Int. J. of GEOMATE, Dec. 2011, Vol. 1, No. 2 (Sl. No. 2), pp. 122-129
Geotec., Const. Mat. and Env., ISSN:2186-2982(P), 2186-2990(O), Japan

Impact Analysis of Water Price Reform of Zhangye, China

Atsushi Koike, Dept. of Civil Eng., Kobe University, Japan,
Zhongmin Xu and Kang Wang, CAREERI, Chinese Academy of Sciences, China
Bunei Itoga, Regional Futures Research Center, Japan

ABSTRACT: The Hei River Basin is located in northwest region of China. This region belongs to arid zone, and water resources are one of the main limiting factors of harmonizing the development of ecology, economy and society. Due to the economic growth and the population increase, water consumption has grown rapidly since 1970s in this region especially in the Zhangye district. The rapid increase of water demand has degraded the ecosystems of the whole watershed. Water pricing is very important instrumentally in balancing water supply and demand. Appropriate water price is a very effective countermeasure in changing the social behavior towards water resource conservation, promoting economic efficiency and investment in more efficient equipments. The aims of this study are to analyze the comprehensive impacts of Water Price Reform of the Zhangye district by using an operational Computable General Equilibrium (CGE) model based on building a social accounting matrix (SAM).

Keywords: Water Demand Management, Water Price Reform, Computable General Equilibrium model, Zhangye, China

1. INTRODUCTION

The Hei River Basin is one of the major grain producing regions in China. The water shortage is mainly caused by the drastic population growth and the development of the irrigation area in the middle basin over the past decades. Water saving measures have to be taken to improve the irrigation system efficiency both on-farm and in the main canal system including water-saving measures, efficiency improvement and reuse of water. On the other hand, institutional management, water pricing and agricultural sector adjustment will play an important role in balancing demand and supply [15].

Water management includes water supply management and water demand management (WDM). WDM refers to the activities that aim to reduce water demand, improve water use efficiency and avoid the deterioration of water resources. Demand management offers sustainable water management solutions in the face of increasing water scarcity and growing conflicts over water use [6], [12]. For the Hei River Basin, the WDM measures consist of both technical and non-technical measures. Since irrigated agriculture uses 80% of the available fresh water, and the efficiency of this water use is very low, large quantities of water are wasted. Considerable economies can be realized if agricultural water is used in a more efficient way. Furthermore, water pricing and institutional reform can help controlling water demand and implement water saving [15].

Appropriate pricing of water (i.e., implementing an increasing block rate pricing structure) has proven to be a very effective measure in changing the public behavior towards water conservation and promoting economic efficiency and investment in new equipment [10].

However, the reform of water price will take impacts in regional economic system. The data on direct water consumption reveal that the amount of water consumed directly by the primary industry (agriculture, forestry, livestock, and fishery) is much greater than that consumed by the industrial and service sectors, with agricultural consumption exceeding 2 billion m^3, and the latter only consuming a small fraction of this amount (approximately 55 million m^3). This finding confirms the well-known fact that agriculture is the main consumer of water resources in Zhangye district, and is responsible for 94% of the total water consumption in the region. In comparison, the volume of water consumed directly by the industrial and service sectors is nearly negligible. However, when indirect water is considered, it becomes obvious that water consumption by the industrial and service sectors increased greatly. This is often unnoticed in analysis that focuses exclusively on the lower values for direct water consumption by these sectors. This means that although these sectors use only a small amount of water directly in production, in order to produce the inputs (generated by other sectors) that they incorporate into their production processes, a high consumption of water is necessary. Thus, it appears that the industrial and service sectors also consume large amounts of water indirectly. In this sense, indirect consumption seems to make up a significant part of the water consumption in the study area [17]. Therefore, water pricing will impact not only the agricultural sector but also other sectors.

Water resources are the fundamental components which drive the evolution of ecological-economic system. Therefore, we should evaluate the impacts of water price reform before it was implemented. The aims of this study are to analyze the comprehensive impacts of Water Price Reform of the Zhangye district by using an operational Computable General Equilibrium (CGE) model based on building a Social Accounting Matrix (SAM).

In this study, we build the SAM for water price reform and the CGE model based on the SAM. And, three water price reform scenarios are considered. We present the results from simulation experiments that we performed with the model to analyze the effects of each water price reform scenario.

2. STUDY SITE

The Hei River Basin spans Qinghai, Gansu and Nei Mongol, and is located in the arid zone of northwestern China. This is the second largest inland river basin in China. It covers an area of approximately 130,000 km2. Its upper reaches source from the boundary district of Gansu and Qinghai, and its lower reaches end to the desert in the western part of Inner Mongolia. Administratively, the basin includes a county of Qinghai Province located in the upstream region of the Hei River Basin; a city and counties of Gansu Province, all of which lie in the midstream region, namely Zhangye district, Minle district, Shandan district, Linze district and Gaotai district, respectively; and a county (within the Ejina Oasis with the location in the downstream region of the basin) in the Inner Mongolia [9] (Fig.1).The study site is Zhangye district, located in the middle reaches of the Hei River, is 42,000 km2 in size and has a population of 1.264 million, including a rural population of 9.11 million and an urban population of 3.53 million. The climate of this region is arid, with annual precipitation ranging from approximate 100 to 300 mm, and potential annual evapotranspiration reaching 2,000 mm.

Although located in one of the driest zones in the world, Zhangye district consists of many oasis ecosystems that are mainly watered by the Hei River. Water use in this city accounts for about 93% of all water use from the river, with 94% of this water used for agriculture. According to the Zhangye Statistical Yearbook [4], the irrigated area in Zhangye district was about 68,667 ha in the 1950s, but by 2002, it expanded to approximate 266,000 ha, including 212,000 ha of farmland and 41,000 ha of forest and grassland. As a result of irrigated farming, Zhangye district has become an important center of Gansu Province for the production of commodity grains.

Since the Chinese national economic reforms that began in 1978, new industrial sectors have arisen, such as mining (including coal production), production of building materials, electric power, metallurgy, machinery assembly, transportation, and services. In recent years, Zhangye district has experienced considerable economic growth as a result of these changes. The gross domestic product (GDP) was 837.3 million US$ in 2001, which was 8% greater than that in 2000. In 2002, 2003, and 2004, the GDP increased to 916.8, 1013.1, and 1206.7 million US$, respectively, representing annual increases of 10%, 11%, and 12%, respectively, over the values in the previous year [8].

Expanding agriculture and rapid economic growth have resulted in excessive use of the region's water resources. According to GPBWR (2003) [7], in 2002, the annual available water resources were 2.05 billion m^3, including 1.63 billion m^3 surface water and 0.42 billion m^3 groundwater while the actual annual water utilizations were 2.42 billion m^3, of which 90% was consumed by the socio-economic systems, and of this amount, 96% was used for agriculture. Ecological and environmental water demands are severely restricted for the excessive water use in socio-economic systems. As a result, the city seems to have locked into an environmental-economic dilemma through increasing dependency on the scarce water resources and further erosion of environmental quality [16].

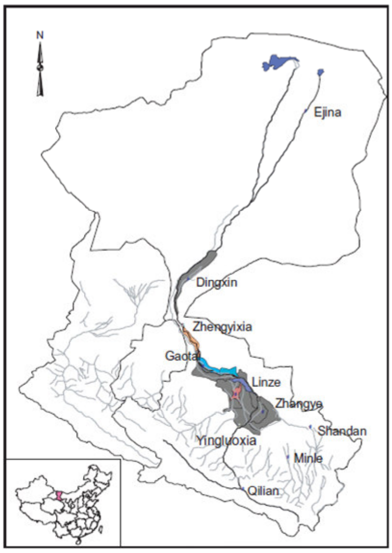

Fig.1 Hei River Basin [15]

3. SOCIAL ACCOUNTING MATRIX FOR WATER PRICE REFORM

3.1 Social Accounting Matrix

A Social Accounting Matrix (SAM) can be defined as an organized matrix representation of all transactions and transfers between different production activities, factors of production, and institutions (like households, firms and government), actual or imputed, within the economy and with respect to the rest of the world. A SAM is thus a comprehensive accounting framework within which the full circular flow of income-from production to factor income to household income to household demand and back to production-is captured. In a SAM, all the transactions in an economy are presented in the form of matrix as opposed to the double-entry format. Each row of the SAM details the receipts of an account while the columns detail the corresponding expenditure. The row and the column follow the same ordering and hence, a SAM must always be square matrix. An entry in row i and column j of the SAM denotes the receipts of account i from account j.

A SAM can be regarded as an extension of the Input-Output (I-O) table. The I-O table is a widely used matrix framework supplying detailed information on the flow of goods and services and on the structure of production cost. The SAM extends the I-O matrix in one fundamental way: unlike the I-O matrix, the SAM shows the interrelationship between income distribution and final expenditure. In other words, the circular flow of income, which is not closed in the I-O model, is partly closed at the macro level in the SAM model. For example, the economy wide effects of a change in an exogenous variable (say, export demand) turn out to be larger in the SAM model than in the I-O model, because the SAM model captures the induced effect on production and income that operate via household incomes and final demand. More importantly for policy-making, the structural pattern of effects due to such an exogenous change differs significantly between the SAM and I-O models. A further difference between the SAM and I-O

Table.1 SAM structure

		activity	commodity	factor			institution			other institution		
				labor	capital	water	household	water authority	government	tax	rest of the world	investment
activity			domestic marketed outputs									
commodity		intermediate					final demand		government demand		export	investment demand
factor	labor	labor input										
	capital	capital input										
	water	water input										
institution	household			labor income	capital income of household				transfer from government		transfer from rest of the world	
	water authority				capital income of water authority	water income						
	government									government revenue		
other institution	tax	value added tax					payroll tax	direct tax of water authority				
	rest of the world		import									
	investment						saving	investment of water authority	investment of government		investment of rest of the world	

models is that the I-O models do not include enough institutional detail (for example, income distribution) to provide a framework for obtaining the full impact of a policy change.

3.2 Features of SAM for Water Price Reform

Table.1 shows a SAM structure with verbal explanations in the cells instead of numbers. First, the SAM distinguishes between accounts for “activity (a)” and “commodities (c)”. The receipts are valued at producer prices in the activity accounts and at market prices (including import) in the commodity accounts. This separation of activities from commodities is preferred because it permits activities to produce multiple commodities (for example, a dairy activity may produce the commodities cheese and milk) while any commodity may be produced by multiple activities (for example, activities for small-scale and large-scale maize production may both produce the same maize commodity). This treatment provides the data needed to model imports as perfect or imperfect substitutes with domestic goods.

Second, as noted, the government is disaggregated into a core government account and different tax accounts, one for each tax type. This disaggregation is often necessary because the economic interpretation of some payment may otherwise be ambiguous. In any given application, the SAM may exclude any of the individual tax accounts. In the SAM, payments between the government and other domestic institutions are reserved for transfers [2].

Finally, the domestic nongovernment institutions in the SAM consist of households and water supply authority (water authority). Households hold labor and capital, and earn factor income. It may also receive transfers from government and rest of the world. Households expend to final demand, payroll tax and saving. The water authority is public institution and manages water supply. The water authority holds water and capital, and earns factor incomes. Their incomes are expended for direct tax and investment. As opposed to households, water authority does not consume. Actually, there are three water authorities: industrial water authority, agricultural water authority and daily life water authority in Zhangye district. Water qualities are different in each water authority. But in this model, it is supposed that there is one water authority for simplification. The specializations of this SAM to analyze the water price reform are that production factors have water in addition to labor and capital. Thus, the study can analyze the impact of water price reform. In this study, the SAM employs 10 enterprises, “agriculture”, “forestry”, “livestock”, “fishery”, “agriculture, forestry and fisheries service (agriculture service) ”, “mining”, “manufacture”, “electricity”, “construction”, “others”.

The data source of labor input, capital input, value added tax, capital income of household, final demand, government demand, investment demand, income transfer to household from government, payroll tax and direct tax of water authority is from the Zhangye Statistical Yearbook 2007 [4]. And other data is determined as following. Water input is calculated by multiplying quantity of water [4] by water price [14]. Intermediate, import and export are determined by Input-Output questionnaire. Labor income is total labor. Capital income of water authority is total water input minus capital income of household. Water income is total water input. Government revenue is sum of value added tax, payroll tax and direct tax of water authority. Saving is total household income minus total final demand minus payroll tax. Investment of water authority is total water authority income minus direct tax of water authority. Government investment is government revenue minus total government demand minus transfer. Investment of rest of the world is total import minus total export.

4. CGE MODEL FOR WATER PRICE REFORM

4.1 Computable General Equilibrium model

A Computable General Equilibrium (CGE) model is a general equilibrium model that implements the textbook description of an economy. There are utility-maximizing consumers whose decisions determine the demand for goods and supply of labor. There are profit-maximizing producers whose decisions determine the supply of goods and the demands for primary factors (labor, capital, and land) and intermediate inputs. There is international trade. There is a government which collects taxes and tariffs; may set exchange rates; and provides transfers, subsidies, and services. Finally, there are market-clearing conditions specifying supply-demand balance, which will determine equilibrium prices. The model is a "general equilibrium" because all domestic supplies, demands, prices, and incomes are determined simultaneously within the model. It is computable because the model solves empirically for all endogenous variables in a highly non-linear system of simultaneous equations.

Changes in policy alter demand through changes in prices. The wide scope of the model makes it especially useful for evaluating projects that have broad effects, changing incomes in many sectors through intersectoral linkages. When there is a generating many ripples in the economy, a general equilibrium framework are the appropriate tool of analysis [3].

The CGE model can consider the complex relationships in economic system, and it has been a popular tool in policy analysis. Water issues are important also in the world. Numerous state and regional economic impact studies of water management have been conducted. [Peter Berck, 1990] employ CGE procedure to investigate the reallocation of water in the San Joaquin Valley [11]. and [Chang K. Seung, 1997] investigate the economic impacts of transferring surface water from irrigated agriculture to recreational use at the Stillwater National Wildlife Refuge in Churchill Country, Nevada[5]. [Alexander Smajgl, 2006] develop a conceptual framework of water reform and generates an Applied General Equilibrium (AGE) model to investigate the impacts of potential water reform scenarios for an irrigation area with features of the Lower Burdekin [1]. [Okuda and Hatano, 2005] provides water-rights transaction model at China's province level applying general equilibrium theory, in which sets a virtual water-rights market for YRB [13]. We built the Social Accounting Matrix (SAM) [2] of Zhangye district and used an operational CGE model to analyze the impacts of water price reform of Zhangye district. And this study analyzes the impact on the Zhangye economy by water price reform methods by using the CGE model.

The CGE model explains all of the payments recorded in the SAM. The model therefore follows the SAM disaggregation of factors, activities, commodities and institutions. It is written as a set of simultaneous equations, many of which are nonlinear.

4.2 Features of CGE Model for Water Price Reform

Fig.2 shows the Framework of the CGE model for water price reform. Continues line shows flow of goods and factors, and it shows money flow in opposite sense. Dash line shows the flow of tax, subsidy, saving and transfer.

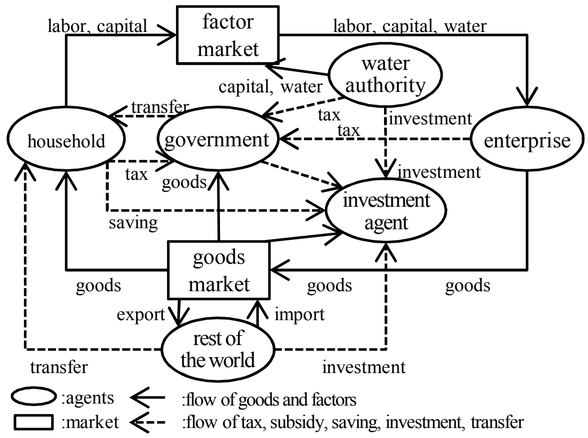

Fig.2 Framework of the CGE model for water price reform

In this CGE model, agents are presented by household, water authority, government, rest of the world, investment agent and ten enterprises. And there are factor market and goods market. Enterprises are "agriculture", "forestry", "livestock", "fishery", "agriculture, forestry and fisheries service (agriculture service) ", "mining", "manufacture", "electricity", "construction", "others".

The household income is composed of returns to labor and capital, as well as transfers from government and the rest of the world. And it is supposed that transfers to households from government are proportionate to government income. Household expend on saving, consumption of commodity and tax. The households consume the domestic consumer goods. It is assumed that each household maximizes its utility function subject to consumption expenditure constraint. The utility functions are defined as Cobb-Douglas functions.

The water supply authority (water authority) holds water and capital. It supplies water using by capital, pays a tax and invests.

It is supposed that government revenue is composed of value added tax, household tax and direct tax of water authority. Government expenditures are divided into transfer to household, consumption and saving.

Each producer is assumed to maximize its profits, defined as the difference between revenues earned and the cost. Profits are maximized subject to a production technology; the structure of which are shown in Fig.3.

Value added (V) is composed of water (W), labor (L) and capital (K) by the Cobb-Douglas function. Domestic production (DP) is a combination of value added and intermediate (X), which are characterized as strict complements according to Leontief function. In other words, zero-value substitution elasticities are assumed for intermediate inputs and value added. It is assumed that input coefficients of intermediate goods are fixed. Domestic production is transformed to domestic goods (D) and export (E) by CET (constant elasticity of transformation) function and export price is domestic consumer goods price. Domestic consumer goods are obtained to compose of domestic goods and import (M) by CES (constant elasticity of substitution) function and import price is fixed the price of rest of the world. The import price is the price paid by domestic users for imported commodities. And, the export price is domestic consumer goods price. In Zhangye district, most of import and export is transaction between Zhangye district and other national region. In this model, we assumed that the import price is fixed the price of rest of the world. In this model, foreign saving and transfer to household from rest of the world are fixed. The fact that all items except imports and export are fixed mean that, in fact, the trade deficit also is fixed. Model detail is in appendix.

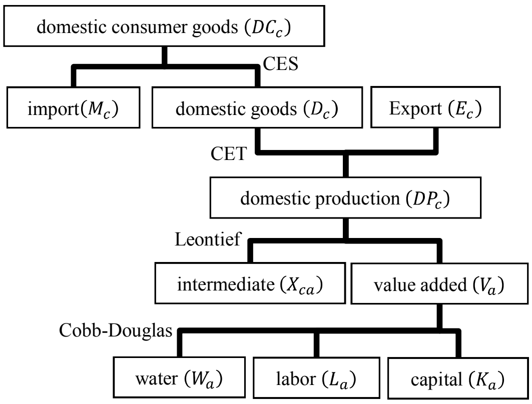

Fig.3 Framework of Production Technology

4.3 Scenario Definition

The primary water price is different in each activity as Fig.4. The primary price – also called benchmark – is compared with each scenario which is described in this section. Three scenario conditions are summarized in Table.2.

Scenario 1 means that the amount of the water price charge for construction, mining, manufacture, electricity and others are larger than the amount of price charge for agriculture, forestry, livestock, fishery and agriculture service

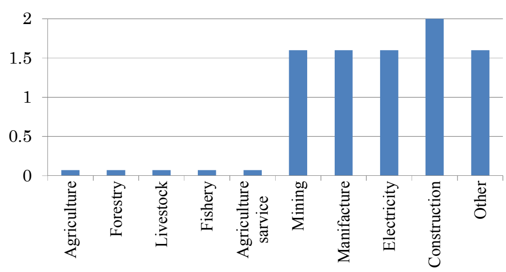

Fig.4 Primary water price of each activity (Yuan/m^3)

Scenario 2 means that the amount of the water price charge for construction, mining, manufacture, electricity and others are less than scenario 1, and the amount of price charge for agriculture, forestry, livestock, fishery and agriculture service is larger than sccenario1.

Then, water supply with water price reform doesn't exceed the present water authority income. The price that the water supply exceeds the income of water authority is unfeasible.

Table.2 Scenario definition

Scenario 1	Constant rate price charge for all activities $P_a^w \Rightarrow (1+\alpha)P_a^w$
Scenario 2	Constant additional price charge for all activities $P_a^w \Rightarrow P_a^w + P$
Scenario 3	Constant price for all activities $P_a^w \Rightarrow P^w$

P^w : primary water price
α : water price increase rate
P : water price increase amount
a : suffix of activity

5. RESULTS AND INTERPRETATION

5.1 Welfare Loss with Quantity of Water Saving

In this section, we compare the welfare loss with quantity of water saving in each scenario. The main output of CGE is utility level of household. The welfare loss is defined as the equivalent variation (EV). The EV is an estimate of the hypothetical variation in the household income, which would have produced the same change in the utility of the representative consumer, at fixed prices.

$$EV = \frac{U_0}{\prod_c \left(\frac{\beta_c^H}{P_{0c}^{DC}}\right)^{\beta_c^H}} - \frac{U_1}{\prod_c \left(\frac{\beta_c^H}{P_{0c}^{DC}}\right)^{\beta_c^H}} \quad (1)$$

U : utility
P_c^{DC} : domestic consumer goods price
β_c^H : household domestic consumer goods demand Share parameter
0 : before water price reform
1 : after water price reform

Amount of water saving is defined as the amount of water using without water price reform minus the amount of water using with water price reform. We can analyze the welfare loss when the same amount of water is saved in each scenario.

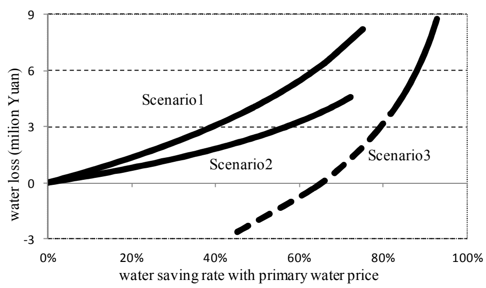

Fig.5 Welfare loss with water saving rate

Fig.5 shows that the welfare loss with quantity of water saving in each scenario. Scenario 3 is the least of welfare loss when the equal amounts of water are saved. It shows that scenario 3 is the best water price reform method. But scenario 3 is also unfeasible, because water supply sector needed to be subsidies when the water prices are under 0.7 (Yuan/m^3) (dash line in Fig.5), and the amount of water savings exceeds 80% of the amount of present water using when the water price is more than 0.7 (Yuan/m^3) (continuous line in Fig.5). Looking at the welfare loss with quantity of water savings, scenario 2 is the best water price reform method except for scenario 3.

5.2 Impact on Domestic Production of Water Price Reform

Fig.6 shows the change of quantity and the change rate of domestic production. Fig.6 shows that water price reform of scenario 1 affects the domestic production of mostly agriculture and manufacture. On the other hand, water price reform of scenario 2 affects domestic production of mostly agriculture. Even though, impact on agriculture of scenario 1 is larger than scenario 2 although the water price charge for agriculture of scenario 1 are smaller than scenario 2.

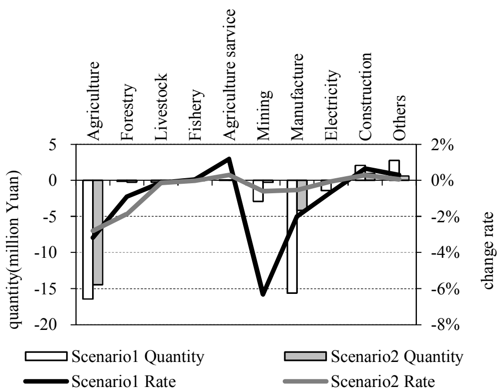

Fig.6 Change of quantity and change rate of domestic production to save the water of 1 billion m3

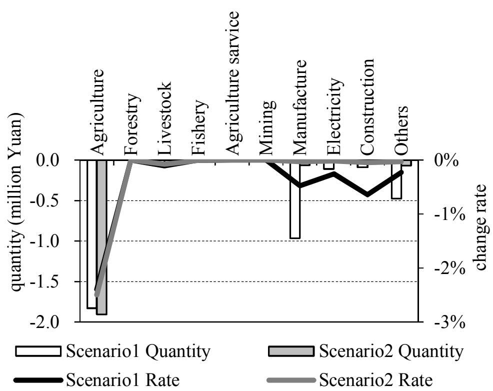

Fig.7 Change of quantity and change rate of final demand to save the water of 1 billion m^3

Looking at Fig.7 and Fig.8, the impact on final demand of agriculture of scenario 1 is smaller than scenario 2, and the impact on final demand of agriculture of scenario 1 is also smaller than scenario 2. Looking at Fig.9, the impact on total intermediate demand of agriculture of scenario 1 is larger than scenario 2. This means that the impacts on domestic production are caused by total intermediate demand (Fig.10). Because, manufacture demand has a relative large amount of intermediate from agriculture, and water price reform of scenario 1, therefore there is a decrease of domestic production in manufacture.

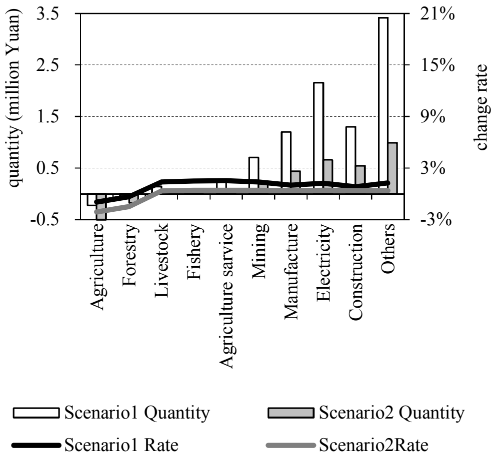

Fig.8 Change of quantity and change rate of investment demand to save the water of 1 billion m^3

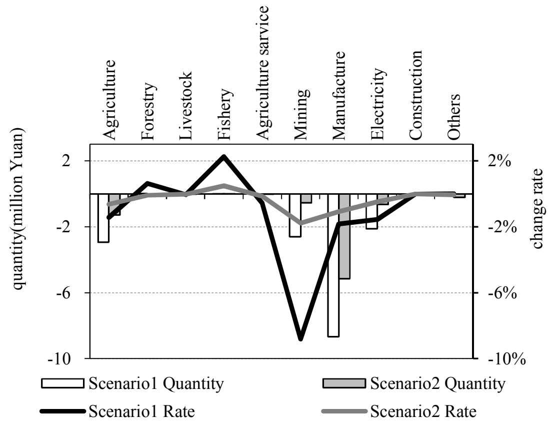

Fig.9 Change of quantity and change rate of total intermediate demand to save the water of 1 billion m^3

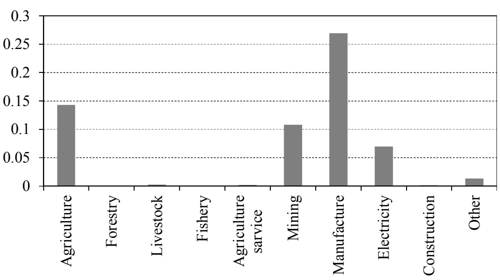

Fig.10 Input coefficient of manufacture

6. CONCLUSION

In this paper, we built a CGE model for water price reform. We applied the CGE model to the Zhangye economy. The proposed method provided three water price reform scenarios and these impacts on economy. Constant price for all activities of welfare loss is the least when the equal amounts of water are saved. But it is also unfeasible, because the water supply sector are needed to be subsidies when the water prices are under 0.7 (Yuan/m3). And the amount of water savings has exceeded 80% beyond the amount of present water using when the water prices are more than 0.7 (Yuan/m3). Looking at the welfare loss with quantity of water savings, constant additional price charge for all activities have larger decrease of welfare loss than constant rate price charge. But, additional price charge for all activities affects mostly agriculture. On the other hand, constant rate price charge for all activities more decrease welfare loss than constant additional price charge. But constant rate price charge for all activities affects mostly agriculture and manufacture. In other words, constant rate price charge for all activities decreases more in welfare loss, and decrease of domestic production are incurred by mainly agriculture and manufacture. On the other hand, constant additional price charge for all activities decreases less in welfare loss and the decrease of domestic production are incurred mainly by agriculture.

7. ACKNOWLEDGMENTS

This work was supported by JSPS Core University Program and in part by Global COE Program "Global Center of Excellence for Dryland Science," MEXT, Japan.

8. REFERENCES

[1] Alexander Smajgl, Romy Greiner, Colin Mayocchi, "Estimating the implications of water reform for irrigators in a sugar growing region," Environmental Modeling and Software, vol. 21, 2006, pp. 1360-1367.

[2] Basanta K. Pradhan, M.R. Saluja, Shalabh K. Singh, "Social Accounting Matrix for India," SAGE Publication, 2006.

[3] Bell, C. and S, Devaraian, "Intertemporally Consistent Shadow Prices in an Open Economy "Estimate for Cyprus"," Journal of Public Economics, Vol.32, 1987, pp. 263-285.

[4] Bureau of Statistics of Zhangye, "Zhangye Statistical Yearbook," Zhangye, China, 2007.

[5] Chang K. Seung, Thomas R. Harris, MacDiarmid, "Economic impacts of surface water reallocation policies: A comparison of supply-determined SAM and CGE models," The Journal of Regional Analysis and Policy, vol. 27, 1997, pp.55-76.

[6] Frederick, K.D., "Balancing water demands with supplies: the role of management in a world of increasing scarcity," World Bank Technical Paper No. 189, 1993.

[7] Gansu Provincial Bureau of Water Resources (GPBWR), "Gansu water resource official report of 2002," Beijing: China Water Power Press, 2003.

[8] Gansu Statistical Bureau (GSB), "Gansu Yearbook (1979–2005)," Beijing: China Statistics Press, 1978–2004.

[9] Gao, Q. Z. and Li, F. X. "Case Study of Rational Development and Utilization of Water Resources in the Heihe River Basin. Lanzhou," Gansu Science and Technology Press, 1991.

[10] Hanemann, M., "Pricing as a tool for demand management: Workshop water for the city: strategic planning, demand management and network losses control," Athens : National Technical University of Athens, University of the Aegean, Water Supply and Sewerage Company of Athens, 2001.

[11] Peter Berck, Sherman Robinson, George Goldman, "The Use of Computable General Equilibrium Models to Assess Water Policies," California Agricultural Experiment Station Giannini Foundation of Agricultural Economics, Working Paper No. 545, 1990.

[12] Postel, S, "Dividing the Waters: Food Security, Ecosystem Health and the New Politics of Water Scarcity," World Watch Institute, 1996, pp.65-76.

[13] Takaaki Okuda and Takayuki Hatano, "A General equilibrium modeling on water allocation in the Yellow River Basin, China," Proceedings Annual Meeting of Environmental Systems Research. 33, 2005, pp. 65-72.

[14] Water Authority of Zhangye, "Water Management Practices in Zhangye," Zhangye, China, 2007.

[15] Yan Chen, Dunqiang Zhang, Yangbo Sun, Xinai Liu, Nianzhong Wang, Hubert H.G. Savenije, "Water demand management: A case study of the Heihe River Basin in China," Physics and Chemistry of the Earth 30, 2005, pp. 408–419.

[16] Yong Wang, Hong-lang Xiao, Rui-fang Wang, "Water Scarcity and Water Use in Economic Systems in Zhangye City," Northwestern China , Water Resour Manage 23, 2009, pp. 2655–2668.

[17] Y. Wang, H.L. Xiao, M.F. Lu, "Analysis of water consumption use a regional input–output model: Model development and application to Zhangye City. Zhangye,", Northwestern China Journal of Arid Environments 73, 2009, pp.894–900.

Appendix. Model equation

Income of Household

$$IH = P^L \cdot \overline{L}_H + P^K \cdot \overline{K}_H + TG + TR \quad (2)$$

$$TG = \gamma^G \cdot IG \quad (3)$$

IH : income of household
P^L : wage
P^K : capital rent
$\overline{L}_H$: labor endowment (exogenous variable)
$\overline{K}_H$: capital endowment (exogenous variable)
TG : income transfer to household from government
TR : income transfer to household from the rest of the world (exogenous variable)
γ^G : share parameter
IG : government revenue

Income of Water Supply Authority (Water Authority)

$$IW = P^K \cdot \overline{K}_W + \sum_a P_a^W \cdot W_a \quad (4)$$

IW : income of water authority
$\overline{K}_W$: supplied Capital of water authority (exogenous variable)
P_a^W : water price of each sector
W_a : water input of each sector

Government Revenue

$$IG = \sum_a \tau_a^V \cdot P_a^V \cdot V_a + \tau^H \cdot IH + \tau^W \cdot IW \quad (5)$$

P_a^V : price of value added
V_a : quantity of value added
τ_a^V : value added tax rate
τ^H : direct income tax rate of household
τ^W : direct tax rate of water authority

Household Expenditure

$$U_c = \sum_c H_c^{\beta_c^H} \quad (6)$$

$$\sum_c \left(P_c^{DC} \cdot H_c\right) = \left(1 - \tau^H\right) \cdot IH - SH \quad (7)$$

$$H_c = \frac{\beta_c^H}{P_c^{DC}} \left\{\left(1 - \tau^H\right) \cdot IH - SH\right\} \quad (8)$$

H_c : quantity of household domestic consumer goods
SH : household saving

Water Supply Authority Expenditure

$$IW = \tau^W \cdot IW + SW \quad (9)$$

SW : saving of water authority

Government Expenditure

$$G_c = \frac{\beta_c^G}{P_c^{DC}}\{IG - SG - TG\} \tag{10}$$

$$TG = \gamma^G \cdot IG \tag{11}$$

G_c : quantity of government domestic consumer goods
β_c^G : share parameter of government demand
SG : government saving (exogenous variable)

Investment

$$I_c = \frac{\beta_c^I}{P_c^{DC}}\{SH + SW + SG + IR\} \tag{12}$$

$$SH = \gamma^H \cdot IH \tag{13}$$

$$SW = IW - \tau^W \cdot IW \tag{14}$$

I_c : quantity of investment demand for commodity
IR : investment of rest of the world
β_c^I : share parameter of investment demand
γ^H : share parameter of household saving

Domestic Production

$$DP_a = \min\left(\frac{X_{1a}}{\beta_{1a}}, \frac{X_{2a}}{\beta_{2a}}, \cdots, \frac{X_{ca}}{\beta_{ca}}, \cdots, \frac{X_{Ca}}{\beta_{Ca}}, \frac{V_a}{\beta_{0a}}\right) \tag{15}$$

$$X_{ca} = \beta_{ca} DP_a \tag{16}$$

$$V_a = \beta_{0a} DP_a \tag{17}$$

DP_a : quantity of domestic production
X_{ca} : quantity of intermediate inputs
β_{ca} : intermediate input coefficient
β_{0a} : value added input coefficient

Composition of Water and Labor and Capital

$$\pi_a^V = P_a^V V_a - \left(P^L L_a + P^K K_a + P_a^W W_a\right) \tag{18}$$

$$V_a = \alpha_a^V L_a^{\beta_a^L} K_a^{\beta_a^K} W_a^{\beta_a^W} \tag{19}$$

$$L_a = \beta_a^L \left(\frac{P_a^V}{P^L}\right) V_a \tag{20}$$

$$K_a = \beta_a^K \left(\frac{P_a^V}{P^K}\right) V_a \tag{21}$$

$$W_a = \beta_a^W \left(\frac{P_a^V}{P_a^W}\right) V_a \tag{22}$$

β_a^L : share parameter
β_a^K : share parameter
β_a^W : share parameter

Composition of Domestic Goods and Import

$$\pi_c^{DC} = P_c^{DC} DC_c - \left(P_c^M M_c + P_c^D D_c\right) \tag{23}$$

$$DC_c = \eta_c^{DC}\left(\varphi_c^{DCM} M_c^{\frac{\sigma_c^{DC}-1}{\sigma_c^{DC}}} + \varphi_c^{DCD} D_c^{\frac{\sigma_c^{DC}-1}{\sigma_c^{DC}}}\right)^{\frac{\sigma_c^{DC}}{\sigma_c^{DC}-1}} \tag{24}$$

$$M_c = \left(\frac{\eta_c^{DC\,\frac{\sigma_c^{DC}-1}{\sigma_c^{DC}}} \varphi_c^{DCM} P_c^{DC}}{P_c^M}\right)^{\sigma_c^{DC}} DC_c \tag{25}$$

$$D_c = \left(\frac{\eta_c^{DC\,\frac{\sigma_c^{DC}-1}{\sigma_c^{DC}}} \varphi_c^{DCD} P_c^{DC}}{P_c^D}\right)^{\sigma_c^{DC}} DC_c \tag{26}$$

DC_c : quantity of domestic consumer goods
M_c : quantity of import
D_c : quantity of domestic goods
P_c^D : domestic consumer goods price
P_c^M : import price (exogenous variable)
η_c^{DC} : CES scale parameter
σ_c^{DC} : substitution elasticity
φ_c^{DCM} : CES share parameter
φ_c^{DCD} : CES share parameter

Transformation of Domestic Production

$$\pi_c^{DP} = \left(P_c^{DC} E_c + P_c^D D_c\right) - P_c^{DP} DP_c \tag{27}$$

$$DP_c = \eta_c^{DP}\left(\varphi_c^{DPE} E_c^{\frac{\sigma_c^{DP}-1}{\sigma_c^{DP}}} + \varphi_c^{DPD} D_c^{\frac{\sigma_c^{DP}-1}{\sigma_c^{DP}}}\right)^{\frac{\sigma_c^{DP}}{\sigma_c^{DP}-1}} \tag{28}$$

$$D_c = \left(\frac{\eta_c^{DP\,\frac{\sigma_c^{DP}-1}{\sigma_c^{DP}}} \varphi_c^{DPD} P_c^{DP}}{P_c^D}\right)^{\sigma_c^{DP}} DP_c \tag{29}$$

$$E_c = \left(\frac{\eta_c^{DP\,\frac{\sigma_c^{DP}-1}{\sigma_c^{DP}}} \varphi_c^{DPE} P_c^{DP}}{P_c^{DC}}\right)^{\sigma_c^{DP}} DP_c \tag{30}$$

E_c : quantity of export
P_c^{DP} : domestic production price
η_c^{DP} : CES scale parameter
σ_c^{DP} : substitution elasticity
φ_c^{DPE} : CES share parameter
φ_c^{DPD} : CES share parameter

Composite Commodity Market

$$P_a^{DP} = \frac{\left(\sum_c P_a^{DC} X_{ca}\right) + \left(1 - \tau_a^V\right)_a^{DC} P_a^V V_a}{DP_a} \tag{31}$$

$$DC_c = \left(\sum_a X_{ca}\right) + H_c + G_c + I_c \tag{32}$$

Factor Market

$$\sum_a K_a = \overline{K}_H + \overline{K}_W \tag{33}$$

$$\sum_a L_a = \overline{L}_H \tag{34}$$

Interregional Balance

$$\left(\sum_c E_c P_c^{DC}\right) + IR + TR = \left(\sum_c M_c P_c^M\right) \tag{35}$$

International Journal of GEOMATE, Dec. 2011, Vol. 1, No.2 (Sl. No. 2)
MS No. 2i received Aug.30, 2011, and reviewed under GEOMATE publication policies.

Pertinent discussion including authors' closure, if any, will be published in the Dec. 2012 if the discussion is received by June 2012.
Corresponding Author: Atsushi Koike