Impacts of Water Management System on Agricultural Production and Household Welfare within Urbanization of China: a Computable General Equilibrium Analysis

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This paper simulates urbanization under two different water management systems: i) the water parallel pricing system and ii) the water pricing system. The purpose is to discover which water management system is better for agricultural production and household welfare. The main conclusion is that the water pricing system is better than the water parallel system because it will increase the welfare, income and consumption of both urban and rural households. However, under the water pricing system, more water will be reallocated from agricultural sectors to the industrial and service sectors, especially to households; therefore, agricultural outputs will suffer greater losses.

Key words： CGE model, water management system, agricultural production, urban and rural households, urbanization

1. Introduction

Over the last ten years, urbanization in China has continued to advance: the shares of the urban population and persons employed in urban areas increased from 39.08% and 34.33% to 57.27% and 47%, respectively. The comparable percentages for rural areas thus decreased from 60.91% and 65.67% to 48.73% and 53%, respectively [6]. On the other hand, agriculture remains the dominant source of water use in China, siphoning from 373.6 to 374.4 billion m^3 between 2002 and 2011, but its share of total water use has gradually declined from 67.96% to 61.3%. In contrast, both industrial and residential users have been increasing and accounted for 23.9% and 12.9% of total use, respectively in 2011 [4]. In this study, we simulate the urbanization as a background by varying in the supplies of agricultural labor supply and non-agricultural labor for measuring the impacts of two water management systems on agricultural production and households' welfare.

2. Water Management System

The water management system plays an important role in coordinating water use with economic growth. Overall, the current water management system is fragmented, such that irrigation water is operated by the local government and pipe water by state-owned water companies, each with different pricing systems; this is the water parallel pricing system (WPPS) [8]. Moreover, China's initial efforts to integrate urban and rural water affairs management began in 1993 in Shenzhen, Guangdong Province. This reform aimed to restructure water management by creating a Water Affairs Bureau (WAB) to incorporate all resource management, service regulation and environmental management functions, and also redesigning the functions of the then-current pricing system, namely the water pricing system (WPS) [13]. However, many regions still have yet to carry out the reform due to the complicated socio-economic and environmental implications of water use. In the near future, China will continue to strengthen and improve the function of WAB and both irrigation water and pipe water will be priced together under an integrated water management system, the water pricing system [10]. Thus, we assess the water parallel pricing system and water pricing system using a computable general equilibrium (CGE) model.

3. CGE model with Water Management System

Our CGE model is based on China's social accounting

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matrix (SAM) for 2007 contributed by Ge and Tokunaga [3]. In the basic SAM, We introduce "pipe water production" as a production sector, which is given from the Input-Output Tables of China 2007 [5]; and also introduce the irrigation water input as a factor, which is estimated according to official database [7]. Precisely, the data of pipe water production is recorded in the "Water Production and Distribution" of that database. However, this sector only covers pipe water but not irrigation water according to its explanation. Based on our survey, the value of irrigation water is included in the capital input for each crop. In detail, in most rural areas of China, local government directly control the supply of irrigation water, so that farmers need to pay the irrigation cost per area to local government, which plays as the irrigation water price. Therefore, the value of irrigation water for each crop is separated from the initial capital input and then plays as one of factors regulated by the government revenue account. Furthermore, we aggregate the initial 16 provinces' agricultural labor and croplands into the macro level, and then divide cropland into irrigation land and non-irrigation land according to the sectoral irrigated rates calculated by Calzadilla, Rehdanz and Tol [2] using the 2000 baseline data (April 2008) of IMPACT [16]. We admit that these irrigated rates do not match with the actual data because it is too old and lack of evident since official database do not provide such data. In future study, we will make some surveys to estimate the actual data of them.

Moreover, this basic SAM is divided into two SAMs, of which the two water management systems vary: i) in the SAM with the water parallel pricing system (SAM-WPPS), the value of total supply of irrigation water is fixed to become a part of government revenue, and pipe water is operated by its production sector (see Appendix); ii) in the SAM with the water pricing system (SAM-WPS), we assume the irrigation water and pipe water will be integrated as one sector, the integrated water production sector, and thus the total water supply will come from this sector. Therefore, the prices of irrigation water and pipe water are estimated in WPPS; in WPS, the integrated water price is estimated. In detail of the modification from SAM-WPPS to SAM-WPS, irrigation water input (cell 'WAR'-'AGR') adds into pipe water input (cell 'WAP'-'AGR') to derive the integrated water input for each crop, and then the capital input of pipe water production is added a value equal to the total amount of irrigation water (cell 'CAP'-'WAP' plus 158). In other words, we assume that no additional intermediate inputs and labors are employed in the integrated water production. Accordingly, the capital income and direct tax of water production enterprise (cell 'ENT-WAP'-'CAP' and 'DTAX'-'ENT-WAP') should be increased by the same value (158) to keep the SAM balance. This setting assumes that the government would increase the direct tax for the water production enterprise to guarantee the balance of its revenue and expenditure.

Using these two SAMs, we construct two CGE models with two water management systems respectively referring to Zhong, Okiyama and Tokunaga [15] and the GTAP-W model [2]. We also refer to many previous studies including Akune, Okiyama and Tokunaga [1], Okiyama and Tokunaga [9], and Tokunaga, Resosudarmo, Wuryanto and Dung [11]. The production sectors are separated into two categories: i) farming sectors, including: paddy, wheat, corn, vegetable, fruit, oil seed, sugarcane, potato, sorghum, and other crops; and ii) other sectors, including the non-farming agricultural, industrial and service sectors. The nested constant elasticity of substitution (CES) production function type is used for each production sector (see Figure 1). Furthermore, the pipe water used in farming sectors is combined with the irrigation water with the value of substitution elasticity equal 30, which reflect the fact that there is no difference between pipe water and irrigation water for farming productions.

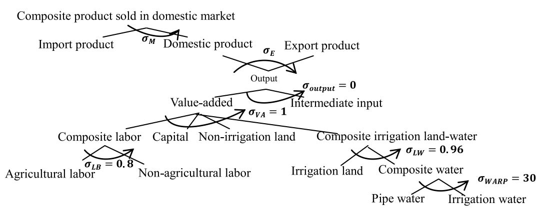

Figure 1 Nested CES production structure of farming sectors

Note: $\sigma = 0.8$ is derived from Ge and Tokunaga [5]; $\sigma = 0.96$ is given from GTAP-W model [3];$\sigma = 0$ and $\sigma = 1$ represent the Leontief and Cobb-Douglas assumptions, respectively

Moreover, similar to other country CGE models, China is assumed to be a small open economy, and the

Armington assumption and constant elasticity of transformation (CET) function are followed to describe trade between the foreign and domestic markets. The consumption behaviors of households are presented by the Stone-Gary utility function. The equivalent variation (EV) measures monetary change in welfare: if EV is positive, the simulation increases welfare; if it is negative, the simulation decreases welfare. The values of the elasticity parameters "**σ**" in the above functions are given from previous studies [2] [12] [14]. All of initial prices including water price are equal one before simulation, and thus the simulation results represent the percentage changes in the valuable rather than the valuable itself. The wage of non-agricultural labor is fixed as the price numeraire. The total supplies of capital, labor and land are also fixed as the given endowments[1].

4. Simulation results

In China, urbanization is rapidly expanding. Under urbanization, we wonder whether the current water parallel pricing system is efficient compared with the future water pricing system. Thus we considered the annual changing rates of employed persons in urban and rural areas: between 2007 and 2011, the amount of people employed in urban areas increased by 3.79% per year, while those employed in rural areas decreased by 2.35% per year. These two percentage changes are introduced into the CGE model (for non-agricultural labor and agricultural labor).

Moreover, in both of WPPS and WPS, the total water supply will be fixed: i) in WPPS, the pipe water supply will be fixed to follow an "effective" pipe water production with an endogenous production parameter; ii) in WPS, the setting for the integrated water production is the same as the pipe water production in WPPS. This setting is used because, in the CGE model, the number of variables should always be equal to the number of equations. Therefore, when we fix the initial endogenous variable as an exogenous one, we should define another initial exogenous variable as an endogenous one. In this simulation, we are going to fix the water supply, the pipe water and the integrated water, which is the initial endogenous variable defined in the model, and then an initial exogenous Leontief variable is selected to be endogenous to represent the "effective" water production. In this way, the number of variables will continue to be equal to the number of equations in the simulation.

In simulation, Table 1 shows that in WPPS, the irrigation water price and pipe water price increase by 5.27% and 5.80%, respectively; in WPS, the integrated water price increases by 5.59%. Moreover, in WPPS, total water use in farming, industrial and service sectors decrease by 0.19%, 0.02% and 0.26%, respectively, while households' total water consumption increases by 0.25%. In WPS, total farming, industrial and service water uses decrease by 0.48%, 0.01% and 0.16%, respectively, while households' total water consumption increases by 0.31%.

Table 1 Results for water distribution and price

Unit: %	WPPS	WPS
Total water use in farming sectors	-0.19	-0.48
Total water use in industrial sectors	-0.02	-0.01
Total water use in service sectors	-0.26	-0.16
Total water consumption of rural and urban households	0.25	0.31
Total water supply	Fixed	Fixed
Irrigation water price	5.27	*N.A.*
pipe water price	5.80	*N.A.*
Integrated water price	*N.A.*	5.59

Source: derived from simulation. Note: (1) *N.A.*, not available; (2) water use in farming sectors indicates the composite water in WPPS and the integrated water in WPS, respectively.

According to Table 2, in both WPPS and WPS, the decline in the supply of agricultural labor has a negative effect on farming production, especially for sorghum, corn and oil seed. However, the situation in WPS is more serious than in WPPS, where the decreases in the output and export of crops are more severe and the increases in producer prices and imports are higher. The main reason for this worse situation in WPS, as shown in Table 1, is that the farming water decreased more significantly than that in WPPS. For example, in WPPS, sorghum's output and export decreased by 5.07% and 7.32% respectively, and its producer price and import increase by 6.69% and 5.32%; in WPS, sorghum's output and export decrease by 5.09% and 7.35%, respectively, and its producer price and import increase by 6.71% and 5.34%.

[1] The detailed structure of similar CGE model sees Zhong, Okiyama and Tokunaga [15], pp. 60-69.

The results for households shown in Table 3 indicate that all households are projected to be better off under WPS in case of urbanization, and urban households are better off than the rural households. Among former 15 provincial rural households, those from Shandong, Sichuan, Henan, Guangdong, Anhui, Hebei and Hubei improve their welfare more significantly than others in both two water management systems. Furthermore, in WPS, both urban and rural households benefit from greater increases in welfare due to the higher levels of income and consumption, especially water consumption. Precisely, the differences between the increases in income and consumption of these two systems are not significant, while the increases in water consumption in WPS are higher than those in WPPS for both urban and rural households. Accordingly, higher water consumption is the main reason from higher welfare of households.

Therefore, compared with WPPS, WPS is a better policy option for both urban and rural households, and under WPS, their welfare, income and consumption would increase more significantly. Under the WPS, however, the decline in farming output would be worse than that under the WPPS because WPS would redistribute more water from farming sector to industrial and service sectors as well as households by generating the integrated water price, which is higher than the irrigation price but lower than the pipe water price.

Table 2 Results for agricultural output and producer price

Unit: %	WPPS: Water parallel pricing system				WPS: Water pricing system			
	Producer price	Output	Export	Import	Producer price	Output	Export	Import
Paddy	4.64	-0.89	-0.91	3.87	4.65	-0.90	-0.92	3.88
Wheat	4.51	-0.88	-0.99	3.56	4.52	-0.89	-0.99	3.57
Corn	5.40	-3.27	-3.43	0.28	5.41	-3.27	-3.43	0.28
Vegetable	6.49	-2.56	-2.65	3.19	6.50	-2.56	-2.65	3.20
Fruit	3.74	-0.55	-0.64	1.73	3.74	-0.55	-0.64	1.73
Oil seed	5.26	-3.25	-3.45	1.12	5.27	-3.26	-3.45	1.12
Sugarcane	5.47	-0.02		8.38	5.47	-0.02		8.39
Potato	6.62	-2.96	-3.05	2.94	6.62	-2.96	-3.05	2.94
Sorghum	6.69	-5.07	-7.32	5.32	6.71	-5.09	-7.35	5.34
Other crops	5.76	-2.66	-2.69	2.04	5.76	-2.66	-2.69	2.04

Source: derived from simulation.

Table 3 Results for households

Unit: for welfare, ten million yuan; for income and consumption, %		WPPS: Water parallel pricing system				WPS: Water pricing system			
		Welfare	Income	Consumption	Water consumption	Welfare	Income	Consumption	Water consumption
16 provinces' rural households	Guangdong	260.553	4.238	1.784	0.861	260.696	4.239	1.785	0.924
	Jiangxi	162.002	4.250	1.795	0.870	162.122	4.251	1.796	0.933
	Hainan	26.700	4.377	1.890	0.982	26.707	4.378	1.891	1.045
	Yunnan	183.590	4.634	2.233	1.295	183.650	4.635	2.233	1.358
	Guangxi	194.310	4.545	2.076	1.171	194.389	4.546	2.077	1.235
	Henan	280.328	4.366	2.095	1.092	280.429	4.367	2.096	1.153
	Jilin	95.280	4.361	1.981	1.019	95.311	4.362	1.982	1.081
	Anhui	234.725	4.331	1.949	0.994	234.790	4.332	1.950	1.056
	Heilongjiang	136.606	4.607	2.234	1.271	136.663	4.609	2.235	1.334
	Hebei	223.383	4.321	2.000	1.019	223.479	4.322	2.001	1.080
	Hubei	217.647	4.356	1.940	0.998	217.720	4.357	1.940	1.061
	Chongqing	86.223	4.361	1.938	1.004	86.247	4.362	1.939	1.067
	Sichuan	297.802	4.253	1.831	0.897	297.856	4.254	1.831	0.960
	Inner Mongolia	100.512	4.638	2.308	1.319	100.555	4.639	2.309	1.381
	Shandong	438.282	4.563	2.232	1.252	438.456	4.564	2.233	1.314
	Other provinces	1943.446	4.219	1.840	0.879	1944.689	4.220	1.841	0.941
Total change of rural household		4881.391	4.348	1.939	0.910	4883.758	4.349	1.940	0.973
Urban households		8197.744	3.406	1.130	0.129	8200.721	3.406	1.131	0.186

Source: derived from simulation.

5. Conclusion

Using a computable general equilibrium model of China's macro economy with 16 provincial rural households, we assessed the impacts of different water management systems of the water parallel pricing system and the water pricing system on farming production and urban and rural households by the simulation of urbanization. From the simulation results, we found that compared with the water parallel pricing system, the water pricing system would make both urban and rural households better off with higher levels of welfare, income and consumption. Therefore, the better policy option for both urban and rural households is the water pricing system. However, the water pricing system would decrease agricultural outputs more significantly and then their producer prices would be higher because more water would be reallocated from farming sector to the industrial and service sectors as well as households.

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Appendix: Macro-SAM with the water parallel system of China for 2007 (SAM-WPPS)

Unit: 0.1 billion yuan		Activities and Commodities			Factors						Institutions					Others					Total
		AGR	OTH	WAP	WAR	LAR	LAD	AGRLB	NAGRLB	CAP	16HHDRUAL	HHDURBN	GOV	ENT-NWAP	ENT-WAP	S-I	DTAX	INDTAX	TAR	ROW	
Activities and Commodities	AGR	6877	27514	0							6013	6301	342			3581				666	51294
	OTH	13348	503647	590							19106	65968	34849			109503				94875	841886
	WAP	9	837	41							52	270				-30					1179
Factors	WAR	158																			158
	LAR	105																			105
	LAD	52																			52
	AGRLB	26564																			26564
	NAGRLB	618	82621	244																	83484
	CAP	1115	115819	229																	117163
Institutions	16HHDRUAL					105	52	26564	5036	6651			793	8088	17					905	48211
	HHDURBN								78448	2328			5602	20468	44					2008	108898
	GOV				158											5700	11965	38519	1433	-12	57761
	ENT-NWAP									106331											106331
	ENT-WAP									229											229
Others	S-I										22013	34199	16053	69015	149					-22675	118754
	DTAX										1027	2158		8760	19						11965
	INDTAX	48	38396	75																	38519
	TAR	73	1360	0																	1433
	ROW	2328	71693	0						1623			122								75766
Total		51294	841886	1179	158	105	52	26564	83484	117163	48211	108898	57761	106331	229	118754	11965	38519	1433	75766	

Source: Ge and Tokunaga [3] constructed the main part of this SAM, except pipe water sectors, irrigation water, irrigation land and non-irrigation land within the bold edges, which are contributed by author. In their SAM, Saving/investment (S-I) acts as the balancing account for both activity and institution.

Note: (1) AGR = Agricultural sectors as activities/commodities, including paddy, wheat, corn, vegetable, fruit, oil seed, sugarcane, potato, sorghum and other crops as well as animal husbandry, forestry, fishery and the agriculture services; OTH = Other sectors as activities/commodities; WAP = pipe water production sector as one of activities/commodities; WAR = Irrigation water as a factor input; LAR = Irrigation land as a factor input; LAD = Non-irrigation land as a factor input; AGRLB = Agricultural labor as a factor input; NAGRLB = Non-agricultural labor as a factor input; CAP = Capital as a factor input; 16HHDRUAL = 16 regions' Rural households; HHDURBN = Urban households; GOV = Government; ENT-NWAP = Enterprise of non pipe water production; ENT-WAP = Enterprise of pipe water production; S-I = Saving and Investment; DTAX = Direct tax; INDTAX = Indirect tax; TAR = Tariff; ROW = Rest of the world; (2) to construct the integrated water production (represented by 'WAT') of SAM-WPS, the cell 'WAR'-'AGR' are added into the cell 'WAP'-'AGR' to derive the 'WAT'-'AGR' of SAM-WPS, and then the cell 'CAP'-'WAP' plus 158 to have the 'CAP'-'WAT' of SAM-WPS, and finally the cell 'ENT-WAP'-'CAP' and 'DTAX'-'ENT-WAP' are added 158 respectively to create the 'ENT-WAT'-'CAP' and 'DTAX'-'ENT-WAT' to keep the balance of SAM-WPS.