balance (change in billion m^3)	GDP (%)	Trade balance (change in mln $)	Contribution of ToT to EV (change in mln $)	EV welfare (change in mln $)
USA	0.03	-0.01	0.06	-0.001	1260	-277	-378
CAN	0.04	-0.01	0.02	-0.004	156	-6	-33
WEU	0.03	-0.02	0.01	-0.003	1674	-236	-501
JPK	0.07	-0.02	-0.06	-0.001	1925	-290	-341
ANZ	0.04	-0.02	0.01	-0.003	119	-16	-32
EEU	0.00	0.00	0.00	0.000	-10	6	5
FSU	0.02	-0.02	0.03	-0.002	131	-23	-33
MDE	0.01	-0.02	0.01	-0.001	116	-13	-25
CAM	0.01	0.00	0.00	-0.001	80	1	-6
SAM	0.02	-0.01	0.07	-0.002	269	-32	-76
SAS	0.00	-0.02	0.05	-0.002	160	-26	-41
SEA	0.02	0.00	-0.04	-0.001	432	-7	-19
CHI	-0.16	1.85	-0.25	0.007	-6432	971	1090
NAF	0.01	-0.02	0.01	-0.003	40	-7	-14
SSA	0.00	-0.03	0.06	-0.003	48	-40	-52
ROW	0.01	-0.01	0.01	-0.003	31	-6	-16

Table 3. Water transfer by all three routes and capital investment (Scenario 3)

	Water demand (%)	**Technical augmenting change (%)**		**Investment**	**Virtual water trade balance (change in billion m^3)**	**GDP (%)**	**Trade balance (change in mln $)**	**Contribution of ToT to EV (change in mln $)**	**EV welfare (change in mln $)**
		Agricultural sector	**Water distribution**						
USA	-0.56	0	0	-0.02	-5.45	-0.001	4094	-1133	-1363
CAN	-1.21	0	0	-0.04	-1.51	-0.011	547	-83	-151
WEU	-0.50	0	0	-0.03	-3.21	-0.007	5345	-569	-1192
JPK	-0.29	0	0	0.02	0.63	0.015	5460	-342	289
ANZ	-1.23	0	0	0.00	-0.91	-0.008	354	-74	-116
EEU	-0.26	0	0	0.17	-0.20	0.011	-131	35	71
FSU	-0.56	0	0	0.08	-1.72	0.000	260	55	48
MDE	-0.56	0	0	0.15	-0.46	0.014	33	330	427
CAM	-0.38	0	0	0.07	-0.59	0.001	211	-4	-4
SAM	-0.30	0	0	-0.02	-1.59	-0.010	913	-161	-365
SAS	-0.10	0	0	-0.04	-1.26	-0.004	530	-140	-175
SEA	-0.36	0	0	0.19	-1.05	0.004	945	259	263
CHI	6.58	15.00	40.61	5.41	21.98	3.235	-18859	2005	34666
NAF	-0.40	0	0	-0.03	-0.27	0.001	118	31	30
SSA	-0.57	0	0	-0.04	-3.86	-0.010	135	-237	-273
ROW	-0.30	0	0	0.10	-0.55	-0.003	45	29	21

Table 4. % Variations in prices and production levels in China

	Scenario 1		Scenario 2		Scenario 3	
	Price change (%)	Change in production level (%)	Price change (%)	Change in production level (%)	Price change (%)	Change in production level (%)
Land	-26.59	0.00	-0.29	0.00	-26.34	0.00
Labour	3.48	0.00	0.49	0.00	4.21	0.00
Capital	4.70	0.00	0.53	0.00	5.46	0.00
Natural Resources	6.70	0.00	-0.21	0.00	7.12	0.00
Rice	-19.64	-0.27	0.23	-0.36	-19.37	-0.73
Wheat	-23.74	-0.08	0.25	-0.26	-23.50	-0.35
Other cereals and crops	-16.13	9.20	0.26	-0.20	-15.83	8.97
Vegetables and Fruits	-16.55	7.44	0.27	-0.17	-16.20	7.52
Animals	-18.76	10.26	0.30	0.04	-18.43	10.71
Forestry	2.87	0.10	0.45	0.00	3.51	0.03
Fishing	5.13	1.72	0.29	-0.06	6.00	1.82
Coal	2.39	-0.03	0.17	-0.13	2.76	-0.15
Oil	1.83	-0.88	0.18	-0.15	2.15	-1.06
Gas	2.26	0.85	0.30	-0.22	2.73	0.66
Refined oil products	1.73	1.11	0.22	0.06	2.09	1.31
Electricity	2.52	0.23	0.34	-0.18	3.04	0.14
Water distribution	-28.49	6.58	0.44	-0.01	-27.41	6.58
Energy intensive industries	1.79	-0.55	0.35	-0.33	2.31	-1.00
Other industries and services	-0.05	1.65	0.34	-0.51	0.45	0.95
Market services	2.28	1.70	0.40	0.54	2.86	2.34
Non market services	2.23	1.12	0.40	0.05	2.82	1.31
Capital goods	1.31	3.56	0.34	1.85	1.81	5.41

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