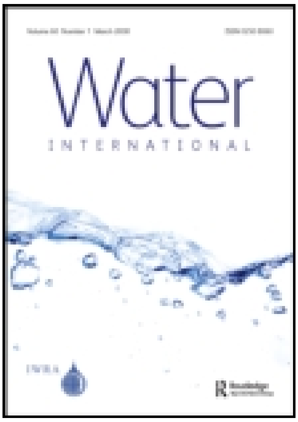

Water International
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rwin20

The economic impact of water tax charges in China: a static computable general equilibrium analysis

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Available online: 13 Jun 2012

To cite this article: Changbo Qin, Yangwen Jia, Z. (Bob) Su, Hans T.A. Bressers & Hao Wang (2012): The economic impact of water tax charges in China: a static computable general equilibrium analysis, Water International, 37:3, 279-292

To link to this article: http://dx.doi.org/10.1080/02508060.2012.685554

Water International
Vol. 37, No. 3, May 2012, 279–292

The economic impact of water tax charges in China: a static computable general equilibrium analysis

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(*Received 28 February 2011; final version received 13 April 2012*)

This paper presents a static computable general equilibrium model of the Chinese economy with water as an explicit factor of production. This model is used to assess the broad economic impact of a policy based on water demand management, using water tax charges as a policy-setting tool. It suggests that imposing water taxes can redistribute sectoral water use and lead to shifts in production, consumption, value added, and trade patterns. Another important finding is that water taxes imposed on the agricultural sector drive most of the effects.

Keywords: Computable general equilibrium; water allocation; water pricing; water tax; water scarcity; China

Introduction

Despite significant decreases in water use per capita and per unit GDP, total demand for fresh water is rising in China due to an increasing population, rapidly developing economic and social needs, accelerated urbanization, and improvements in both the standard of living and surrounding ecosystems. In 2007, the largest users of water were agriculture (63.5%) and industry (24.1%) (Fig. 1). Inter-sectoral competition for water is increasing because of increased total demand and pressure from climate change.

Supply-side engineering approaches are becoming less viable because of resource constraints and increasing marginal costs. The Chinese government has recognized that increases in water charges are necessary, not only for demand management but also to recover costs. Increases in water charges are likely to have economy-wide impacts, however. The main purpose of this study is to explore those impacts.

Many scholars have used partial equilibrium models to analyze changes in GDP and industry output arising from water resource policies (Conrad *et al*. 1998, Yang and Zehnder 2001, Rosegrant *et al*. 2002, de Fraiture *et al*. 2004). However, this approach fails to take into account interactions between water markets and the rest of the economy. General equilibrium analysis allows the consideration of a wider set of economic feedbacks and a

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ISSN 0250-8060 print/ISSN 1941-1707 online

http://dx.doi.org/10.1080/02508060.2012.685554
http://www.tandfonline.com

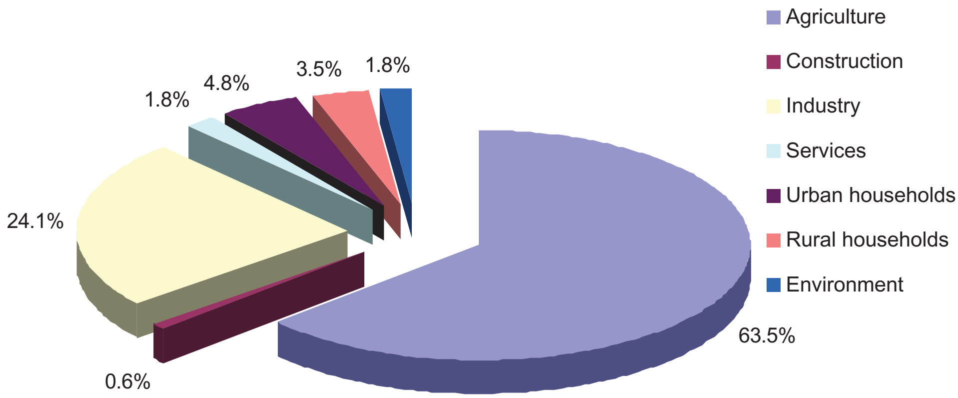

Figure 1. Water use patterns in China, 2007.
Source: MWR (2008).

complete assessment of welfare implications. Because they consider how the entire economy adapts after a policy change and the interactions between the different activities, CGE (computable general equilibrium) models are well suited for comparing alternative water management policy scenarios (see Appendix 1). In this study, the GeneRal Equilibrium Analysis sysTem for Water (GREAT-W), an economy-wide static Walrasian CGE model with water as a production factor, is developed to assess the likely effects of water tax charges on the Chinese economy.

The paper is organized as follows. The first section gives scenarios behind the simulations of water taxation policies. The second section analyzes the impact of water taxes on China's economy, and the final section presents the conclusion. Appendix 1 reviews the literature on application of CGE models to water management problems. Appendix 2 discusses the CGE model, data, and parameters.

Experimental simulation scenarios

With the view to protect limited water resources, the Chinese government is increasing water resource fees charged to all sectors of water users. These increases could be described as a water tax. Applying the model described in Appendix 2, three plausible simulations were constructed, each dealing with the economic impacts of water tax policies. The scenarios are as follows:

Scenario 1, selective pricing: extra water tax of CNY0.2 per m^3 on just the agriculture sector.
Scenario 2, uniform pricing: extra water tax of CNY0.2 per m^3 on all sectors.
Scenario 3, differential pricing: extra water tax of CNY0.2 per m^3 on the agriculture sector and CNY0.5 per m^3 on non-agriculture sectors.

Results and discussion

Table 1 presents the changes in sectoral outputs and their production prices for each of the three water tax scenarios (S1, S2, and S3). Each total sectoral output declined slightly –

Table 1. Results from simulations: changes in sectoral outputs (%).

	Price			Quantity		
	S1	S2	S3	S1	S2	S3
Agriculture	1.272	1.190	1.070	−2.098	−2.210	−2.374
Mining	−0.433	−0.342	−0.206	0.246	−0.021	−0.413
Food and tobacco	0.528	0.510	0.483	−1.367	−1.535	−1.782
Textiles and apparel	0.169	0.194	0.231	−1.712	−1.887	−2.146
Wood, paper, and printing	−0.185	−0.105	0.013	−0.121	−0.262	−0.470
Petroleum refining and coking	−0.403	−0.317	−0.190	0.140	−0.034	−0.288
Chemical products	−0.298	−0.170	0.017	−0.301	−0.541	−0.893
Nonmetallic products	−0.408	−0.330	−0.215	0.060	−0.021	−0.141
Metal products	−0.397	−0.304	−0.167	0.360	0.216	0.003
Machinery and equipment	−0.443	−0.400	−0.337	0.387	0.300	0.172
Other manufacturing	−0.083	−0.115	−0.163	−0.115	−0.212	−0.355
Electricity, heat-power, and gas	−0.430	0.215	1.166	0.022	−0.681	−1.704
Construction	−0.422	−0.385	−0.331	0.003	−0.002	−0.009
Services	−0.359	−0.399	−0.459	0.373	0.416	0.480
Total	−0.209	−0.155	−0.075	−0.100	−0.215	−0.383

by 0.10%, 0.22%, and 0.38%, respectively. As the major consumer of water, the agricultural sector exhibited decreased output of more than 2% in all three scenarios, because its production costs increased due to the additional water charge. A similar pattern of decline is also noted for two non-agricultural sectors: food and tobacco, and textiles and apparel. This is because both sectors purchase large amounts of goods from the agricultural sector as inputs to their own production (Qin *et al*. forthcoming). Thus, the added water charge on the agricultural sector will indirectly impact the production costs of these two sectors. Comparing the results of S2 and S3 with those of S1, it is apparent that the outputs of the non-agricultural sectors decreased in different ways: in particular, the output from the electricity sector declined more markedly than those of other non-agricultural sectors because it is water-intensive. Notably, water charges on these water-intensive users will impact production patterns, while charges on the agricultural sector will drive most of the effects on the sectoral output.

Changes in sectoral outputs due to increases in water prices under the different scenarios also had a direct impact on value added. Table 2 reports the changes in sectoral demand of labour and capital. With the charge on water resources, some sectors but not others can replace water with other factors (labour and capital). These will have varying impacts on factor remuneration. (Table 4, discussed later, presents the possible impacts of water taxes on labour wages and capital returns.) Under S1, the average return on capital increased slightly by 0.04%, while under S2 and S3 the average return on capital decreased by 0.08% and 0.25% respectively. The possible economic reason is that water taxes may increase or decrease the demand for capital by some sectors. Since capital is fixed in the short run, capital prices increased under S1 to reduce excess capital demand, while under S2 and S3 prices decreased to reduce excess capital supply. In the simulations under the three scenarios, average labour wages decreased by 0.97%, 1.10%, and 1.29%, respectively. Such declines indicate that water charges had negative impacts on the demand for labour in some sectors. In this situation, to reduce the excess supply of labour, average wages must decline until market equilibrium is again achieved. This generally leads to a decline in household incomes, because incomes for most households come from wages.

Table 2. Results from simulations: changes in value added (%).

	Labor			Capital		
	S1	S2	S3	S1	S2	S3
Agriculture	−1.825	−1.895	−1.998	−2.321	−2.397	−2.507
Mining	0.546	0.371	0.111	0.038	−0.143	−0.409
Food and tobacco	−0.838	−0.943	−1.097	−1.009	−1.116	−1.272
Textiles and apparel	−1.761	−1.833	−1.940	−2.109	−2.185	−2.297
Wood, paper, and printing	0.196	0.120	0.006	−0.210	−0.290	−0.409
Petroleum refining and coking	0.434	0.365	0.262	−0.024	−0.098	−0.207
Chemical products	0.086	−0.067	−0.290	−0.420	−0.578	−0.808
Nonmetallic products	0.376	0.398	0.429	−0.081	−0.065	−0.041
Metal products	0.726	0.678	0.608	0.216	0.163	0.085
Machinery and equipment	0.824	0.837	0.855	0.467	0.476	0.488
Other manufacturing	0.224	0.229	0.236	−0.283	−0.284	−0.285
Electricity, heat-power, and gas	0.251	−0.282	−1.073	−0.256	−0.792	−1.587
Construction	0.309	0.398	0.529	−0.198	−0.115	0.007
Services	0.722	0.840	1.015	0.213	0.324	0.490

A shift in sectoral output has consequences for supply, export, and import of commodities. Table 3 reports the changes in trade patterns with each scenario. Exports of agricultural commodities declined by 7.93%, 7.58, and 7.05%, respectively, while the domestic supply of agricultural commodities decreased by 1.97%, 2.10%, and 2.28% respectively. Because the production of agricultural commodities requires a great deal of water, their production costs increase as the water tax rises. As with the sectoral output, the same trend in export changes was recorded in two non-agricultural sectors – food and tobacco, and textiles and apparel – that utilize large quantities of goods supplied from the agricultural sector for their own production inputs (Qin *et al*. 2010). Thus, water charges indirectly raised their production costs. Comparing the results of S2 and S3 with those of S1, charges on non-agricultural

Table 3. Results from simulations: trade patterns in China (%).

	Export			Import		
	S1	S2	S3	S1	S2	S3
Agriculture	−7.9309	−7.5788	−7.0535	0.3374	0.0236	−0.4372
Mining	0.8988	0.4357	−0.2439	−0.0761	−0.2464	−0.4974
Food and tobacco	−4.4656	−4.3945	−4.2878	−0.1791	−0.4411	−0.8252
Textiles and apparel	−3.4286	−3.5291	−3.6783	−0.4914	−0.7216	−1.0597
Wood, paper, and printing	−0.4664	−0.7526	−1.1732	0.1297	0.0945	0.0428
Petroleum refining and coking	0.6718	0.3251	−0.1838	−0.0590	−0.1677	−0.3273
Chemical products	−0.1961	−0.7703	−1.6090	−0.3401	−0.4548	−0.6238
Nonmetallic products	0.6117	0.3897	0.0633	−0.1079	−0.1462	−0.2027
Metal products	0.8665	0.5212	0.0142	0.1910	0.1139	−0.0003
Machinery and equipment	1.0809	0.9963	0.8698	−0.0441	−0.1320	−0.2613
Other manufacturing	−0.8657	−0.6609	−0.3600	0.1150	−0.0746	−0.3535
Electricity, heat-power, and gas	0.6593	−2.4255	−6.7710	−0.1713	−0.1425	−0.1049
Construction	0.6087	0.6310	0.6628	−0.1807	−0.1942	−0.2137
Services	0.7243	1.1081	1.6745	0.2559	0.1864	0.0853
Total	−0.0317	−0.1224	−0.2559	−0.0403	−0.1557	−0.3256

water use also resulted in reductions in exports of highly water-intensive commodities and increases in exports of less water-intensive commodities. Taking electricity as an example, compared with S1, exports decreased by 3.09% and 7.43% in S2 and S3. Changes in trade patterns have an important role in appealing for a more reasonable level of water use. This is quantified by the water embedded in commodities, called "virtual water" (Chapagain and Hoekstra 2008). In terms of virtual water trade, as expected, a reduction of exports of highly water-intensive commodities leads to a decrease in virtual water exports. Water-starved countries can meet their demand for water-intensive products by importing them rather than producing them. Based on the results in Table 3, imports of most commodities will decline slightly if water charges are imposed. The possible reason for the decline is that domestic household consumption weakens due to reductions in household incomes and increases in the consumer price index induced by the water taxes.

Water charges can lead to shifts in production, consumption, value added, and trade patterns. In turn, such changes in production, consumption, and trade patterns also impact sectoral water demand and reallocate sectoral water use. Table 4 shows the changes in sectoral water use from simulations under each scenario. Decreases in agricultural output and exports reduced agricultural water demand, thereby allowing water to be reallocated to sectors with higher water-use efficiency. Because taxing agricultural water use indirectly reduces output and exports of the food and tobacco and textiles and apparel sectors, their water demands also declined. Comparing the results of S2 and S3 with those of S1, water charges on non-agricultural water use also resulted in water demand reduction of water-intensive sectors. Taking electricity again as an example, compared with S1 its water use decreased by 0.26% and 0.70% under S2 and S3, respectively. With water charge on sectoral water use, less intensive sectors will increase their water demands. Therefore, these results suggest that water charges on water-intensive sectors will lead to a reallocation of sectoral water use.

As a whole, the total water demand in China's economy decreased by 5.0, 5.2, and 5.3 billion cubic meters, respectively, under the three water tax scenarios, accounting for about 1% of the total water uses for production. Water saved can be reallocated to other sectors with high water-use efficiency or returned to nature for environmental use, thus achieving economical and environmental gains. Real GDP decreased slightly, by

Table 4. Results from simulations: sectoral water use (%).

	S1	S2	S3
Agriculture	−1.661	−1.650	−1.620
Mining	0.744	0.693	0.636
Food and tobacco	−0.456	−0.426	−0.359
Textiles and apparel	−1.531	−1.491	−1.415
Wood, paper, and printing	0.710	0.840	1.064
Petroleum refining and coking	0.801	0.899	1.070
Chemical products	0.009	−0.094	−0.236
Nonmetallic products	0.516	0.637	0.832
Metal products	0.801	0.846	0.928
Machinery and equipment	1.118	1.264	1.499
Other manufacturing	0.407	0.543	0.764
Electricity, heat-power, and gas	1.031	0.775	0.431
Construction	0.548	0.770	1.118
Services	0.703	0.885	1.166

Table 5. Results from simulations at the macro level (%).

Wage	−0.970	−1.098	−1.286
Capital rent	0.040	−0.079	−0.252
Real GDP	−0.216	−0.222	−0.231
Government income	3.322	4.311	5.839
Consumer price index (CPI)	1.718	2.204	2.978
Agricultural household (EV)	−0.985	−1.245	−1.625
Non-agricultural household (EV)	−0.760	−1.047	−1.467
Total water demand	−0.967	−0.989	−1.005

0.21–0.23%. In this study, the Hicksian equivalent variation (EV) was used to analyze the impact of water charges on household welfare. Equivalent variation refers to the amount of additional money an agent would need to return to its initial utility after a change in prices, a change in product quality, or the introduction of new products. In the results given in Table 5, the EV of agricultural households decreased 0.99%, 1.25%, and 1.63%, respectively, for each pricing scenario, and the EV of non-agricultural households decreased 0.76%, 1.05%, and 1.47%, respectively. These results suggest that water charges lead to general welfare decline within both agricultural and non-agricultural households.

Policy makers wanting to use water taxation to achieve environmental dividends might find it hard to trade off a drop in GDP or losses in welfare. Here the environmental dividends comprised reductions and reallocations in water use. Results in Tables 6 and 7 suggest that water charges do yield environmental dividends. Although the water tax changed production, consumption, and trade patterns, it induced negative effects in achieving economic dividends, because it reduced GDP and household welfare. According to the double dividend theory (Pearce 1991, Repetto *et al.* 1992), revenues from environmental taxes can lower the economic cost of the environmental tax. In this study, government incomes in each pricing scenario increased by 3.3%, 4.3%, and 5.8%, respectively. A subsidy, as a government transfer payment, can be provided to affected households to offset welfare losses in households. Due to the importance of food security for China's large population, added government income can also be used as a production subsidy to invest

Table 6. Results from simulations of sectorial water use (%).

	S1	S2	S3
Agriculture	−1.661	−1.650	−1.620
Mining	0.744	0.693	0.636
Food and tobacco	−0.456	−0.426	−0.359
Textiles and wearing apparel	−1.531	−1.491	−1.415
Wood, paper and printing	0.710	0.840	1.064
Petroleum refining and coking	0.801	0.899	1.070
Chemical products	0.009	−0.094	−0.236
Nonmetallic products	0.516	0.637	0.832
Metal products	0.801	0.846	0.928
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Construction	0.548	0.770	1.118
Services	0.703	0.885	1.166

Table 7. Results from simulations at the macro level (%).

	S1	S2	S3
Wage	−0.970	−1.098	−1.286
Capital rent	0.040	−0.079	−0.252
Real GDP	−0.216	−0.222	−0.231
Government income	3.322	4.311	5.839
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Non-agricultural household (EV)	−0.760	−1.047	−1.467
Total Water demand	−0.967	−0.989	−1.005

in water-saving irrigation technology and equipment, and could help avoid food shortages and reduce welfare losses for agricultural households. In addition to subsidies, negative economic effects can also be reduced by lowering other taxes, for example income taxes. Quantitative analysis on subsidies and other taxation cuts falls outside of this study. However, some empirical studies indicate that it is possible to achieve a double dividend if the environmental tax reform is implemented intelligently (Letsoalo *et al.* 2007).

Conclusions

This paper has presented a static computable general equilibrium model of the Chinese economy introducing water as an explicit factor of production. The CGE model was used to assess the economy-wide impact of a water pricing policy in the form of a water tax. Through three arbitrary scenarios, impacts on various sectors were tested. The results suggest that water-use charges can reallocate sectoral water use and lead to shifts in production, consumption, value added, and trade patterns. Water price increases led to declines in total output, total export, GDP, and household welfare. Sectoral outputs and exports with high water-use intensity were reduced by higher water charges. Specifically, output and exports of agriculture and related sectors declined most markedly. Through water charges, total water use declines and water scarcity is reduced. In addition, simulation results indicated that water can be transferred into sectors with high water-use efficiencies. Furthermore, any water pricing policy should take into account who and what is being taxed. Sectors not taxed directly are nonetheless affected by other taxed sectors. In the simulations, water tax charges on water-intensive sectors led to water reallocations to other sectors maintaining high water-use efficiencies. In China, water taxes in the agricultural sector drive most of this water reallocation, shifts in production, consumption, and trade patterns, as well as welfare changes.

In the results of this simulation, decline in GDP was less than linear in the reduction of water usage, whereas losses in welfare were more than linear in the reduction of water usage. Usually, policy makers who want to use a water tax to reduce water consumption find it hard to accept a drop in GDP or losses in welfare. To mitigate the negative effects of water taxes, more attention should be paid to revenues collected from water taxes that can lower the economic cost of the environmental tax (Letsoalo 2007). Subsidies on water-saving irrigation technology and for impacted households and lowering of other taxes are measures that could help alleviate the negative impact of water taxes on the economy and household welfare.

This analysis needs to be extended in several ways to remove a number of limitations. First, welfare losses elicit a non-linear response under changes in water tax charges. Excess burdens and equity considerations need to be incorporated into the model. Second, the amount of water saved can be released back into nature for environmental use, and water tax revenues can also be used to restore damaged environments arising from excess water use. Therefore, the functions of these environmental welfare effects should also be added into the model. Third, a single data-set was used for water use and water resources, ignoring the uncertainties in the data. Fourth, the regional differences cannot be captured adequately by a single country model, because the distribution of water resources is extremely uneven in China and economic development is also unbalanced among the different regions. Fifth, introduction of a dynamic mechanism would lead to more accurate long-term water policy analysis.

Acknowledgements

The research received partial financial support from the National Scientific Foundation of China (projects 50939006, 51021006, and 50779074), the National 973 Program of China (2006CB403404), and the Public Utility Research Program of the Ministry of Water Resources, China (200801012). The comments and revision suggestions by the reviewers and editors on the manuscript are also appreciated.

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Appendix 1. Literature review: application of CGE models to water management problems

Susangkarn and Kumar (1997) used a CGE model for Thailand incorporating water use costs into the production sector. Decaluwé *et al.* (1999) developed another model to compare different water pricing policies for Morocco. Seung *et al.* (2000) combined a country-level dynamic CGE model with a recreation demand model to analyze temporal effects of reallocating water from agricultural to recreational use in rural Nevada. Diao and Roe (2003) and Diao *et al.* (2005) used an inter-temporal CGE model, allowing for analysis of both top-down and bottom-up linkages, to analyze water and trade policies for Morocco. Diao *et al.* (2008) extended their Morocco model, differentiating ground water and surface water as inputs for agricultural production and urban water demand, to evaluate direct and indirect effects of ground water regulation on agricultural and non-agricultural sectors. Xia *et al.* (2010) used a general equilibrium model to analyze changes in GDP and industry output under water price increases in Beijing using the GEMPACK software tool. Fang *et al.* (2006) investigated the economic impacts of efficient intra-regional and inter-regional water reallocation and examined their corresponding economic gains in China with a Ramsey-type growth model of a small, open, competitive economy. Juana *et al.* (2012, this issue) used a CGE model to investigate socio-economic consequences of climate change on water resources in South Africa. Based on the global general equilibrium model GTAP-W, Calzadilla *et al.* (2010) offered a method for investigating the role of green (rain) and blue (irrigation) water resources in agriculture within the context of international trade. Qin *et al.* (2011) applied an extended environmental dynamic computable general equilibrium model to assess the economic consequences of implementing a total emission control policy. Their study indicated that a modest emission reduction target for 2020 can be achieved at a relatively low macroeconomic cost and that environmental policy can lead to an important shift in production, consumption, and trade patterns from dirty sectors to relatively clean sectors.

Appendix 2. Analytical framework

This section describes the structure of the CGE model, constuction of the social accounting matrix (SAM), and calibration of model parameters.

Model structure

The model was developed using the Mathematical Program System for General Equilibrium (MPSGE), which is a general algebraic modelling system (GAMS) extension developed by Rutherford (1998), and its MCP GAMS solver. Figure A1 presents a diagrammatic overview of the structure of the model. Its theoretical structure is typical of most static CGE models, and consists of equations describing producers' demands for produced inputs and primary factors; producers' supplies of commodities; demands for capital investment; household demands; export demands; government demands; relationships of basic values to production costs and to purchasers' prices; market-clearing conditions for commodities and primary factors; and numerous other macro-economic variables and price indices.

In this paper's standard neo-classical CGE model, each activity is assumed to maximize profits, defined as the difference between revenue earned and the cost of factors and intermediate inputs. As full competition and constant returns to scale are assumed, no excess profits can be reaped and the maximum-profit condition reduces to a least-cost condition. Profits maximized are subject to a production technology. The model uses multi-level nested production functions to determine the level of production. At the top level, the technology is specified by a constant elasticity of substitution (CES) function of two quantities: value added, and aggregated intermediate inputs. The aggregate

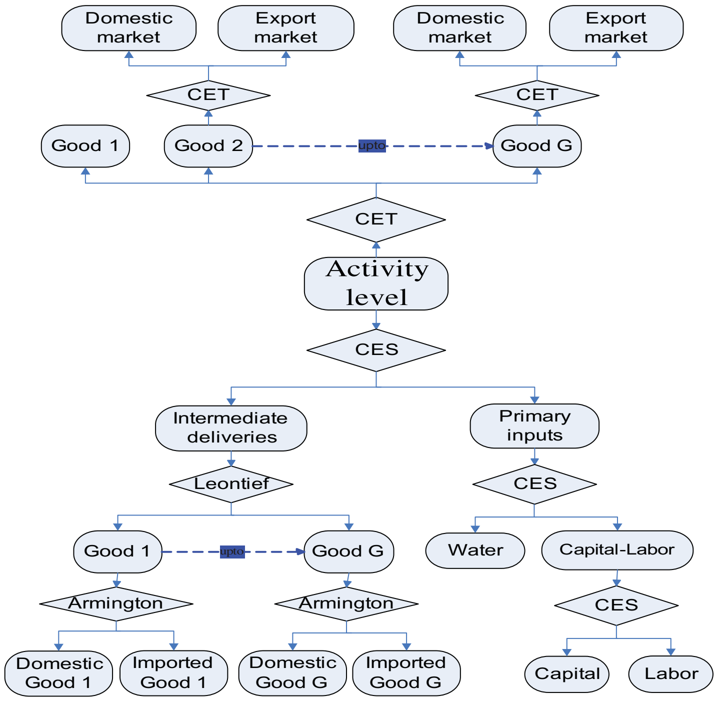

Figure A1. Structure of the water CGE model.

intermediate input is determined by a Leontief function of disaggregated intermediate inputs, while value added is itself a nested CES function of primary factors. In economics, the Leontief production function implies the factors of production will be used in fixed (technologically pre-determined) proportions, as there is no substitutability between factors. The CES function uses the elasticity parameter of substitution between factors to measure the percentage change in factor proportions due to a percentage change in the marginal rate of technical substitution. From no substitution (the Leontief case of fixed coefficients) to perfect substitution (linearity) there is a whole range of possibilities for CES functions. Capital and labour are combined by a CES function at the bottom level, and this capital-labour composite is subsequently linked with water by a CES function. This combination of composite primary inputs is the same across production sectors. However, this does not imply the same composite factor endowment combination for every product because shares of inputs and the elasticity parameters between inputs are not the same across the production sectors.

Each activity is assumed to produce exactly one commodity, which is used to satisfy domestic and foreign demands. The revenue of the activity is determined by the level of the activity, yields, and commodity prices at the producer level. Factors are assumed to be freely mobile across sectors. The capital and labour markets are closed by assuming that the demand for each of these factors is equal to their supply. In contrast, the total water usage cannot be greater than the total water supply; moreover, water pricing may differ across sectors. These assumptions imply that while labour and capital are fully employed, water demand does not necessarily exhaust supply.

The model also assumes imperfect substitution among goods differing in origin or destination. Aggregated domestic output is allocated between domestic sales and exports by maximizing revenue for any given output level. A producer maximizes profits by finding optimal combined use of domestic output for domestic sales and exports. The constant elasticity of transformation (CET) function is used to formalize this concept of imperfect substitution between domestic consumption of sectoral output and foreign demands. The CET is the corollary CES function, where the production possibilities of the industry are a function of different combinations of supply activities (Philippidis 1999). Domestic market demand is made up of the sum of demands stemming from household consumption, government expenditure, investment, and intermediate inputs. All domestic market demands are for a composite commodity made up of imports and domestic outputs. In this study, the Armington CES-function form is used to determine demand composition between domestic outputs and imported goods. The Armington elasticity represents the elasticity of substitution between products of different countries, based on the assumption made by Armington (1969) that products traded internationally are differentiated by country of origin. The trade distortions against export and import flows are specified as foreign savings and *ad valorem* tariffs.

Households receive direct and indirect income from factor endowments of labour and capital, enterprises, and transfer payments from other institutions (i.e. the government and the rest of the world). Each household's consumption decision is subject to a budget constraint. After a fixed share of the income is transferred in remittances and another fixed proportion goes to private savings, the household maximizes its utility through adjusting its consumption choices on different goods which are characterized by a linear expenditure system (LES). The LES is a form of utility function which overcomes the drawback that household expenditures on any particular category of good are unaffected by the price (Stone 1954).

Enterprises do not consume any commodities. Their major source of income is the return on capital. Enterprises obtain net profits after paying direct taxes and receiving transfer payments from government. One part of net profits after tax is transferred to households, and the remaining is kept as enterprise savings. The government receives its income from tax revenues, water revenues, and lump-sum transfer payments from the rest of the world (ROW). Government expenditure consists of consumption for different goods and transfer payments to households, enterprises, and the rest of world. The residual of revenue over expenditure constitutes government savings.

Social accounting matrix

The social accounting matrix (SAM) used in the CGE model is a consistent, multi-sectoral, economy-wide data framework that integrates national accounts, input-output, flow-of-funds, and foreign trade statistics into a comprehensive and consistent dataset. It is typically set up to represent the economy of a nation (Li 2002).

In the absence of an official SAM published by the government, a SAM must be built by combining data from various sources into a consistent framework. Following the method adopted by He *et al.* (2010) for building China's 2005 SAM, a macro-SAM was first built for China's economy in 2007, and then the micro-SAM was compiled by further splitting the accounts in the macro-SAM. The data for activities, commodities, and import and export accounts were based on the national input-output table of China's economy for the same year. The quantity of import and export commodities and the data of tariffs came from the *Customs Statistics Yearbook 2008* (GAC 2008). Because the trade tariffs are included in the accounts of intermediate inputs of the input-output table, they needed to be extracted from the accounts of activities and commodities when compiling the SAM. The revenue of expenditure accounts of the government came from *Finance Yearbook of China 2008* (MOF 2008) and tax data from *Tax Yearbook of China 2008* (SAT 2008). The revenue and expenditures of households, enterprises, and government were adjusted based on the flow-of-funds accounts in the *China Statistical Yearbook 2008* (NBS 2008). The macro-SAM developed by the authors for China's economy in 2007 is shown in Table A1.

In this study, activities and commodities accounts in the micro-SAM were disaggregated into 14 sectors: agriculture (AGR), mining (MIN), food and tobacco (FOO), textiles and apparel (TEX), wood, paper, and printing (PPP), petroleum refining and coking (PET), chemicals (CHM), non-metallic products (NME), metal products (MET), machinery and equipment (MAC), other manufacturing (OHM), electricity (ELE), construction (CON), and services (SER). Due to limitations in the data, the households account was only divided into agricultural and non-agricultural constituents. Government activities were split into a main government account and several taxation accounts. As a key factor in this study, a detailed water account was added into a micro-SAM to account for sectoral water allocation and use in the economy. Information on water supply and usage came from *The Water Resources Statistics Bulletins 2007* (MWR 2008). National average water prices were estimated based on the statistics of water prices in different cities.

The design and construction methods for SAMs are not standardized. A SAM needs only to fulfil two conditions: the matrix must be square and the row total (total revenue) and column total (total expenditure) for each account must be equal (Qin, 2007). Owing to the use of different sources of data and various statistical discrepancies, the compiled SAM for China in 2007 was not initially balanced. To fulfil the row-column constraint, the cross-entropy method was adopted to balance the micro-SAM for China under the GAMS software environment.

Table A1. Macro-SAM of China's economy (billion CNY).

	1	2	3	4	5	6	7	8	9
1. Activities		80868.8							80868.8
2. Commodities	55281.5			9655.3		3519.1	9554.1	10513.1	88523.1
3. Factors	21168.3						40.0		21208.3
4. Households			12524.0		3122.7	544.7	294.0		16485.4
5. Enterprises			8463.8			206.1	160.6		8830.5
6. Government	4419.0	143.3	220.6	1399.7	877.9		−1.2		7059.2
7. Rest of the world		7511.0							7511.0
8. Saving/investment				5430.4	4829.8	2789.4	−2536.4		10513.1
9. Total	80868.8	88523.1	21208.3	16485.4	8830.5	7059.2	7511.0	10513.1	

Table A2. Values for key elasticities in the CGE model.

Elasticity	Values
Export demand elasticity (σ_T)	4
CES between imported and domestic goods (σ_A)	1 to 3
CES between capital and labour (σ_{KL})	0.1 to 0.8
CES between capital-labour composite and water (σ_{KLW})	0.1 to 0.8
CES between factors and intermediate inputs (σ_{TOP})	0.6

The cross-entropy method is an efficient method for the estimation of rare-event probabilities. It involves two steps: generation of a sample of random data (trajectories, vectors, etc.) according to a specified random mechanism; and updating the parameters of the random mechanism, on the basis of the data, in order to produce a "better" sample in the next iteration. The cross-entropy approach was first applied to SAM balancing by Sherman Robinson and colleagues at IFPRI (Robinson *et al.* 1998). The estimation procedure for updating a SAM is to find a new SAM X^1 close to an existing SAM X^0 by minimizing the cross-entropy distance between the new and the prior estimated probabilities, respecting all constraints.

Calibration of the model

The parameter values are crucial in determining the results of the alternative policy simulations. Ideally, all the parameters should be econometrically estimated in the CGE model. However, due to the required sophistication of techniques and limitations of the data it is usually considered infeasible to determine them through this method (Gunning and Keyzer 1995). Therefore, parameter values were determined by a calibration procedure (Mansur and Whalley 1984).

In the CGE model, the share parameters (such as consumer and government consumption share, average savings rate, and average tax rate) that can be calibrated by the benchmark dataset provided in the balanced SAM (He *et al.* 2010). The calibration procedure ensures that the parameters of the model are specified when the model could reproduce the initial dataset as an equilibrium solution. Once the SAM is reproduced, the model will respect all constraints of the SAM. Because the row total (total revenue) is equal to column total (total expenditure) for each account in the SAM, the share parameters will be determined through such a calibration procedure.

The other type of parameter includes the elasticity parameters, such as elasticity parameters of substitution between production factors, Armington elasticity, and CET elasticity, which are fixed exogenously. The elasticity parameters used in the model – based on the studies of other scholars (Dervis *et al*. 1982, Zhuang 1996, Zheng and Fan 1999, Zhai 2005, Willenbockel 2006) – are summarized in Table A2. In this study, CET elasticity between export and domestic demand was 4, and Armington elasticity between imported goods and domestic supply was between 1 and 3. CES elasticities between labour and capital were between 0.1 and 0.8 for different industries. CES elasticities between water and the labour-capital composite were also between 0.1 and 0.8 for different industries.