Intelligent Automation And Soft Computing, 2018
Copyright © 2018, TSI® Press
Vol.24,no.3,553–561

A Computable General Equilibrium Model based Simulation on the Water Conservancy Investment

JUN WANG

Zhejiang University of Water Resources & Electric Power, Hangzhou, China

ABSTRACT
The water conservancy industry is one of the oldest fundamental industries in human history with high attention all the time, which is a vital factor to national well-being and people's livelihood. The "Five Water Governance" is one of important strategies as a breakthrough to force transforming and upgrading for ecological water conservancy and sustainable development. A regional dynamic CGE model was constructed to simulate and analyze the short-term and long-term influence of the water conservancy investment to water conservancy industry itself, other national economy sectors and macro economy, so as to provide scientific proof for policy-making of water conservancy, and coordinated and sustainable development police-making of the whole society.

KEY WORDS: Computable general equilibrium, Five water governance, Water conservancy

1 INTRODUCTION

THE water conservancy industry is always one of the fundamental and oldest industries of economy society in all ages, which aims at "taking advantages and getting rid of disadvantages of water" and is closely linked to the economy, people's livelihood, and even national security. In view of the special role, all governments have paid great attention to the water conservancy industry and the topic has appeared many times in central number one documents. Investment of water conservancy will definitely promote the economy (W. Yi-jia and F. Mei-lan 2006, L. CHEN 2009, L. Lei 2011) and support the development of society (W. Huang, X. Zhang, et al. 2011). Literature about benefits of investment of water conservancy are numerous, but they are usually based on water conservancy itself or correlation analyses to a part of the national economy, which means we can only see the trees but not the forest to the role of water conservancy in the whole economy.

In view of industry linkage, investment of water conversancy will promote production of upstream industries, such as steel, cement and machinery, and will facilitate the development of downstream industries such as agriculture, electricity and water transport. Water conversancy constructions may be used for flood control and disaster reduction, farmland water conservancy, reclamation, water resource optimization, and water ecological protection. That is to say, different construction purposes will lead to different social and economic benefits. In view of capital flow, increment of water conversancy investment will crowd out investment non-beneficial industries to some extent, and governmental, public and fundamental investment of water conversancy will crowd out private capital. Therefore, some industries will benefit from water conversancy investment directly or indirectly, and some will not. So, only to analyze the whole framework of the national economy may get comprehensive, objective and accurate results and provide references and basis for scientific decision making.

Some scholars have analyzed the investment influence of water conservancy with input-output table or social accounting matrix, SAM for short, in the framework of macro economy. (L. Xiuli and C. Xikang 2003) studied the shadow prices of industrial and productive water for water price reform with the IO table of the nine major river basins in China. (T. Wen-jin, X. Xiao-wei, et al. 2011, W. Tang, X. Xu, et al. 2012) evaluated the backward economic effects of different kinds of water conservancy investment and the pull effect of large-scale investment in water conservancy based on SAM multiplier analysis. It can only roughly analyze linear influence of water conservancy investment. It cannot describe

CONTACT Jun Wang swiftone@163.com

endogenous behaviors and macro performance of economy society, and cannot simulate and forecast mid-term and long term trends of economy on the condition of external shocks and policy changes.

It is a specialty and advantage of the Computable General Equilibrium model, CGE for short, to simulate external shocks and policy changes, which may help to make in-depth and comprehensive analysis of linkages among industries and different term effects of all parts of the national economy. For example, (H. Gan and M. Cheng 2012) simulated different investment portfolios of 4 trillion to survey optimized financial investment structures. CGE analysis can provide scientific proof for policy making, evaluation, and implementation based on SAM by simulating and predicting the economy system running with abstracted equations from the structure and running mode of the economy system, regional simulation model from behavior instantiation of economic agents, and external shock variables from quantification of economic environment changes. (Z. Jing, H. Xiao-li, et al. 2013) evaluated investment benefits of water supply with the CGE model. (M. D. Azdan and M. S. M.A. 2001)，(Z. Yong, W. Jin-feng, et al. 2008)，(Z. Na, J. Yang-wen, et al. 2014) and some other literatures simulated and analyzed policies of the water resource, such as water price and water right. (C. Wen, X. Hao, et al. 2012)，(T. OKUDA and C. NI 2010) and some other literatures paid attention on evaluation of water environment policies.

Zhejiang province is famous for its abundant resources, which is a land of milk and honey, with eight major river systems and over 30 lakes with at least 1 million cubic meters volume. The government always attaches great importance to water conservancy construction. The Five Water Governance was proposed as a development strategy at the 4th session of 13th provincial Party committee, which is regarded as a breakthrough to force and promote the transformation and upgrading. The amount of investment grew from 27.287 billion at 2011 to 55 billion at 2015, standing first in China. In the whole 12th five-year period, the total investment of water conservancy was more than 200 billion, with 93% increment than 11th five-year period and average 19% year growth rate. In the 13th five-year period, eight key projects with more than 300 billion are listed in the development planning. Long term and sustained investment of water conservancy must bring many influences to the economy and society. Therefore, it has great theoretic and practical significance for CGE modeling and analyzing on investment of water conservancy, taking Zhejiang province as an example.

2 REGIONAL SAM CONSTRUCTION OF WATER CONSERVANCY

2.1 *Regional Macro SAM Construction*

SAM can reflect complex relationships of the whole economy system much more completely, comprehensively and consistently. It is mainly based on IO table and kinds of statistical year books, and is the fundamental of the macro economy analysis with SAM multiplier or CGE. Its structure is familiar to the IO table with column accounts and row accounts as the framework of the data organization to describe information of income, expenditure, transfer payment, transaction cost and so on for those corresponding accounts such as household, government, enterprise etc. The account system of SAM is the premise of IO table, which is main data source meanwhile, as shown in Table 1.

The cross cell of the row account and the column account means expenditure of the row account to the column account. According to the above SAM framework, we get the following macro SAM of Zhejiang province shown in Table 2.

2.2 *Regional Water Conservancy Micro SAM Construction*

(1)Water Conservancy Account

Accounts of SAM can be customized as required with great flexibility, but usually based on the IO accounting system. There are usually 122 departments, 42 departments IO tables based on related rules of national economic accounting classification. Accounts of SAM are usually accounts or accounts combination of IO table. As the main data source, the grain size of IO table decides the data consistence of SAM to IO table.

In view of availability and authority of the national statistical year book, the account scale of the national statistical bureau is often regarded as the accounting standard, though there are some rules and studies of item definitions of the water conservancy industry. But there is no account of water conservancy according to national statistical scale, which means all data of related items of water conservancy should be extracted from the current statistical account and merged to a new account as the water conservancy. According to Classification of National Economic Industries (GB/T4754-2011), the water conservancy industry is usually regarded as a collection of “Water Resource Manufacture of Special Purpose Machinery”, “Production and Supply of Water”, “Construction of Water Conservancy and Inland Port Engineering”, “Service in Irrigation” and “Service in Fishery” of “Service in Agriculture”, in the national statistical yearbook. Unfortunately, limited to issue IO tables, some data are unavailable, as Table 3 shows.

Table 1. General Framework of Regional SAM

		Activities	Factors		Households	Enterprises	Government	Rest Of the World		Saving-Investment	Total
			Labor	Capital				Other Regions	Abroad		
Commodities		intermediate inputs			private consumption		government consumption	call out	exports	investment	Total Output
Factors	Labor	labor payment									Factor Income
	Capital	capital returns									Factor Income
Households			labor income	capital income		surplus	transfers		foreign transfers		Household Income
Enterprises				capital income							Enterprise Income
Government		production taxes, tariffs			direct taxes	direct taxes			transfers		Government Income
ROW	Other Regions	call in								net assets change	Other Regions Income
	Abroad	imports		capital income			payment abroad				Foreign Exchange Outflow
Saving-Investment					resident savings	enterprise savings	government savings		foreign saving		Savings
Total		Total Input	Factor Expenditures	Factor Expenditures	Household Expenditures	Enterprise Expenditures	Government Expenditures	Outside Expenditures	Foreign Exchange Inflow	Investment	

Table 2. Macro SAM of Zhejiang Province in 2012 (100 million RMB)

		Act	Fac		Hou	Ent	Gov	Other Regions	Abroad	S-I	Total
			Lab	Cap							
Com		80171.5			12072.0		3743.8	19450.0	14716.7	14688.3	144842.3
Fac	Lab	14775.8									14775.8
	Cap	15782.1									15782.1
Hou			14775.8	0.2		-202262.5	311.0		225833.1		38657.7
Ent				15781.9			4.9		841.0		16627.8
Gov		5502.6			178.9	537.0	0		-11.0		6207.4
Other Regions		22599.6								-3149.5	19450.0
Abroad		6010.9									6010.9
S-I					26406.8	218353.3	2147.7		-235369.0		11538.8
Total		144842.3	14775.8	15782.1	38657.7	16627.8	6207.4	19450.0	6010.9	11538.8	

Table 3. **Availability from IO Table of Water Conservancy Sub-industries**

Sub-industries of Water Conservancy	Statistical Account (GB/T4754-2011)		Availability
	Item	Corresponding Secondary Directory	
Service in Agriculture and Water Conservancy (SAWC for short)	Service in Irrigation (Code: 0512) Service in Fishery (Code: 0540)	Service in Support of Agriculture (Code: 05)	No
Water Resource Manufacture (WRM for short)	Water Resource Manufacture of Special Purpose Machinery (Code:3597)	Manufacture of Special Purpose Machinery (Code: 35)	No
Production and Supply of Water (PSW for short)	Production and Supply of Water (Code: 46)		Yes
Construction of Water Conservancy (CWC for short)	Construction of Water Conservancy and Inland Port Engineering (Code: 482)	Civil Engineering (Code: 48)	No
Management of Water Conservancy (MWC for short)	Management of Water Conservancy (Code: 76)		Yes

For data that is unavailable in the IO table, proportional approximation for evaluation based on other available statistical reports is often adopted. The production information of sub-industries of the Service in Support of Agriculture is still unavailable in all kinds of regular statistical reports. The second national census provides a good data source for proportional approximation. The proportional factor of sub-industry can be defined as the output value proportion of it to its parent item, where the statistical information of the SAWC and the CWC can be found. For example, define the proportional factor of the SAWC as the output value proportion of the sum of Irrigation and Fishery to Agriculture. The statistical information of Construction of Water Conservancy can be found in the China Industry Statistical Yearbook and China Construction Statistical Yearbook as an independent item.

These statistical reports are always nationwide, so only nationwide proportional factors can be defined by this method, which is only the average level in China. In view of massive rivers and water conservancy facilities in Zhejiang province, with great development in water conservancy, a compromised method is used.

$$\alpha_v = \frac{v}{V} * \frac{31 * i}{I} , \quad (1)$$

In the above equation, "v" is the nationwide output value of one sub-industry, "V" is the nationwide output value of its parent industry, "i" is the investment of water conservancy in Zhejiang and "I" is the total investment of water conservancy in China. Therefore, the proportional factor, α_v, reflects both the industry proportion relationship and regional industry development.

(2) SAM Construction

Given α_v =t, a parent account A can be split into two children accounts, A^1, A^2 , as Figure 1 shows. According to statistical reports such as the China Industry Statistical Yearbook, China Construction Statistical Yearbook, China Water Conservancy Statistical Yearbook and China Rural Statistical Yearbook, we get the SAM of water conversancy in Zhejiang with operations of account split and immerge, shown in Table 4.

3 REGIONAL CGE MODEL

THE LHR model proposed by (H. Lofgren, R. L. Harris, et al. 2002) is a international used and easy extended CGE model with many characters of a developed country. The key equations of price block, trade block, institution block and system constraint block are listed as follows:

3.1 *Trade Block*

This block defines the market optimization in the process of production and sales. Commodities from abroad, local region and other regions usually compete in local markets, and enterprises often optimize their sales of outputs among export, local sales and domestic sales.

For one commodity, given local outputs defined as QD in quality and PDD in price, other regions outputs defined as QI in quality and PI in price, imports defined as QM in quality and PM in price, they are incomplete substitutive of each other. Consumers have to optimize their purchase of different kinds of commodities to maximize their utility under the constraint of income, which can be described as the following equations.

$$QQ_c = \alpha_c^q \cdot \left(\delta_c^q QM_c^{-\rho_c^q} + \delta_c^{q2} QI_c^{-\rho_c^q} + (1-\delta_c^q-\delta_c^{q2}) QD_c^{-\rho_c^q}\right)^{\frac{-1}{\rho_c^q}}, \quad (2)$$

$$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q-\delta_c^{q2}}\right)^{\frac{1}{1+\rho_c^q}}, \quad (3)$$

$$\frac{QI_c}{QD_c} = \left(\frac{PDD_c}{PI_c} \cdot \frac{\delta_c^{q2}}{1-\delta_c^q-\delta_c^{q2}}\right)^{\frac{1}{1+\rho_c^q}}, \quad (4)$$

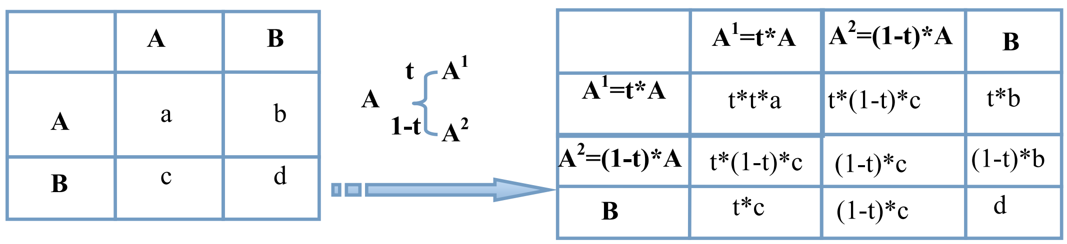

Figure 1. **The Diagram of Account Split in IO Table**

$$QX_c = \alpha_c^t \left(\delta_c^t QE_c^{\rho_c^t} + \delta_c^{t2} QO_c^{\rho_c^t} + (1-\delta_c^t-\delta_c^{t2}) QD_c^{\rho_c^t}\right)^{\frac{1}{\rho_c^t}}, \quad (5)$$

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \frac{1-\delta_c^t-\delta_c^{t2}}{\delta_c^t}\right)^{\frac{1}{\rho_c^t-1}}, \quad (6)$$

$$\frac{QO_c}{QD_c} = \left(\frac{PO_c}{PDS_c} \frac{1-\delta_c^t-\delta_c^{t2}}{\delta_c^{t2}}\right)^{\frac{1}{\rho_c^t-1}}, \quad (7)$$

For the outputs of one commodity, it can be sold abroad, QE in quality and PE in price, locally, QDD in quality and PDS in price, and domestic, QO in quality and PO in price. To maximize the profit, enterprises will optimize their sales strategy, which can be described as the following equations.

3.2 Price Block

Given no trade barrier in the domestic market, commodities can flow freely, so the price of one commodity is the sum of original price and trade cost as equations (8 and 9) show. In the process of trade optimization, no new value is created, so identical equations (10 and 11) are established.

3.3 System Constraint Block

For the region as a whole, given RSAV representing regional saving or regional trade balance, the balance of region can be defined as equation 13 and equation 14.

3.4 Dynamic Block

Some influence of investment of water conservancy will not appear in a short time, which needs a long process of conduction and diffusion, when the dynamic CGE model is required. The variations of saving accumulation and labor growth are main powers of the dynamic of the economy system for the static CGE model. The dynamic recursive equations of capital and labor are shown in the following equations, given the depreciation rate and labor growth rate are r and δ, CAP and LAB are capital and labor, t is the simulation term, QFS is the quality of factors and QINV is the inventory.

$$PI_c = pwi_c + \sum_{c'} PQ_{c'} \bullet ici_{cc'} , \quad (8)$$

$$PO_c = pwo_c + \sum_{c'} PQ_{c'} \bullet ico_{cc'} , \quad (9)$$

$$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + PM_c \cdot QM_c + PI_c \cdot QI_c , \quad (10)$$

$$PX_c \cdot QX_c = PDS_c \cdot QD_c + PE_c \cdot QE_c + PO_c \cdot QO_c , \quad (11)$$

$$\sum_c (pwi_c \bullet QI_c) = \sum_c (pwo_c \bullet QO_c) + RSAV \quad (12)$$

$$QFS(CAP)_{t+1} = (1-\delta) \cdot QFS(CAP)_t + QINV_t , \quad (13)$$

$$QFS(LAB)_{t+1} = QFS(LAB) \cdot (1+r) , \quad (14)$$

4 SIMULATION AND ANALYSIS OF INVESTMENT OF WATER CONSERVANCY

4.1 *Simulation Scenarios*

The investment of water conservancy in Zhejiang province has increased rapidly every year always at a two-digit rate in recent years. It was up to 55 billion in 2015, as the top one in China. It will keep a high rate increment in the 13th five year period, which will be 300 billion totally, that is 60 billion a year. Therefore, we simulated the CGE model with the investment information, with a perfect competition market assumption and small country assumption as well.

4.2 *Simulation Results Analysis*

According to the simulation results, the investment increment of water conservancy will promote directly the development of water conversancy, which is proven by the simulated outputs, showing a 45.17% increase. Meanwhile, the outputs will change with 0.83 percent increments for the secondary industry, 2.68 percent decline for the primary industry and 1.3 percent decline for the tertiary industry. It is well known that the investments of the water conservancy are usually in fundamental construction, therefore, the secondary industry, tightly related to fundamental construction, has obviously positive correlation with the investment of water conservancy. However, the primary industry and tertiary industry have slightly negative correlation with it.

As for the view of the whole economy, we get the following conclusion that the increment of water conservancy investment will promote the social production, based on the static simulation results of 0.73 percent increment of social outputs, 0.06 percent increment of the nominal GDP, 0.08 percent increment of the real GDP, 0.32 percent increment of total imports and 4.08 percent increment of total investment. The variation of GDP in the dynamic simulation with 5 terms is shown in Figure 2.

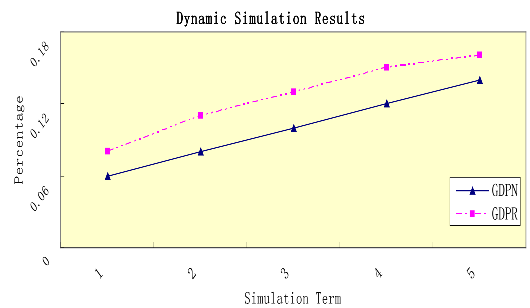

Figure 2. Dynamic Simulation of GDP

It can be concluded that the GDP of Zhejiang province is rising yearly for the influent of water conservancy investment, and the growth rate of real GDP is always higher than that of nominal GDP, which means a higher quantity of economy. So, the investment of water conservancy mainly in form of “Five Water Governance” should promote the regional economy development significantly in both short-term and long-term rising yearly. Dynamic simulations of detailed items of the economy are shown in Figure 3 and Figure 4.

The imports and exports of Zhejiang province are rising yearly under the influence of water conservancy investment, and the total outputs is still in a increment trend as imports and exports. However, social consumption is constrained due to the increment of investment, with a totally controllable and gentle trend.

Table 4. **Micro SAM of Water Conservancy in Zhejiang province in 2012 (100 million RMB)**

	Water Conservancy	Primary Industry	Secondary Industry	Tertiary Industry	Lab	Cap	Hou	Enterprises	Government	Other Regions	Abroad	S-I	Total
Water Conservancy	40.91	2.79	114.45	42.34			79.83		39.07	7.21	17.24	1035.24	1379.06
Primary Industry	3.00	129.17	1623.43	383.25			1164.53		5.81	165.05	18.07	280.78	3773.09
Secondary Industry	737.08	613.37	54860.66	4533.54			5862.67			16052.44	12618.50	11363.78	106642.03
Tertiary Industry	269.51	230.07	8452.69	8135.23			4964.94		3698.96	3225.34	2062.91	2008.51	33048.15
Lab	152.38	1594.48	6288.08	6740.82									14775.76
Cap	103.67	132.35	7877.05	7669.04									15782.11
Hou					14775.76	0.22		-202262.48	311.05		225833.15		38657.70
Enterprises						15781.87			4.91		841.03		16627.81
Government	44.82	-70.20	3523.37	2004.58			178.93	536.97			-11.02		6207.45
Other Regions	18.17	997.87	18885.07	2698.45								-3149.52	19450.04
Abroad	9.54	143.20	5017.23	840.90		0.02							6010.88
S-I							26406.80	218353.32	2147.65		-235368.99		11538.79
Total	1379.06	3773.09	106642.03	33048.15	14775.76	15782.11	38657.70	16627.81	6207.45	19450.04	6010.88	11538.79	

Note: Since there is an independent water conservancy account, corresponding sub-industries of water conservancy are excluded from primary industry, secondary industry and tertiary industry in this paper.

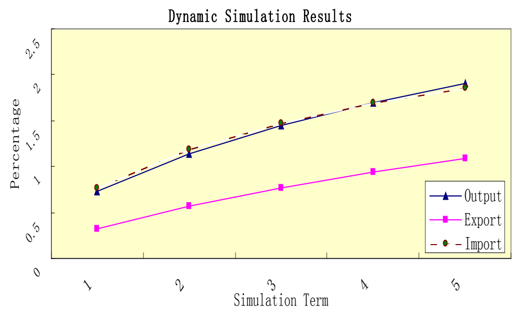

Figure 3. Dynamic Simulations of Imports, Exports and Outputs

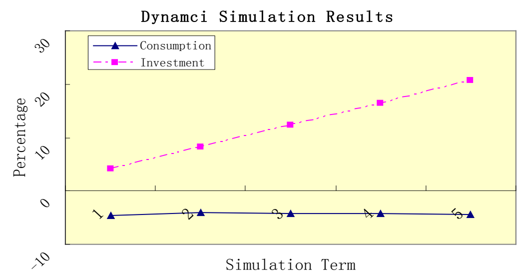

Figure 4. Dynamic Simulations of Investment and Consumption

5 CONCLUSION

THE "Five Water Governance" is one of the main contents and essential breakthroughs in order to improve eco-environmental quantity overall, forcing economic transforming and upgrading by enhancing water ecological treatment and ecological water conservancy construction, constructing beautiful Zhejiang and creating a good life for residents in Zhejiang. It is proven in the static and dynamic simulations of CGE in this paper. As one main content of the "Five Water Governance", water conservancy investment cannot only promote the development of the water conservancy industry significantly, but also be beneficial to short-term and long-term development of society and economy of Zhejiang province, with increments of total outputs, GDP, imports and exports. Though there will be some negative impacts in the agriculture industry, tertiary industry and consumption due to the investment increment of water conservancy, but totally it is controllable and encouragement policies about them are suggested to keep coordinated development of all industries and steady economy development.

6 ACKNOWLEDGEMENT

THE work was supported by Humanity and Social Science Foundation of P. R. China for Young Scholars of Education Ministry, China (Grant No. 13YJC630164, 14YJC630109).

7 REFERENCES

L. CHEN (2009). "Study on the Role of Water Conservancy Investment to Economy in Zhejiang" Market Modernization (569): 2.

M. Donny Azdan and M.Sc M.A. (2001). Water Policy Reform in Jakarta Jndonesia a CGE Analysis, The Ohio State University.

H. Gan and M. Cheng (2012). "Economic influence of the 4 Trillions and Optimization of Financial Investment Structure, Based on CGE" Economist (10): 71-80.

W. Huang, X. Zhang, et al. (2011). "Multi-Agent System Computing And Simulation Of Inter-Basin Water Transfer" Intelligent Automation & Soft Computing 17(7): 897-908.

Z. Jing, H. Xiao-li, et al. (2013). "Economic Impact of Water Investment Based on CGE Model -- As a Case of Heilongjiang Province" JOURNAL OF NATURAL RESOURCES (04): 696-704.

L. Lei (2011). "Emperical Analysis of Economic Benefits in Water Conservancy Investment" Rural Economy and Science-Technology (5): 3.

Hans Lofgren, Rebecca Lee Harris, et al. (2002) "A Standard Computable General Equilibrium (CGE) Model in GAMS."

Z. Na, J. Yang-wen, et al. (2014). "Research development of water resource Computable General Equilibrium（CGE）Model" Journal of China Institute of Water Resources and Hydropower Research (01): 76-80.

T. OKUDA and C. NI (2010). "Computable General Equilibrium Analysis on Domestic Tradable Permits for Water Resource Management in Yellow River Basin" Doboku Gakkai Ronbunshuu G 66(2): 75-84.

W. Tang, X. Xu, et al. (2012). "Water Conservancy investment multiplier effect calculation: based on input—output table and social accounting matrix" South China Journal of Economics (11): 146-155.

C. Wen, X. Hao, et al. (2012). "Water Pollution Taxes in Huanan Pronvinces: The Design and General Equilibrium Analysis of Its Levying Effect" The Theory and Practice of Finance and Economics (01): 73-77.

T. Wen-jin, X. Xiao-wei, et al. (2011). "On the Stimulating Effect of Large-scale Water Conservancy Project Investment on China s Economy: Based on the Analysis of Water Conservancy Social Accounting Matrix" Contemporary Finance & Economics (11): 20-29.

L. Xiuli and C. Xikang (2003). "The Application of Input-Output Analysis of Calculating Shadow Prices of Water Resources of Chinese nine Drainage Areas" Management Review 15(1): 6.

W. Yi-jia and F. Mei-lan (2006). "The Empirical Research of the Relevance of Water Conservancy Investment and Agricultural Output in Zhejiang" Water Consercancy Science and Technology and Economy 12(10): 3.

Z. Yong, W. Jin-feng, et al. (2008). "Review of CGE models on water resources" ADVANCES IN WATER SCIENCE (05): 756-762.

Jun WANG received Ph.D. degree in Management Science and Engineering at School of Information Management & Engineering, Shanghai University of Finance & Economics. He works at Zhejiang University of Water Resources & Electric Power in China as an associate professor. His research interests mainly include industry management science, policy simulation and analysis.