Doctoral Dissertation

Impact of Water Policy on Chinese Economy Using Computable General Equilibrium Model Based on System of Environmental-Economic Accounting

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ABSTRACT

An effective water policy is necessary for the sustainable development of water resources and a balanced economic system. This article employs a social accounting matrix based on the system of environmental-economic accounting (SEEA) to demonstrate the water resource flow in China. A computable general equilibrium (CGE) model was constructed to evaluate the development trends in water consumption and the Chinese economy. The effects of water supply and price change on economic growth in the long term were assessed using a dynamic CGE (DCGE) model. Taking advantage of the CGE and DCGE models helped estimate the effect of water resource on several agriculture sectors (e.g., wheat and rice) in China. The results confirm the need for better water-saving strategies across agriculture sectors. Water policy could help develop the service sector in the direction of sustainability. The study makes two important contributions: A preliminary CGE model that includes water resource was established, while the model, which was calibrated by a series of social accounting matrix data, reflects the observed structure of the current Chinese economy and effects of water management.

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CHAPTER 1

INTRODUCTION

1.1 Background

In China flow 6% of the world's total water resources, an amount that stands in disparity against its large population, which accounts for at least 20% of the global total. This is one of the reasons for the acute water scarcity in China, it is among the 13 most water-scarce countries, with an especially non-uniform spatial distribution of water resources. Although Beijing is the political center of China, the Beijing Water Resources Bulletin 2015 reports that the capital's per capita water resource is measured at 123 m^3, compared with the global average of 5,925 m^3. Shanghai and Tianjin, which are also economic superpowers, suffer from acute water scarcity.

Since the 1978 reform and opening-up, the Chinese government has pursued an open-door policy of economic growth. More than 60% of the demand for water is from the agriculture sector, but severe water shortages and pollution have reduced grain production in the country. As increasing population in China, so has the need to increase the water usage to increase grain yield to meet food demands. This has put even more pressure on irrigation, worsening the water problem. At the same time, industrialization and urbanization are also accelerating the demand for water resources. Besides the low quality of water resources, water use in China is also inefficient, which is a threat to economic development. With worsening water scarcity, pollution, sanitation, and related waste, we are set to witness greater limits on food production, the proper functioning of the ecosystem, and urban supply. Indeed, the severe and adverse effects on the Chinese economy can already be seen.

Because the supply of water seems inexhaustible and always available, it is usually not accounted in cost analysis. Without proper water policy and management, China now faces severe water resources shortages, increased water pollution, and deteriorating aquatic ecology and environment. With time, these problems will worsen, and put pressure on the waters supply.

So far, China has adopted three measures to protect water resources. The government established a “water law” that treats water as an essential resource for production, while also calling for a greater balance between economic growth and environmental protection. The law was formally promulgated in 1988 and serves as the fundamental guidance for water use and supply. Since 1999, public awareness of and education on water protection have been prioritized as well. The overview of this policy to balance the economy and environment through a robust water policy is shown in Table 1.1.

Table 1.1 Water policy in China

Policy	Year	Major focus	Scenarios
The three red lines[1]	2012	Water consumption will not exceed 700 billion m^3 by the year 2030 under the assumption	Total water use control (WUC)
The three red lines	2012	Irrigation efficiency should exceed 60%	Agriculture water use efficiency improvement (WUE)
The three red lines	2012	40 m^3 per RMB 10,000 industrial GDP by 2030	Industry water use control (WUI)
Report on the work of the government[2]	2019	The reduction of value-added tax of the manufacturing sector from 16 to 13%	Production tax decrease (PDX)
National water conservation plan[3]	2021	Focus on water resource saving and conservation	Surface water consumption (TU)
Groundwater management regulation[4]	2019	Focus on the quantity and quality of groundwater and sustainable development	Groundwater consumption (TG)
Circular on promoting water price reform[5]	2004	A reform of the urban water supply price	Surface water price increase (PU)
Groundwater management regulation	2019	The charge of groundwater price level should be set at the level of the operation and maintenance cost	Groundwater price increase (PG)
Minimum procurement price system[6]	2012	Protect agriculture product market system and increase farm income	Increase import price (IMP)
Guiding opinions of the General Office of the State Council on further animating effective private investment and promoting sustainable and sound economic development[7]	2017	Continually optimizing service and business environment	Increase investment (INV)
Regulation on urban water supply (2020 revision)[8]	1994	Protect water resource according to the degree of water scarcity	Household water decrease (HWD)

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[1] http://www.gov.cn/zhuanti/2015-06/13/content_2878992.html

[2] http://www.gov.cn/zhuanti/2019qglh/2019lhzfgzbg/index.html

[3] http://www.china-cer.com.cn/zhengcefagui/2021110815563.html

[4] https://www.wenmi.com/article/pzon2r059fre.html

[5] http://www.gov.cn/xxgk/pub/govpublic/mrlm/200803/t20080328_32372.html

[6] http://www.gov.cn/banshi/2012-08/24/content_2209768.htm

[7] http://lawinfochina.com/display.aspx?id=26410&lib=law

[8] http://lawinfochina.com/index.aspx

Regulation on the Administration of the License for Water Drawing and the Levy of Water Resource Fees (2017 amendment)[9]	2006	Adjusting water demand by reform water resource fee	Water resource fee discharge in agriculture (WRF)

Although the effect of reforms to water policy will be the greatest for water-sensitive sectors such as agriculture, the reforms would also indirectly affect manufacturing and services, as all sectors in an economy are interrelated. However, would changes in water supply and demand further complicate policy implementation?

In this article, I use a social accounting matrix (SAM) to detect the effect of water policy. This matrix describes water resources based on the system of environmental economic accounting (SEEA), and it can accurately demonstrate information from the System of National Accounts (SNA) by the United Nations. The related variables are exogenous and endogenous, and linked by a set of mathematical relations. Specifically, I demonstrate the water resource flow in China using the water social accounting matrix (WSAM) based on the SEEA for 2017.

The WSAM has three advantages that favor its use as a methodological framework. First, it presents the data on economic activity based on the SNA and the data on environmental resources using the SEEA. According to the SNA in 2008, water resources need to be valued as part of the national balance sheet in situations wherein water scarcity leads to restrictions on its use. The dependency relationship between economic activity and environmental resource is captured in this framework. We expect the SEEA framework to support various multinational analyses as more country-level research employ it.

Second, the WSAM based on the SEEA is a general framework for indicators. It captures the effects of policies on economic growth and national wealth. National wealth is indicated by the government's reports of, among others, households, firms, production, income,

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[9] http://lawinfochina.com/display.aspx?id=27415&lib=law

consumption, and investments. Environmental resource has same problems with isolation reports for resource stock accounting. The SEEA governs the principles relating to and provides the measurements for national balance sheet accounting and environmental resource changes based on standardized norms.

Third, the WSAM treats environmental resources dynamically under the SEEA. To estimate the water stock and flows, the SEEA was published based on international statistics standards and as a guideline for accounting that incorporates both the environment and economy. Conventional environmental resource accounting only focuses on representing the water stock, while ignoring the different purposes of water resource abstraction and reuse. The WSAM tracks the extraction of water from the environment to its consumptive use. In general, a policy analysis model for environmental economics could rely on the WSAM, which does provide reliable data for various analyses. The data can be expressed as physical quantities or in monetary units. This has made the SAM a useful database and tool with wide acceptance in national accounting in the twentieth century (Edens et al., 2014; Pal et al., 2016).

In this article, I employ the computable general equilibrium (CGE) model to compile the WSAM table under the SEEA framework using integrated water data for the analysis of environmental economic policy. More specifically, I apply a static CGE model to assess the macroeconomic effect of water use restrictions for the period of 2017. I further design a dynamic CGE, or DCGE, model to explore the effects of water policies for the 2017–2020 period. Ultimately, I hope to observe specific water-sensitive agriculture products in relation to the effect of water policy change.

1.2 Objectives

This study compiles detailed WSAM data based on the SEEA to assess the macroeconomic effect of water use restrictions using the CGE model. The DCGE estimates the economic effects of water policy over a chosen period of time. This model, which is popular in the literature to evaluate policy effects, is designed to provide, if successful, critical insight into China’s current water policy. I also employ the proposed DCGE model to investigate the effect of water resource on different agriculture products.

1.3 Study framework

This dissertation has six chapters (see Fig 1.1). In chapter 1, I explain the background of the water situation and policy in China. In chapter 2, I review the relevant literature. In chapter 3, I demonstrate the water resource flow in China using the SAM (i.e., compile the Environmentally Extended Supply and Use Table or EESUT) based on the SEEA. Using a CGE model and SAM table for 2017, I outline the economic influence on surface water and groundwater at the national level. In chapter 4, I evaluate the development trends of water consumption and the Chinese economy for the 2017–2020 period. The effect of water policy changes on economic growth is then assessed based on the DCGE model, followed by a brief discussion on key issues. In chapter 5, the effect of water resource on four agriculture products using DCGE model is examined. Chapter 6 concludes with some key recommendations.

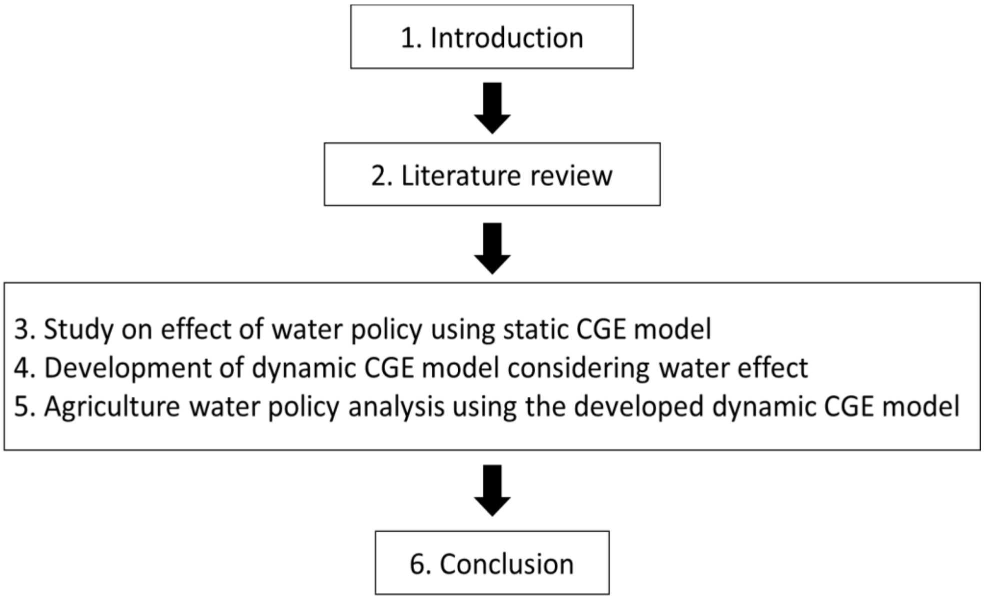


Fig 1.1 Outline of the dissertation

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to SAM and SEEA

Twentieth-century research trends show an uptick in the use of social accounting for national income accounts and input–output analysis. In some of the earliest works in this field, a set of double-entry national income accounts was logically developed (Meade et al., 1941). A framework of social accounting with SNA is developed, which continues to inform national accounting even today (Stone, 1947). The next milestone in this field was development of the SAM, developed to analyze poverty and income distribution problems in developing countries (Pyatt et al., 1985).

The SAM is a powerful and convenient matrix for economic analysis wherein all producers and customers in an economic circle are included in the SAM accounts. Like input–output tables, some SAM accounts have the same function and structure to represent intermediate goods and services in accounts. SAM also captures the circular flow in an economy (see Fig 2.1). It provides a convenient, wide-ranging method to illustrate the process of entire economic activities (Hayden et al., 1982). The most important feature of a SAM is that the sum of (i) row should equal to the sum of (j) column; in other worlds, the total receipts must equal the total expenditure. This feature also conforms to the basic economic accounting principle; otherwise, the transactions are not recorded without balancing.

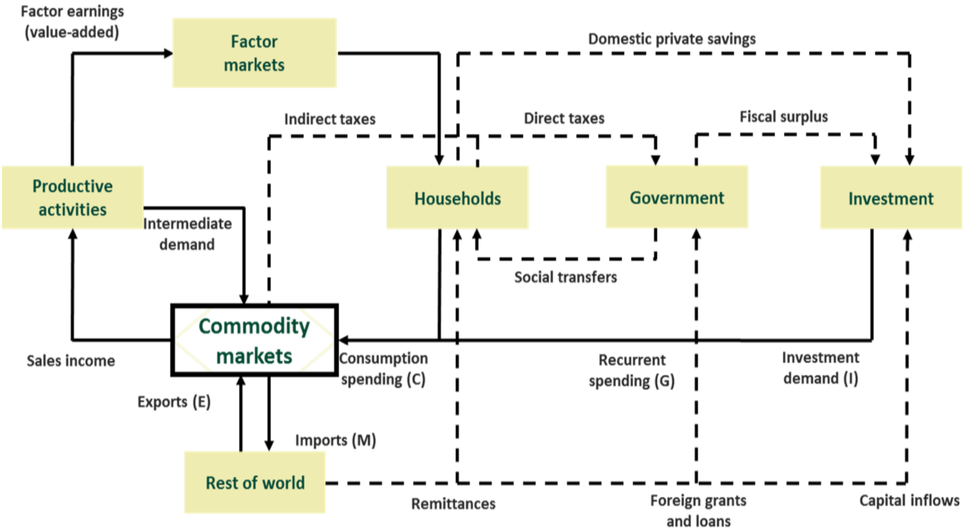
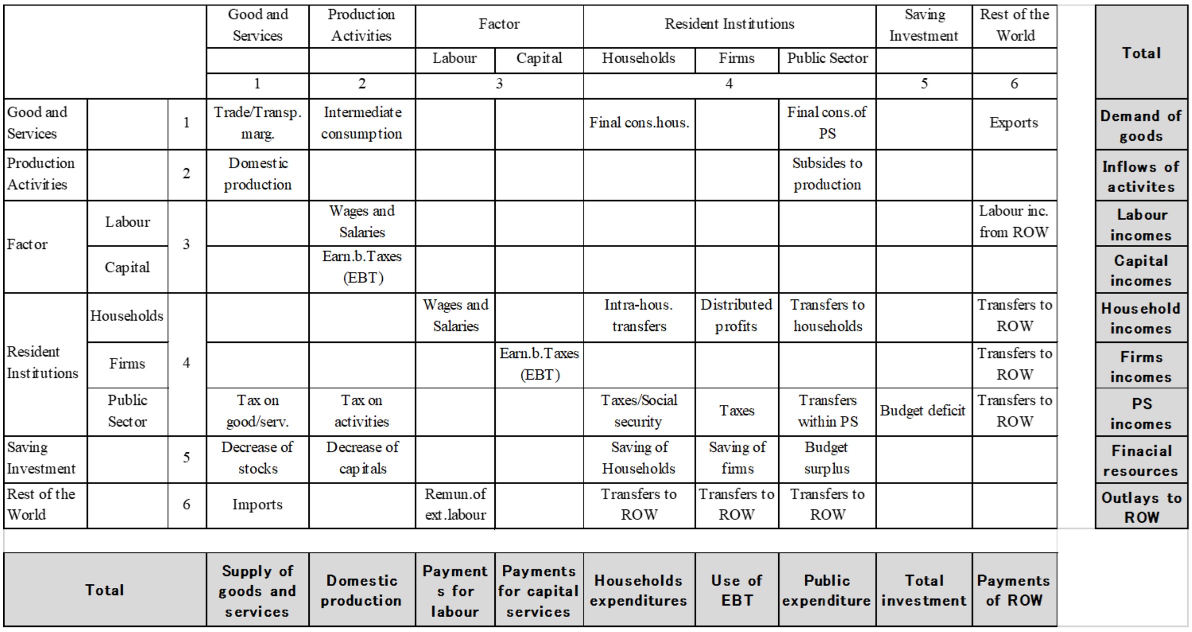


Fig 2.1 Circular flow in the social accounting matrix
(see Miller et al., 2009)

As noted earlier, Sir Richard Stone was a pioneer of SAM-based multiplier research, and a plethora of multiplier studies still refer to Stone's work. Some of the earliest and well-known studies examine the multiplier effect for Sri Lanka (Pyatt et al., 1979), Botswana (Hayden et al., 1982), Korea (Defourny et al., 1984), and Indonesia (Thorbecke et al., 1992). In the SAM, when one part of an economic system's income changes, the influence of the functional and institutional distribution, especially for households, is captured in the economy, as shown in Fig 2.2.



			Good and Services	Production Activities	Factor		Resident Institutions			Saving Investment	Rest of the World	**Total**
					Labour	Capital	Households	Firms	Public Sector			
			1	2	3		4			5	6	
Good and Services		1	Trade/Transp. marg.	Intermediate consumption			Final cons.hous.		Final cons.of PS		Exports	**Demand of goods**
Production Activities		2	Domestic production						Subsides to production			**Inflows of activites**
Factor	Labour	3		Wages and Salaries							Labour inc. from ROW	**Labour incomes**
	Capital			Earn.b.Taxes (EBT)								**Capital incomes**
Resident Institutions	Households	4			Wages and Salaries		Intra-hous. transfers	Distributed profits	Transfers to households		Transfers to ROW	**Household incomes**
	Firms					Earn.b.Taxes (EBT)					Transfers to ROW	**Firms incomes**
	Public Sector		Tax on good/serv.	Tax on activities			Taxes/Social security	Taxes	Transfers within PS	Budget deficit	Transfers to ROW	**PS incomes**
Saving Investment		5	Decrease of stocks	Decrease of capitals			Saving of Households	Saving of firms	Budget surplus			**Finacial resources**
Rest of the World		6	Imports		Remun.of ext.labour		Transfers to ROW	Transfers to ROW	Transfers to ROW			**Outlays to ROW**
Total			**Supply of goods and services**	**Domestic production**	**Payments for labour**	**Payments for capital services**	**Households expenditures**	**Use of EBT**	**Public expenditure**	**Total investment**	**Payments of ROW**	

Fig 2.2 Basic structure of the social accounting matrix

(see Miller et al., 2009)

An increasing number of studies is employing SAM-based CGE models, for example, to conduct policy analyses or for World Bank-related analyses of developing countries. The CGE model was applied to generate a counterfactual numerical simulation on alternative policy options (De Melo et al., 1989). Even studies that seem similarities have significant conceptual differences in the scope, experiments, and approaches adopted.

CGE models share many similarities with input–output analysis. Both are multisectoral models that capture interdependence among sectors and among other agents, such as the government and other indigenous institutions, in the economic system, same as the exogenous sector. The price and intersectoral linkages were explored in the southern portion of the San Joaquin Valley (Berck et al., 1991). CGE models can estimate the effects of reducing water inputs on gross domestic product (GDP) and on sectoral output, employment, and land use. The water price and effects derived can provide policymakers an optimal range of regional price for irrigation water (Radicchi et al., 2008).

The SAM was especially introduced to observe the water price changing effect on regional GDP. However, the most significant feature of CGE models relates to supply–demand decisions by producers and consumers that accordingly determine the supply and demand for products and factors that become mutually consistent through adjustments in relative prices. Fig 2.3 shows the basic structure of a CGE model.

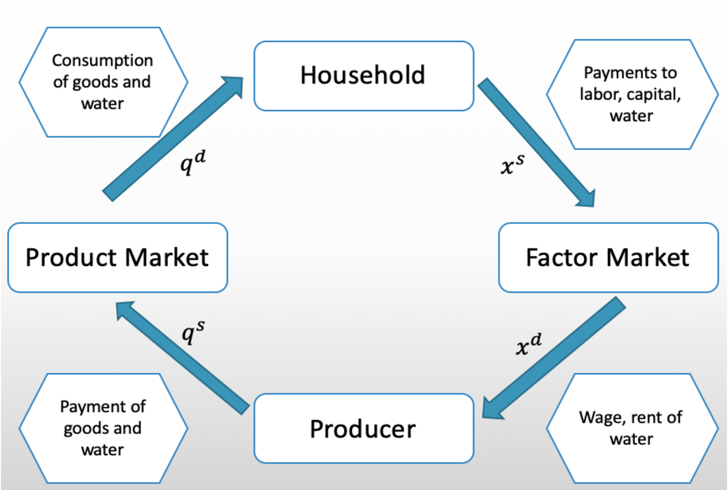


Fig 2.3 Basic structure of CGE framework

Theoretical research on SEEA in China first began in late 1980s. The Chinese Ministry of Geology and Mineral Resources associated with Jilin University developed a study on resources accounting in 1987, including research on water resources accounting and a subnational economic accounting system. Thereafter, a theoretical, integrated environmental and economic accounting framework was established (Yu et al., 2007). Water resources policy was discussed under the SEEA from different perspectives (Gan et al., 2012). Simple environmental economic accounting was employed for water resources in the Zhangye City to establish the physical, value, and industrial allocation of depletion cost and integrated industry accounts (Dong et al., 2003). To enrich and improve the water resources accounting system of China, numerous scholars have explored water resources depletion and environmental degradation costs in their development of an environmental and economic accounting framework of water resources.

2.2 Introduction to CGE model

The CGE model can simulate water policy by adding a scenario relating to, for example, water price and water tax. There is now rising interest in using CGE models to show the effects of Chinese water policy, often quantified with sectoral economic effects at the river basin or city level. Among these studies, limiting the total water use negatively affects economic growth, while improving the irrigation rate could minimize water shortage at the regional level (Zhang et al., 2018). Water price should be improved for sustainable development (Jing et al., 2006), while more recent study showed that taxation on water resources effectively promoted the water use structure and efficiency in the use of water resources for Hebei province (Tian et al.'s 2021). Irrigation subsidy (Zhao et al., 2016), water investments (Zhong et al., 2017), discharge fee (Fang et al., 2016), droughts (Zhong et al., 2016), and industry transformation (Wu et al., 2014) have also been targets of studies on the means to promote water conservation.

Although the parameters of CGE models may be obtained from national accounts, data on water resources is excluded from these databases (Calzadilla et al., 2017). To compensate for the lack of data, the SEEA could demonstrate the environmental stock and flows in national accounts (United Nations, 2012). The SEEA is published as an international statistics standard and guideline for environmental economics. It contains all natural resources that could be useful for economic activity. In the present article, based on the SEEA, I compiled a SAM table to include the water resource flow in China that reveals the water resource use, allowing the accurate estimation of the economic effects.

2.3 An extension to dynamic CGE model

The DCGE model is deeply reflective of economic theory, and can be applied for both economic analysis and policy simulation. Nevertheless, assessments using this model are often complex, especially when adding the variable in a specific moment of time. The structural DCGE model was used to show that investments have positive effect on the Chinese economy (Hu, 2017). DCGE models have also been used in research on water allocation (Ke et al., 2016), tax rate (Tian et al., 2021), and virtual water (Zhao et al., 2021).

2.4 DCGE model on agriculture products

As mentioned before, 60% of water in China is used for agriculture production. There are ample studies that have attempted to determine the driving factors of irrigation water based on a static CGE model. Notably, water price reforms are intended to appropriately allocate water to the agriculture and industry sectors (Zhong et al., 2015). Climate factor is also a factor that is now significantly affecting agriculture water use (Guo et al., 2020). Thus, the DCGE model could be used to understand the policy effect on agriculture production in China and the way to decrease the pressure on water resources.

2.5 General algebraic modeling system

The general algebraic modeling system (GAMS) is a high-level programming language for mathematical optimization. The GAMS is relatively easy to understand for a computer-literate individual and flexible to specify and implement CGE models in the optimization analysis for various issues. Therefore, in this study, I used the GAMS software to simulate the impact effect of water policy on Chinese economy.

2.6 Summary

Based on the fundamentals of analysis using CGE models, I reviewed a selection of literature. Unique to the literature, I integrate water data and compile a WSAM table under the SEEA framework, while using the CGE model, to analyze the environmental economic policy of China. One of the distinguishing features of this study is that the water data were collected at the national level, rather than the regional and prefecture level, as in most studies. I also perform a simulation. Actual policies are analyzed to accurately estimate the influence on an economy and the environmental assets. In the following, I cite the basic theories and achievements as the initial basis to advance further research.

CHAPTER 3

APPLICATION OF STATIC CGE MODEL

3.1 Introduction

The demand for water gradually increased after the Chinese government began to launch an open-door economic policy from 1987 onward. China requires massive volumes of water to produce goods and for economic development. Yet, water becomes more expensive under wider open competition (Calzadilla et al., 2008). Then, urbanization, triggered by economic development, provides a better but more water-consuming lifestyle. The resulting rise in population increases the demand for food from the agriculture sector, which, in turn, increases the pressures on irrigation. In China, the water demand has already exceeded sustainable supply. By 2030, China's total water consumption is predicted to reach 700–800 billion m^3 per year, while the actual available water resources will be about 800–950 billion m^3, bringing the water demand is close to the limit of available water (An et al., 2021). Water problems have now become major bottlenecks inhibiting sustainable economic and social development in the country (Jiang et al., 2014).

China has now begun to tackle its water problem at the national level. Its primary focus has generally been on regional heterogeneities and sustainable use of water resources (Li et al., 2015), with an approach to coordinate the relationships between resources, society, economy, and the environment (Li et al., 2011). One effective measure to reduce the water supply and demand gap is total water use control and improvements to water efficiency. In 2012, the strictest water policy—named Opinions of the State Council on the Implementation of the Most Stringent Water Resources Management—was promulgated to bring China's water use and efficiency to the standard of advanced economies. One target of the policy was to limit total water consumption to 700 billion m^3 by 2030. For the agriculture sector, the water use coefficient rate was set to 0.6[10]. To solve scarcity, the opinion that water agencies should focus on water resources management, is necessitates evaluating the effect of water policy (Kumar et al. 2020).

As noted earlier, the CGE model can estimate the effects of water policy in China, in many cases, to quantify the sectoral economic effects at the river basin or city level. However, limiting total water use could hinder economic growth. Further, national accounts do not contain data on water resources for the parameters of CGE models (Calzadilla et al., 2017). However, the SEEA Central Framework could demonstrate the environmental stock and flows in national accounts (United Nations, 2012). This international statistics standard contains all natural resources needed for economic activity, and is used in the present article to formulate the SAM table, including the water resource flow in China.

Nearly 99% of all water resources in China are surface water and groundwater resources. Although both types are used for similar purposes, they should be evaluated separately. For instance, groundwater is more highly priced than surface water, and water policies and management methods vary by the target resource. To understand the economic effect of water

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[10] The State Council, 2012

policy on surface water and groundwater respectively, I develop the CGE model to estimate the water data in economic flow, and thus calculate the economic effect for each agent.

The remaining chapter is organized as follows. In sections 3.2 to 3.6, I introduce the methodology, including the content of the WSAM and the structure of the CGE model. In section 3.7, I examine the effects of the water policy on China’s economy and investigate the sensitivity of the model. In section 3.8, I offer the concluding remarks on the findings.

3.2 SAM table

To estimate the economic effect of water policy, the SAM table is widely accepted as a useful and effective database. It can critically integrate the multisector and input–output representation of an economy (United Nations., 2012). It is a fitting SNA and good at demonstrating the information through a matrix.

The SAM can organize the data on the social and economic structure of a country for a given period, provide a synoptic view of the flows of receipts and payments in an economic system, and form a statistical basis for building models of the economic system in order to simulate the socioeconomic effect of policies. A complete set of the SNA and input–output table is needed to build the SAM table for China. Additional information of transaction and tax data can be obtained from other sources published by Chinese government. Table 3.1 shows the standard SAM, originally developed based on the 2017 input–output table, which was, in turn, assembled based on current prices in each year with 10 sectors (Liu, 2020).

Table 3.1 Macro social accounting matrix for China in 2017

(CN¥ 100 million)

	com	lab	cap	hhd	fir	gov	row	savinv	total
com	1434498			320426		123750	163846		2407002
lab	423268								423268
cap	299285								299285
hhd		423268	30627		61093	44246			559235
fir			252991			13855			266846
gov	93718			58097	32117		18088		209795
row	149268		15665						164933
savinv				179902	173636	27943	-17001	364480	364480
total	2407002	423268	299285	559235	266846	209795	164933	364480	

Notes. com: commodities; lab: labor; cap: capital; hhd: households; fir: firm; gov: government; row: rest of the world; savinv: saving and investment.

3.3 SEEA framework

The SEEA includes physical and monetary accounts to capture the stock of ecosystems and provides a range of environmental, economic, and social information. The SEEA focuses on the flows of water that either enter the economy as natural inputs or return to the environment from the economy as residuals. Fig 3.1 presents a diagrammatic framework.

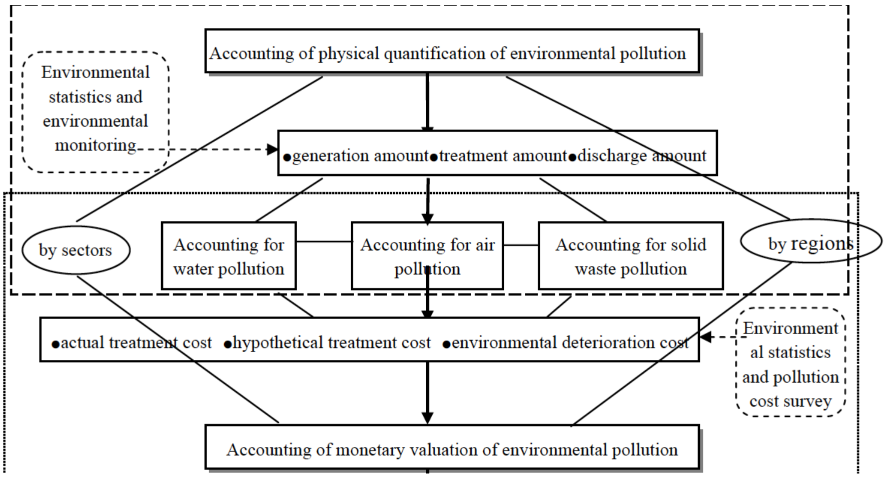

Fig 3.1 Basic structure of the system of environmental economic accounting framework (Yu et al., 2007)

The SEEA framework for China indicates the water and economic information in a coherent and consistent way. The system has its origin in economics, but also includes physical information. The hybrid nature of the accounts gives the analyst the opportunity to study both dimensions.

3.4 WSAM table

The next step is to aggregate water information for the SAM (WSAM). Table 3.2 presents the basic structure of the WSAM (Banerjee et al., 2019). All data are in monetary terms.

Table 3.2 A structure for the water social account matrix

	com	lab	cap	hhd	fir	gov	row	sav-inv	water-gro	water-und	env-mar	total
com	IO			C		G	E	I				
lab cap	VA											
hhd		VA			TR	TR						
fir						TR						
gov	T			TH	TF				TGW	TUW	TEW	
row	M											
sav-inv				SH	SF	SG	SR					
water-gro	int-dem			fin-dem								
water-und	int-dem			fin-dem								
env-mar	int-dem			fin-dem								
total												

Note. com: commodities; lab: labor; cap: capital; hhd: households; fir: firm; gov: government;

row: rest of the world; sav-inv: savings-investment, water-gro: surface water; water-und: groundwater; env-mar: water resource fee; IO: intermediate consumption; VA: value added; T: taxes; M: imports; TR: transfers; C: private consumption; G: government consumption; E: exports; I: investment; TH: personal income tax; TF: cooperate income tax; SH: households savings; SF: firm saving; SG: government savings; SR: foreign savings; TGW: surface water rate; TUW: groundwater rate; TEW: water resource fee; int-dem: intermediate demand; and fin-dem: final demand.

The SAM framework is extended by aggregating the water accounts. The water resource data are taken from the environment (United Nations, 2014). The total row and total column should be equal based on the principle of the SAM table. For illustrative purpose, water resource is divided into three parts: surface water, groundwater, and water resource fee. Notably, different water resources have different prices. I consider two types of water resources: surface water and groundwater. Those sectors are compiled as environment accounts in order to measure the policy effect on the Chinese economy.

The observable period is the year 2017. The effect of water policy may be observed five years after initial implementation. According to official data from the World Bank, the GDP of China continually grew from 2012 to 2017, and the demand for water has followed this upward trend. Because China reformed its water management by strengthening the water policy and has made attempts to improve water use efficiency in both the agriculture and industry sectors, I measure the economic effect of the policy quantitatively. Table 3.3 shows the water use of all sectors included in the SAM table[11].

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[11] Source: Estimated by Liu (2020)

Table 3.3 List of sectors and their respective surface water and groundwater use (100 million m^3)

Code	Sector in the SAM table	Surface Water Use	Groundwater Use
1	Agriculture	3105.31	1137.85
2	Hunting, Forestry and Fishing	330.99	108.07
3	Mining and Quarrying Food	56.86	33.5
4	Food, Beverages and Tobacco	50.59	19.18
5	Textiles, Textile Products and Leather and Footwear	43.54	4.89
6	Pulp, Paper, Printing and Publishing	71.75	10.5
7	Petroleum, Chemicals and Chemical Products	186.05	37.65
8	Other Non-Metallic Minerals	27.14	10.02
9	Basic Metals and Fabricated Metal	96.55	17.52
10	Machinery, Nec	20.59	8.17
11	Electricity, Gas and Water Supply	17.95	0.84
12	Construction	64.66	2.27
13	Service	223.91	17.48

3.5 SAM-based CGE model

3.5.1 Construction of the CGE model

The SAM-based CGE model is frequently used to assess the economic effect on a macro level. This model provides good understanding of intersectoral linkage and current water management in China. The model captures both the direct and indirect effects of policy change. Thus, I include 37 endogenous variables and 37 equations in the model, and build three blocks: production, income–expenditure, and import–export (see Fig 3.2). The detailed theoretical content for the practical programming methods for CGE model can be referred (Hosoe et al., 2016; Pan, 2016).

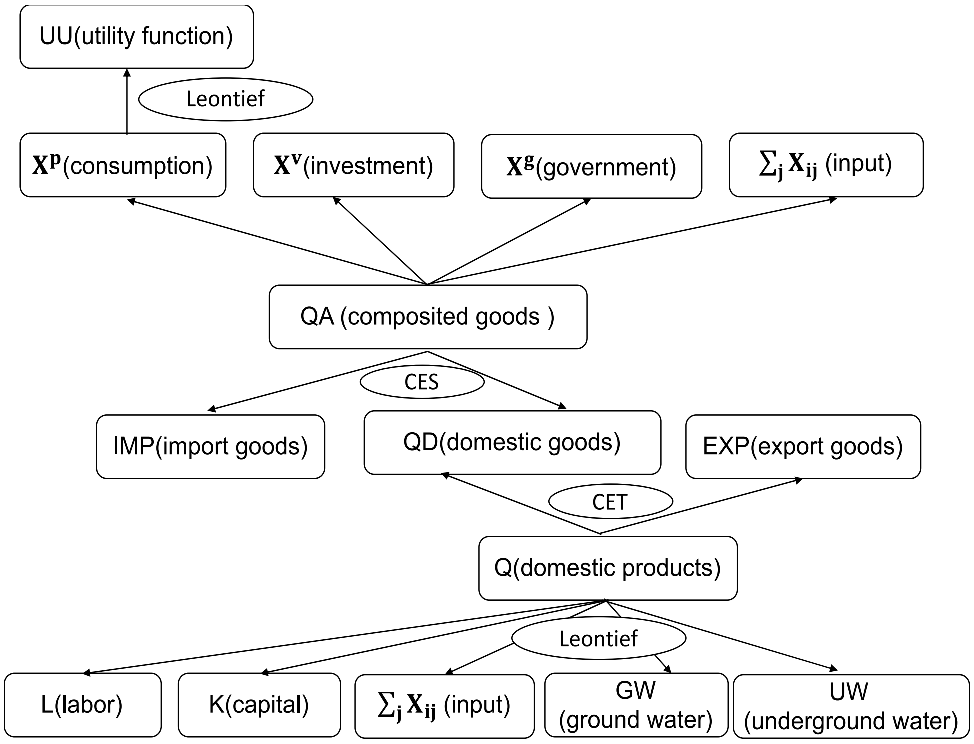


Fig 3.2 Structure of the static computable general equilibrium model

The domestic products Q_i are represented with a Leontief function of intermediate input X_{ij}, labor L_i, capital K_i and water resource costs W_i. Without data calibration, the Leontief function could provide more reliable results. Depending on the supply and demand condition, the formula is expressed below:

$$Q_i = \sum_j X_{ij} + L_i + K_i + W_i. \tag{3.1}$$

The most important equilibrium condition in the system is a market clearing condition; that is, all composite goods QA_i should equal the demand production X_{ij}, household X_i^p, government X_i^g and investment X_i^v.

$$\mathrm{QA}_i = \sum_j X_{ij} + X_i^p + X_i^v + X_i^g. \tag{3.2}$$

Considering the trade part, import is described by the Armington function and export is represented by the constant elasticity transformation function following the small country assumption.

$$QA_i = \alpha_i^{QA}\left[\delta_i^{QA} QD_i^{\rho_i^{QA}} + (1-\delta_i^{QA}) IMP_i^{\rho_i^{QA}}\right]^{1/\rho_i^{QA}} \text{, and} \tag{3.3}$$

$$Q_i = \alpha_i^{Q}\left[\delta_i^{Q} QD_i^{\rho_i^{Q}} + (1-\delta_i^{Q}) EXP_i^{\rho_i^{Q}}\right]^{1/\rho_i^{Q}}. \tag{3.4}$$

where QD_i represents the domestic goods; IMP_i and EXP_i are the imports and exports respectively; α_i^{QA} is the scaling parameter of the Armington function; δ_i^{QA} is the substitution coefficient depending on ρ_i^{QA}; and ρ_i^{QA} is the substitution elasticity of the imported commodity and domestic sales commodity in the production function. α_i^{Q}, δ_i^{Q} and ρ_i^{Q} have the same function for exported commodity and domestic sales commodity.

$$QH_i = \frac{shrh_i \cdot (1-ti_h) \cdot YH - YHGW - YHUW}{PQ_i}. \tag{3.5}$$

where QH_i is the demand of commodity i by household. $shrh_i$ is the share of consumption for commodity i by household.

$$YH = WL \cdot QLS + shrh_{hk} \cdot WK \cdot QKS + shrh_{hgov}. \tag{3.6}$$

where YH is the household income.

$$QG_i = \frac{shrg_i \cdot (YG - transfr_{hg} - transfr_{ent\,g})}{PQ_i}. \tag{3.7}$$

where QG_i is the government consumption.

$$YG = \sum_i (WL \cdot QLD + WK \cdot QKD) + ti_h \cdot YH + ti_{ent} \cdot YENT. \tag{3.8}$$

where YG is the government income.

$$QENT_i = \frac{shrent_i \cdot ((1-ti_{ent}) \cdot YENT - transfr_{h\ ent})}{PQ_i}. \tag{3.9}$$

where $QENT_i$ is the demand of commodity i by firm. $shrent_i$ is the share of consumption for commodity i by firm.

$$HS = sh \cdot HY. \tag{3.10}$$

where HS is the household saving.

$$ENTS = sent \cdot ENTY. \tag{3.11}$$

where $ENTS$ is the firm saving.

$$GS = sg \cdot GY. \tag{3.12}$$

where GS is the government saving.

$$TSAV = HS + ENTS + GS + FS. \tag{3.13}$$

where $TSAV$ is the total saving.

$$TINV = TSAV. \tag{3.14}$$

where $TINV$ is the total investment.

$$INV_i = \frac{iv_i \cdot TINV}{PQ_i}. \tag{3.15}$$

where INV_i is the investment by commodity. iv_i is the investment use of commodity.

3.5.2 Water in the CGE model

The original CGE model (Zhang, 2017) was developed into a water-CGE model. In production function, the water resource embedded in the economic flow is considered an input factor. The Leontief function is applied to represent water use:

$$W = \left(\sum_i w_i \cdot PWAT \cdot X_i \right) + HWU \tag{3.16}$$

where W is total water demand; w_i interprets the water input coefficient; $PWAT$ stands for water price; X_i and HW are the total output and household water consumption, respectively.

Equation (3.17) shows the equilibrium condition in the water resource market. In the equation, it is assumed that water demand is equal to water supply and the price of water is positive.

$$\left(\sum_i WATD_i - WATS \right) \cdot PWAT = 0 \tag{3.17}$$

where $WATD_i$ is the total water demand for commodities i and $WATS$ is the total water supply.

3.6 Simulation scenarios

I study four scenarios to estimate the effects of water policy that has been exogenously fixed. The first scenario is the stimulation with respect to total water use control (WUC). The purpose of this scenario is to understand how water use control affects the economy by reducing 10% of the total water consumption. Water consumption will not exceed 700 billion m^3 by the year 2030 under this assumption. In the second scenario, I investigate agriculture water use efficiency improvement (WUE). This scenario shows us the degree to which water consumption can be reduced in China by cutting 10% of the water use in the agriculture sector. The water use coefficient rate is the percentage of water effectively used for agriculture irrigation without evaporation. To reach a level at part with advanced economies, China should improve this coefficient rate from 0.5 to 0.6 by 2030. The third scenario explores the policy effect on manufacture industries that reduce water consumption by 10% (WUI). The last scenario estimates the reduction of the production tax of the manufacturing sector from 16% to 13% (IDTX).

3.7 Results and discussions

3.7.1 Effect on water resource

The CGE model is a useful tool to predict the influence by water policy on the economy at a national level. Water policy could affect other sectors, especially regarding water consumption. Table 3.4 compares the results of the physical term of water use under two scenarios. The total water consumption decreased for both surface water (0.4%) and groundwater (0.3%) with WUC. The agriculture sector is the biggest consumer of water in the economy. Goods production demands more surface water than groundwater. However, the proportion of groundwater consumption decreased in sector 5 (90 million m^3), sector 11 (495 million m^3), and sector 12 (352 million m^3), respectively.

Table 3.4 Water consumption by sectors in four scenarios

(100 million m^3)

	Surface Water			Groundwater		
	2017	WUC	WUE	2017	WUC	WUE
1	3105.310	3105.306	3090.251	1137.850	1137.849	1132.059
2	330.990	330.989	315.931	108.070	108.070	102.279
3	56.860	56.860	41.801	33.500	33.500	27.709
4	50.590	50.590	35.531	19.180	19.180	13.389
5	43.540	43.540	28.481	4.890	4.890	-0.901
6	71.750	71.750	56.691	10.500	10.500	4.709
7	186.050	186.050	170.991	37.650	37.650	31.859
8	27.140	27.140	12.081	10.020	10.020	4.229
9	96.550	96.546	81.491	17.520	17.519	11.729
10	20.590	20.588	5.531	8.170	8.169	2.379
11	17.950	17.952	2.891	0.840	0.840	-4.951
12	64.660	64.660	49.601	2.270	2.270	-3.521
13	223.910	223.915	208.851	17.480	17.480	11.689

Each water policy scenario also improved the water price and water use (see Table 3.5). In the WUC, the groundwater price rose approximately 6.80% more effectively than that in the WUE (0.02%). The surface water price decreased to 0.99 under the WUE scenario, while the groundwater price increased to 1.005 under the WUC scenario.

Table 3.5 Comparison of different scenarios' effects on water price

	2017 Year	WUC	WUE
Surface water	1	1.004695	0.999969
Groundwater	1	1.068774	1.000187

3.7.2 Effect on total output

Fig 3.3 shows the output change after the water policy was applied in 13 sectors. Unlike the change in water consumption, the output of most sectors decline. The total output of sector 10 reduced by CN¥ 5,000 million, which signifies its high dependence on water supply. The production of sector 11 and sector 13 increased by CN¥ 700 million and CN¥ 1,600 million, respectively. Under the sustainable water use scenario, total production decreased in China (Calzadilla et al., 2010). The WUI scenario only has a marginal effect on all sectors except sector 10. Under the IDTX scenario, production declined in sectors 5 and 10, but increased in sectors 4 and 12.

Fig 3.3 Effects of water policy on total output (CN¥ 100 million)

The reduction in the price of the total output can be captured in all sectors under the WUC and WUE scenarios except in sector 3, as shown in Fig 3.4. In the WUC scenario, the output price in sector 3 went up 0.90%, but the output price of sectors 6 and 8 decreased 0.79% and 0.42%, respectively. In the WUE scenario, the effect on price is too weak to estimate, but all sectors saw an increase in price under the WUI and IDTX scenarios except sector 3.

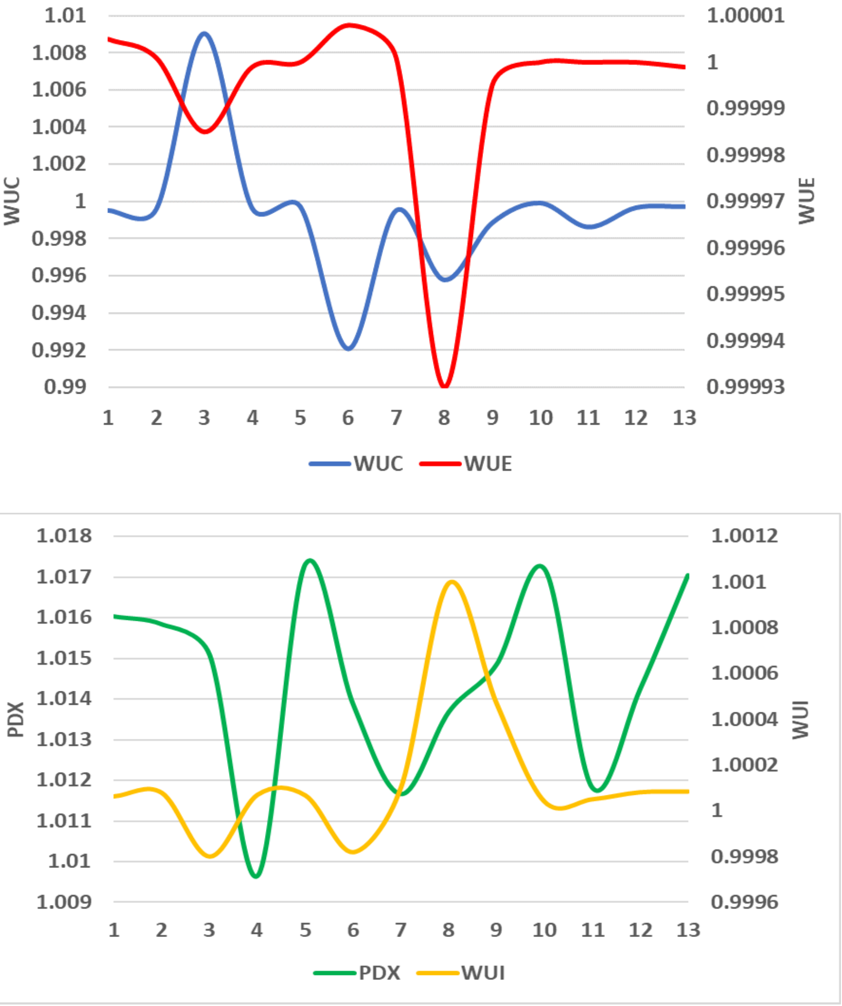


Fig 3.4 The effect of different scenarios on output price

3.7.3 Effect on institutions

The CGE model captured some effects on the household, firm, and government through two water policies. Fig 3.5 shows that the WUC scenario has a negative effect on household income and firm. The income loss from residents is approximate 2.4 times as large as firm losses, whereas government income could benefit from higher taxes. Government income increased by 0.007%, while household income and firm income decreased by 0.03%. Further, household and firm expenditure rose, especially for sectors 6 and 8, while they had less savings. The three institutions all benefited more under the IDTX scenario than the WUI scenario. For example, household increase CN¥ 700,223 million under the IDTX scenario.

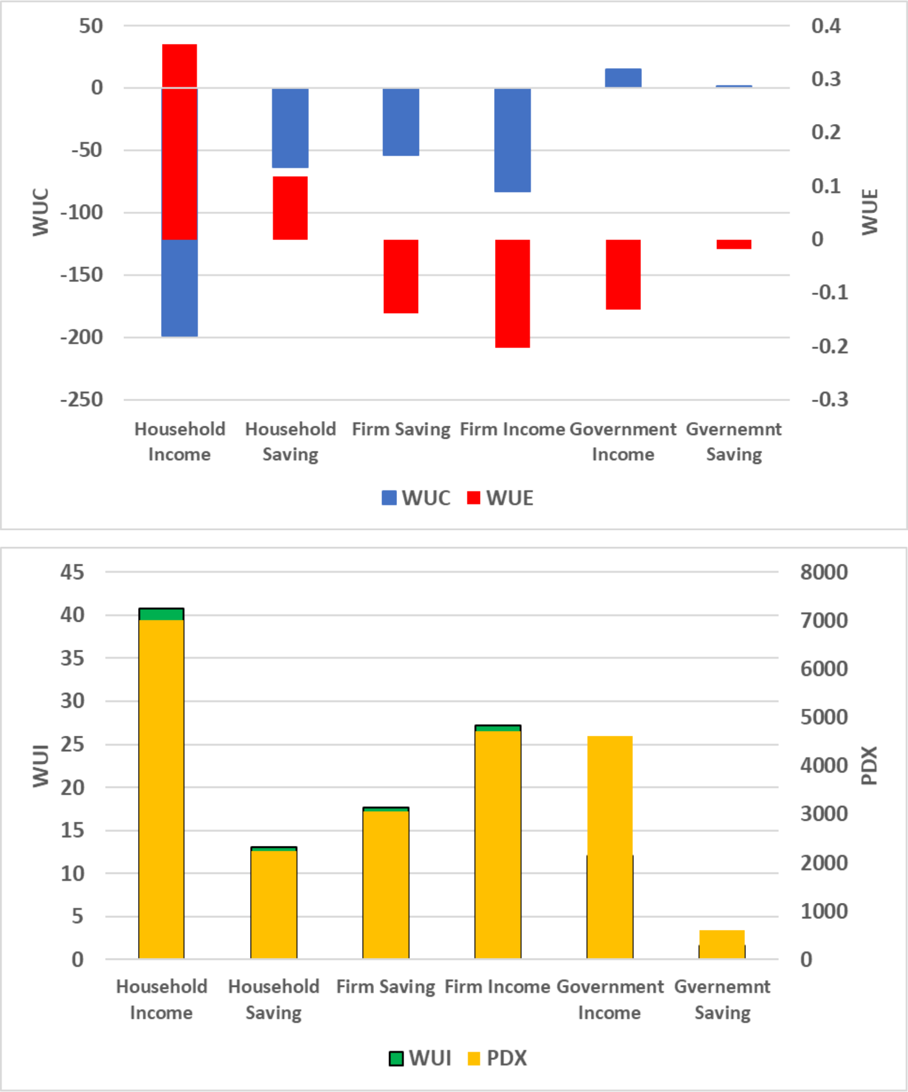


Fig 3.5 The effect of different scenarios on institutions (CN¥ 100 million)

3.7.4 Effect on export and import

The export and import changes under two scenarios are presented through graphs in Fig 3.6. In the WUC scenario, the opposite effect on import and export was captured in some sectors. Logically, it is to be expected that the effect of a water policy would be stronger on import each sector. Evidently, export increased only slightly, whereas import decreased in sectors 1, 3, 4, 7, and 9. Sector 10 shows the closest relationship with water policy, with input and output declining to around CN¥ 1,000 million. In the WUE and WUI scenarios, the effect on export and import is minimal. In the IDTX scenario, sector 10 shows the highest negative effect for import (CN¥ 4,744 million) and export (CN¥ 6,719 million).

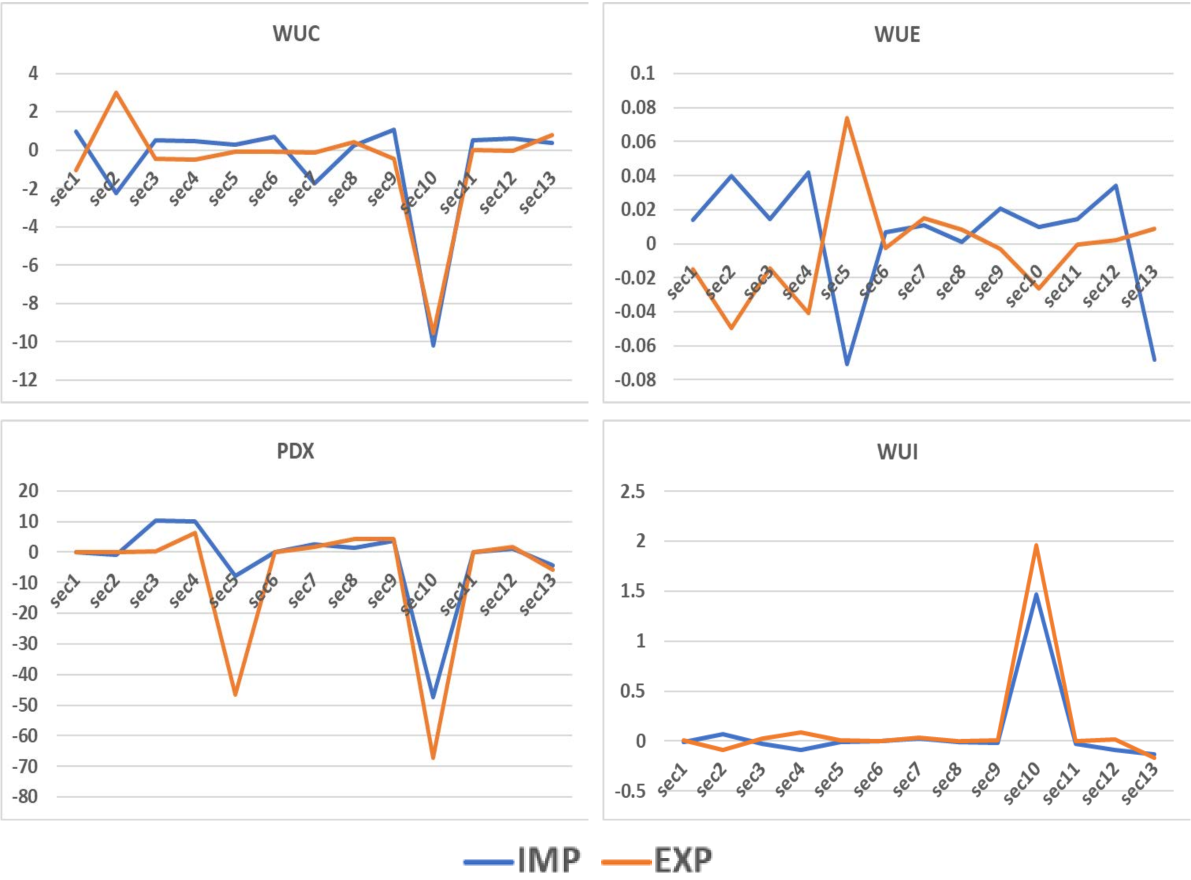


Fig 3.6 Different scenarios for export and import
(CN¥ 100 million)

The change in price of import and export under the four scenarios is shown in Fig 3.7. In the WUC scenario, the price of export increased in sector 3 (1.07) and sector 5 (1.06), but decreased in sector 11 (0.14). The price of import rose in sector 3 (1.022) and sector 5 (1.0008), but went down in sector 11 (0.09). In the WUE and WUI scenarios, the price of several sectors increased slightly for import and export. Export in sector 4 and import in sector 12 reached the highest value of 1.018 and 1.01, respectively. The prices of all sectors increased only slightly under the IDTX scenario for both import and export.

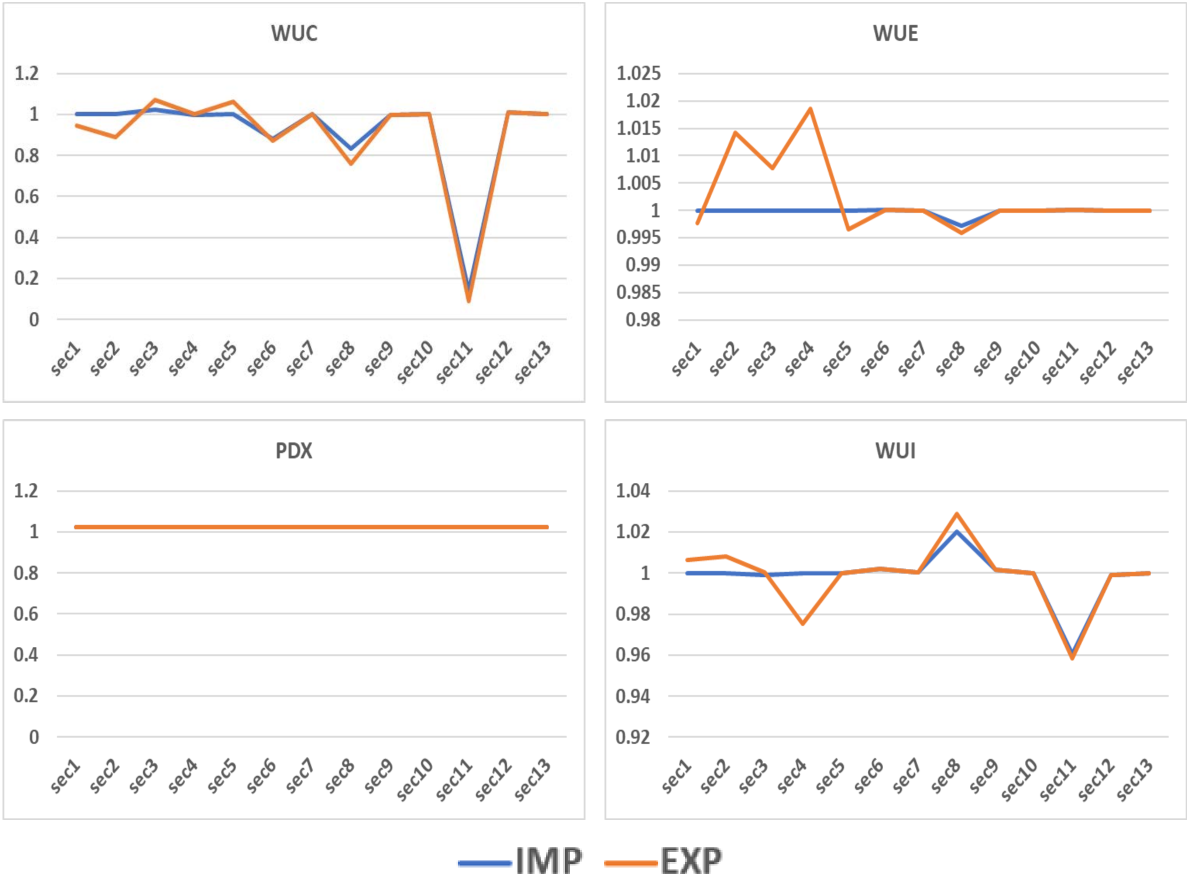


Fig 3.7 The effect of different scenarios on the price of export and import

3.7.5 Sensitivity analysis

Two key parameters on purpose were varied to investigate the sensitivity of the model. Water price is supposed to have a significant influence on total water use. For sensitivity analysis, the price of surface water and groundwater increased 10% and decreased 10%, respectively. Table 3.6 shows that the total water use of surface water and groundwater is 565,163 million m^3 and 212,167 million m^3 in the base year, respectively. When the groundwater price increased 10%, the quantity of water demand decreased. In contrast, when the water price went down, the demand for water rose. Thus, the groundwater price increased, while the groundwater price decreased to 0.99. Note that the groundwater price is more sensitive when factors change in the model. Unsurprisingly, the change in water price does have a substantial effect on the demand of total water.

Table 3.6 Comparison of different water prices and water use (100 million m^3)

	2017	Surface Water Price Increase 10%	Surface Water Price Decrease 10%	Groundwater Price Increase 10%	Groundwater Price Decrease 10%
Surface Water Price	1.00	1.10	0.90	0.99	1.03
Groundwater Price	1.00	1.00	1.00	1.10	0.90
Surface Water Use	5651.63	5645.69	5652.94	5743.86	5617.82
Groundwater Use	2121.67	2122.10	2121.49	2109.15	2125.35

3.8 Conclusion

By integrating the water data and compiling the WSAM table under the SEEA framework, I highlight the economic influence on surface water and groundwater at the national level through a static CGE model. The effects of the “three red lines” water policy and the tax policy on the economy and environmental assets were illuminated. The findings confirm that the control of water is more beneficial than simply improving the efficiency of water use, especially for the tertiary industry. Moreover, a water policy could further sustainably develop the service sector. The model also provides an opportunity for some sectors to transform the extensive pattern to an intensive pattern. However, restricting water use does have a negative effect on economic growth, and improving the irrigation rate also shows a limitation effect for each sector. The results suggest that a sound water policy should concentrate on sectors that are highly dependent on water resources.

Nevertheless, the static CGE model yielded a reliable analysis to reveal the effect of water policy. In the next step, I use the DCGE model to observe and understand the economywide effects of the projected water management reform and structural economic change on water use in China.

CHAPTER 4

DEVELOPMENT OF DCGE MODEL

4.1 Introduction

China must control its water consumption and adjust its water price for efficient management of its resources, especially given the State Council's stringent recommendations for capping consumption and implementing wide-ranging police reforms to the economic structure. In this regard, the CGE model is a useful tool to assess and measure the external shocks to the economy at different scales. The model could provide insight into the current water policy in China as well. Since 1980s, the model has been used in environmental research to evaluate economic influences. It can also estimate the effect of water resource and water price at the city or prefectural level. In the literature, the dynamic effect is also considered in the analysis of the effect of water price, allocation, and pollution (Guo et al., 2020; Ke et al., 2016; Li et al., 2016; Jiang et al., 2014). Commonly, water resource data are directly collected from government publications that have different statistic standards for gathering and compiling economic data.

To estimate the water stock and flows, I employ the SEEA Central Framework, a satellite system of the SNA, which acts as the international statistics standard and guideline for environmental economic (United Nations, 2012). The system provides a standard measurement to test the relevance, accuracy, and coherence of water data (Zhong et al., 2017). Based on the physical supply and use tables (PSUT), monetary supply and use tables (MSUT), and environmental assets, a SAM can be created to demonstrate the water resource investment and consumption in China in terms of environment information. This environmentally extended SAM is an effective tool and widely accepted in economics to explore environmental problem (Zhao et al., 2021; Eden et al. 2014; Borrego-Marín et al. 2016).

The SAM table works with SNA, which is good at demonstrating both economic and environmental information in a matrix. The SAM can capture how policies affect economic growth by considering changes in the stocks of environmental resources. Different from other economic frameworks, it treats environmental resources represented in the SEEA and can quantify how economic activities critically depend on the environment (He et al., 2021). In SAM, water accounts contain supply and use tables that track the extraction of water, from the environment to consumptive use, from regulated discharges to the environment, and then to reuse. One benefit of this model is that it gives us visibility into water resource use and allows us to accurately estimate the environmental assets. The data can be expressed as physical quantities or in monetary units (United Nations, 2012).

I thus compile detailed WSAM data to assess the economic effect of restricting water use at the macro level. The DCGE model estimates the economic effects of water policy over a set period. The remaining chapter is organized as follows. In section 4.2, I introduce the research background, including the SEEA framework, overview of the SAM-based DCGE model, and a description of the model's framework. In section 4.3, the water policy effects on Chinese economy are investigated. Section 4.4 concludes.

4.2 DCGE model based on SEEA

4.2.1 Environmentally extended supply and use table

For sustainable development, water resource consumption should be assessed through an economic accounting system in a coherent and consistent way. The SEEA framework can capture the stock of water and water flows, from the environment to various economic activities. The system not only provides physical information, but also monetary accounts to reflect the real value of the water resource in market. The SEEA framework is not without popularity in Chinese studies (Vardon et al., 2018), such as for establishing a green national economic accounting system that excludes ecological damage, or for evaluating mineral, forest, and water resources based on physical and monetary quantification at the national and local level. Although the cost of environmental pollution take precedence in most studies, I shift the focus to water resource valuation in the whole economy using the SEEA-based EESUT, as it provides the measurement and principle for various types of water resources in the PSUTs. It also extends the MUSTs of the SNA by incorporating columns for the environment, rows for natural inputs, and residuals, as proposed by the SEEA (Xie et al., 2000). Its treatment of environmental resource is thus dynamic under the SEEA. Notably, conventional environmental resource accounting primarily concerns itself with water stocks than water resource abstraction and water reuse. The EESUT tracks the extraction of water, beginning from the environment to consumptive use. In general, an analysis model of environmental economics policy could rely on the EESUT to provide reliable data for various issues. Table 4.1 shows the basic structure of the EESUT (Banerjee et al., 2019).

Table 4.1 Basic structure of the environmentally extended supply and use table

	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21
01. Water supply (Registered/Unregistered)	■	■																			
02. Water use (Registered/Unregistered)	■														■						
03. Cultivated Area (Ha)	■																				
04. Rainfed irrigation use (m^3)	■																				
05. Sprinkler irrigation use (m^3)	■																				
06. Drip irrigation use (m^3)	■																				
07. Gravity use (m^3)	■																				
08. Other use (m^3)	■																				
09. All irrigation (m^3)	■																				
10. Sprinkler irrigation return (m^3)	■																				
11. Drip irrigation return (m^3)	■																				
12. Gravity return (m^3)	■																				
13. Other return (m^3)	■																				

Note. T01: Output/Intermediate consumption; T02: Environment; T03: Imports of goods; T04: Imports of services; T05: CIF/FOB adjustment on imports; T06: Value-added tax (VAT); T07: Tariffs exc. VAT on imports; T08: Taxes on products, excluding VAT and Tariffs; T09: Subsidies on products; T10: Trade margins; T11: Transportation margins; T12: Electricity, gas, water margins; T13: Exports of goods; T14: Exports of services; T15: Household final consumption; T16: NFPI final consumption; T17: Individual government final consumption; T18: Collective government final consumption; T19: Gross capital formation; T20: Stock variation; T21: Valuable objects.

The SAM is meant to estimate the economic effect of water policy. The basic SAM table was originally developed based on the input–output table, which, in turn, is based on the current prices in each year in the eight sectors in 2017, the year of observation (Sakuma et al., 2004). Once a macro-SAM has been constructed, the next step is to disaggregate the economic sectors and water information to build the environmentally extended SAM (EESAM), where the first nine accounts are macro-SAM data and the last three accounts come from the EESUT. Table 4.2 shows the basic structure of the EESAM.

Table 4.2 Accounts of the environmentally extended social accounting matrix

Accounts in EESAM (Liu, 2020)	Author elaboration accounts in EESAM	Abbreviation forms
Agriculture	Agriculture, Forestry, Animal Husbandry & Fishery	C1: Agriculture industry
Forestry, Animal Husbandry & Fishery		
Manufacture of Mining	Manufacture of Mining, Foods, Beverage, Tobacco, Textile, Wearing Apparel, Leather Products, Pape	C2: Light industry
Manufacture of Foods, Beverage & Tobacco		
Manufacture of Textile, Wearing Apparel & Leather Products		
Manufacture of paper		
Coking, Gas, Processing of Petroleum & Chemical Industry	Coking, Gas, Processing of Petroleum & Chemical Industry, Manufacture of Non-metallic Mineral Products, Processing of Metals and metal Products, Manufacture of Machinery and Equipment	C3: Heavy industry
Manufacture of Non-metallic Mineral Products		
Manufacture and Processing of Metals and metal Products		
Manufacture of Machinery and Equipment		
Production and Supply of Electric Power, heat Power and Water	Production and Supply of Electric Power, heat Power and Water	C4: Power industry
Construction	Service	C5: Service
Service		

Compared with other framework, the WSAM is extended by aggregating water accounts in monetary terms. In general, statistical data are only published in physical terms to estimate the water resource. However, only physical data will not allow us to fully grasp water problems. The government should publish the monetary data of water resources to improve water management. Such data could help policymakers develop policy that combines both economic and environmental components, which are naturally and mutually dependent.

The sectors are compiled as environment accounts to measure the policy's effect on the Chinese economy. The observable period is from 2017 to 2020. The influence of water policy is observed after four years of implementation. According to official data from the World Bank, GDP in China continually grew from 2017 to 2020, along with the demand for water.

4.2.2 Flow of DCGE

I develop a DCGE model to estimate the economic effects of water policy from 2017 to 2020. The model provides insight into the current water policy in China. A simulation through annual capital accumulation and investment allocation will further enrich this understanding. There exist several DCGE models on water allocation, shadow price, virtual water (Round et al., 2003; Liu et al., 2020), and the improvement of water resource management by the government. The literature simply confirms that how critical water data are for building this model.

In the DCGE model, water is the same primary factor as the other sectors. The relative price of trade and the global long-term interest rate are 1 and 0.03, respectively (He et al., 2007). The price of labor is fixed at a constant. The input–output table is the control variable, and the RAS method developed by Sir Richard Stone was applied to balance the data. The definition of the Armington function and constant elasticity transformation function are based on the literature (Zhao et al., 2021). Following these studies, I introduce the surface water and groundwater use and supply into the environmental module. Most scholars merge surface water and groundwater into one sector. However, note that the water price is significantly different in their respective production processes.

A nested Cobb–Douglas function is applied to the production function. At the top level, the sectoral output is represented by a Leontief function of intermediate inputs (U) and the value-added inputs (V). The primary factors are represented by two elements: labor (L) and composite capital (WK). The second level is represented by two elements: capital (K) and water (W). At the bottom level, water is characterized by a Leontief function of surface water (GW) and groundwater (UW). Fig 4.1 shows a diagram of the DCGE model.

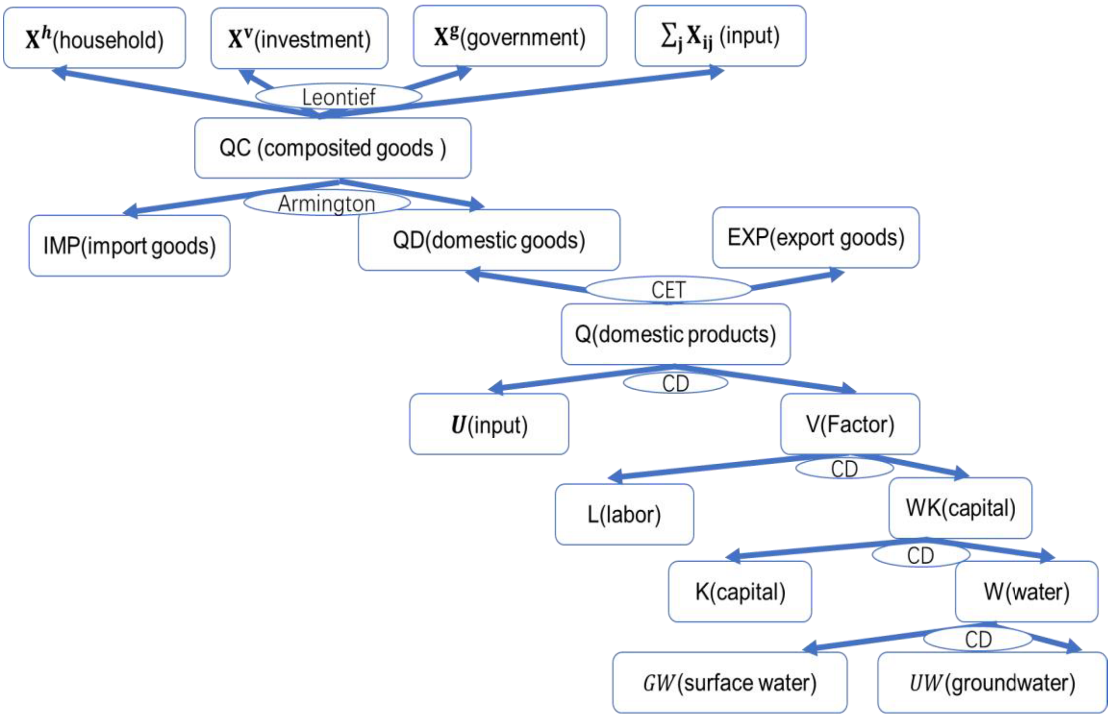


Fig 4.1 Flowchart of dynamic computable general equilibrium model

4.2.3 Explanation of the dynamic effect

Water is consumed for production and by households. Depending on the supply and demand condition, the formula is expressed below:

$$W(TH) = \left(\sum_i w(i,TH) * PWAT * X(i,TH)\right) + HWU(TH). \tag{4.1}$$

where water use is expressed in equation (4.1). $W(TH)$ is the total water demand, $w(i)$ is the water input coefficient, $PWAT$ is the water price, $X(i)$ is the total output, HWU is the household water consumption.

$$\left(\sum_i WATD(i,TH) - WATS(TH)\right) * PWAT(TH) = 0. \tag{4.2}$$

Equation (4.2) shows the equilibrium condition in the market. In the equation, it is assumed that water demand is equal to water supply and the price of water is positive. $WATD(i)$ is the total water demand and $WATS$ is the total water supply. $PWAT$ is the price of water. The income–expenditure block includes household, enterprises, government, and the rest of world. The most important equation in the income–expenditure block is the dynamic household consumption, as shown below:

$$HACV(TH) = HACV(TH-1) * \frac{1+RLTIR(TH)}{1+stp(TH)} * \frac{PHAC(TH-1)}{PHAC(TH)}. \tag{4.3}$$

where $HACV(TH)$ interprets the household aggregate consumption in volume, $PHAC(TH)$ is the price of the household aggregate consumption, $RLTIR(TH)$ and $stp(TH)$ are the exogenous calibrate real long-term interest rate and social discounting rate respectively.

It is assumed that capital is time separable in the DCGE model. The model can determine the current account and the accumulation of an investment asset. The stock accumulation and allocation are calculated based on the capital revenue rate, average rate of total capital, and total supply of capital among sectors. The model allows flexible and realistic investments toward the most productive sectors. The function of the capital accumulation is formulated below:

$$INVCCPSV(i,j,TH) = INVCCV(i) * \left(\frac{K(j,TH)}{\sum K(j,TH)}\right). \tag{4.4}$$

$$INVPSV(j,TH) = \sum_i INVCCPSV(i,j,TH). \tag{4.5}$$

where $INVCCPSV(i,j,TH)$ is the investment to commodity, $INVCCV(i)$ interprets the investment to sectors, $K(j,TH)$ is the initial capital demand, and $INVPSV(j)$ is the investment by producer.

In the capital accumulation equation, capital depreciation rate $dep(j,TH)$ is fixed. The function of capital allocation is shown in equations 4.6-7. The capital stock $KS(j,TH+1)$ is determined by the previous year's capital stock $KS(j,TH)$, investment $INVPSV(j,TH)$, and capital depreciation rate, which is fixed as exogenous calibration.

$$KS(ps,TH) = \mathrm{K(ps,TH)}. \tag{4.6}$$

$$KS(ps,TH+1) = INVPSV(ps,TH) + \big(1 - dep(ps,TH)\big)KS(ps,TH). \tag{4.7}$$

Table 4.3 lists all the variables from equations 4.1 to 4.7.

Table 4.3 Definition of variables in the dynamic computable general equilibrium model

	Variables	Details
Equation 4.1	W_{TH}	Total water demand
	w_i	Water input coefficient
	$PWAT_{TH}$	Water price
	$X_{i,TH}$	Total output
	HW_{TH}	Household water consumption
Equation 4.2	$WAD_{i,TH}$	Total water demand
	$WATS_{TH}$	Total water supply
Equation 4.3	$HACV_{TH}$	Household aggregate consumption in volume
	$PACV_{TH}$	Price of household aggregate consumption
	$RLTIR_{TH}$	Real long-term interest rate
	stp_{TH}	Social discounting rate
Equation 4.4	$INVCCPSV_{i,j,TH}$	Investment to commodity
	$INVCCV_{i,TH}$	Investment to sectors
	$K_{j,TH}$	Initial capital demand
Equation 4.5	$INVPSV_{j,TH}$	Investment by producer
Equation 4.6	$KS_{j,TH}$	Capital stock
Equation 4.7	$dep_{j,TH}$	Capital depreciation rate

4.2.4 Water effect in the DCGE model

The original DCGE model (Pan, 2016) is developed into a water-CGE to include water as a factor in the DCGE model. Water resource includes surface water and groundwater, presented by Leontief production. Both are consumed for goods production and household consumption.

Surface water demand by commodity $GWAT(j,TH)$:

$$GWAT(j,TH) = watground(j,TH) \cdot WAT(j,TH). \tag{4.8}$$

Groundwater demand by commodity $UWAT(j,TH)$:

$$UWAT(j,TH) = watunder(j,TH) \cdot WAT(j,TH). \tag{4.9}$$

Water demand by commodity $WAT(j,TH)$:

$$WAT(j,TH) = gammawat(j,TH) \cdot PWK(j,TH) \cdot WK(j,TH)/PWAT(j,TH). \tag{4.10}$$

Capital demand by commodity $K(j,TH)$:

$$K(i,TH) = gammak(i,TH) \cdot PWK(i,TH) \cdot WK(i,TH)/RPS(i,TH). \tag{4.11}$$

Water demand by capital $WK(j,TH)$:

$$WK(j,TH) = gammawk(j,TH) \cdot PV(j,TH) \cdot V(j,TH)/PWK(j,TH). \tag{4.12}$$

Labor demand by commodity $L(j,TH)$:

$$L(j,TH) = gammal(j,TH) \cdot PV(j,TH) \cdot V(j,TH)/W(TH). \tag{4.13}$$

Price for water resource $PWAT(TH)$:

$$\begin{gathered} PWAT(TH) \cdot \textstyle\sum_j WAT(j,TH) = PGWAT(TH) \cdot \textstyle\sum_j GWAT(j,TH) + \\ PUWAT(TH) \cdot \textstyle\sum_j UWAT(j,TH). \end{gathered} \tag{4.14}$$

Price for surface water $PGWAT(TH)$:

$$PGWAT(TH) \cdot \textstyle\sum_j GWAT(j,TH) + HGWAT(TH) = TGWAT(TH). \tag{4.15}$$

Price for groundwater $PUWAT(TH)$:

$$PUWAT(TH) \cdot \textstyle\sum_j UWAT(j,TH) + HUWAT(TH) = TUWAT(TH). \tag{4.16}$$

4.2.5 Construction of the DCGE model

The DCGE model includes 59 endogenous variables and 59 functions. Table 4.4 summarizes the corresponding sectors, technologies, and the rest of the equation numbers.

Table 4.4 Relationship in the dynamic computable general equilibrium model

Sectors	Technologies	Equation number
Commodity	Leontief function, Cobb-Douglas function	33-36, 59
Labor and capital	Cobb-Douglas function	58
Household and Government		19-26
Investment and saving	Constant elasticity substitution function	27-32, 56-57
ROW	Amington function and CET function	37-43
Cost of production and balance		51-55
Price and other		17-18, 44-50

The remaining equations are price-related for each sector. The production function uses the constant elasticity substitution function with the three-level nested technology. The construction for the DCGE model while considering environmental effects is demonstrated below:

Real long-term interest rate $RLTIR(TH)$:

$$RLTIR(TH) = wir(TH). \tag{4.17}$$

Relative price of trade $ERE(TH)$:

$$ERE(TH) = 1. \tag{4.18}$$

Household aggregate consumption in value $HAC(TH)$:

$$HAC(TH) = HY(TH) - HS(TH). \tag{4.19}$$

Household consumption in value $HC(i,TH)$:

$$HC(i,TH) = shc(i,TH) \cdot HAC(TH). \tag{4.20}$$

Household consumption in volume $HCV(i,TH)$:

$$HCV(i,TH) = HC(i,TH)/PC(i,TH). \tag{4.21}$$

Government consumption in volume $GCV(i,TH)$:

$$GCV(i,TH) = a_g(i,TH) \cdot GY(TH)/PC(i,TH). \tag{4.22}$$

Household income $HY(TH)$:

$$HY(TH) = \sum_i W(TH) \cdot LS(i,TH) + \sum_i RPS(i,TH) \cdot K\ (i,TH). \tag{4.23}$$

Government income $GY(TH)$:

$$GY(TH) = \sum_i it(i,TH) \cdot X(i,TH). \tag{4.24}$$

Household savings $HS(TH)$:

$$HS(TH) = sh(TH) \cdot HY(TH). \tag{4.25}$$

Government savings $GS(TH)$:

$$GS(TH) = sg(TH) \cdot GY(TH). \tag{4.26}$$

Total savings $TSAV(TH)$:

$$TSAV(TH) = HS(TH) + GS(TH). \tag{4.27}$$

Total investment $TINV(TH)$:

$$TINV(TH) = TSAV(TH). \tag{4.28}$$

Investment to sectors $INV(TH)$:

$$INV(TH) = \sum_i pc(i,TH) \cdot INVCCV(i,TH). \tag{4.29}$$

Investment in stock $INVS(TH)$:

$$INVS(TH) = ivs(TH) \cdot TINV(TH). \tag{4.30}$$

Investment to abroad $INVF(TH)$:

$$INVF(TH) = TINV(TH) - INV(TH) - INVS(TH). \tag{4.31}$$

Stock change by commodity in volume $SCV(i,TH)$:

$$SCV(i,TH) = a_s(i,TH) \cdot INVS(TH)/PC(i,TH). \tag{4.32}$$

Activity of domestic production $X(i,TH)$:

$$CX(i,TH) = (1 - it(i,TH)) \cdot PX(i,TH). \tag{4.33}$$

Use of composite intermediate input $U(i,TH)$:

$$U(i,TH) = (X(i,TH)/AP(i,TH)) \cdot (beta(i,TH) \cdot AP(i,TH) \cdot CX(i,TH)/ PU(i,TH))^{sp(i,TH)}. \tag{4.34}$$

Use of composite factor input $V(i,TH)$:

$$V(i,TH) = (X(i,TH)/AP(i,TH)) \cdot (gamma(i,TH) \cdot AP(i,TH) \cdot CX(i,TH)/ PV(i,TH))^{sp(i,TH)}. \tag{4.35}$$

Intermediate demand of commodity $QX(i,TH)$:

$$QX(i,j,TH) = ut(i,j,TH) \cdot U(i,TH). \tag{4.36}$$

Quantity of domestically-produced commodity $Q(i,TH)$:

$$Q(i,TH) = \textstyle\sum_i X(i,TH). \tag{4.37}$$

Quantity of domestically-produced commodity sold in domestic market $QD(i,TH)$:

$$QD(i,TH) = (Q(i,TH)/AT(i,TH)) \cdot (epsilon(i,TH) \cdot AT(i,TH) \cdot PQ(i,TH)/ PQD(i,TH))^{st(i,TH)}. \tag{4.38}$$

Export $EXP(i,TH)$:

$$EXP(i,TH) = (Q(i,TH)/AT(i,TH)) \cdot \left(\left(1 - epsilon(i,TH)\right) \cdot AT(i,TH) \cdot PQ(i,TH)/PEXP(i,TH)\right)^{st(i,TH)}. \tag{4.39}$$

Quantity of composite commodity supplied to or consumed in domestic market $QC(i,TH)$:

$$QD(i,TH) = (QC(i,TH)/AA(i,TH)) \cdot (delta(i,TH) \cdot AA(i,TH) \cdot PC(i,TH)/ PQD(i,TH))^{sa(i,TH)}. \tag{4.40}$$

Import $IMP(i,TH)$:

$$IMP(i,TH) = (QC(i,TH)/AA(i,TH)) \cdot ((1 - delta(i,TH)) \cdot AA(i,TH) \cdot PC(i,TH)/PIMP(i,TH))^{sa(i,TH)}. \tag{4.41}$$

Price of export at local currency $PIMP(i,TH)$:

$$PIMP(i,TH) = EXR(TH) \cdot wpi(i,TH). \tag{4.42}$$

$$QC(i,TH) = \sum_j QX(i,j,TH) + HCV(i,TH) + GCV(i,TH) + INVCCV(i,TH) + SCV(i,TH\ ). \qquad (4.43)$$

Price of household aggregate consumption $PHAC(i,TH)$:

$$PHAC(TH) = \sum_i HCV(i,TH) \cdot PC(i,TH))/\sum_i HCV(i,TH). \qquad (4.44)$$

Price for commodity of domestic production $PX(i,TH)$:

$$PX(i,TH) = PQ(i,TH). \qquad (4.45)$$

Price of composite intermediate input $PU(j,TH)$:

$$PU(j,TH) = \sum_i QX(i,j,TH) \cdot PC(i,TH))/U(j,TH). \qquad (4.46)$$

Price of composite factor input $PV(j,TH)$:

$$PV(j,TH) = \left(\frac{1}{AV(j,TH)}\right) \cdot \left(\frac{W(TH)}{gammal(j,TH)}\right)^{gammal(j,TH)} \cdot \left(\frac{RPS(j,TH)}{gammak(j,TH)}\right)^{gammak(j,TH)}. \qquad (4.47)$$

Price of domestically-produced commodity $PQ(i,TH)$:

$$PQ(i,TH) = \left(\frac{1}{AT(i,TH)}\right) \cdot \left(epsilon(i,TH)^{st(i,TH)} \cdot PQD(i,TH)^{1-st(i,TH)} + \left(1 - epsilon(i,TH)\right)^{st(i,TH)} \cdot PEXP(i,TH)^{1-st(i,TH)}\right)^{\frac{1}{1-st(i,TH)}}. \qquad (4.48)$$

Relative Price of Composite commodity sold in domestic market $PC(i,TH)$:

$$PC(i,TH) = \left(\frac{1}{AA(i,TH)}\right) \cdot \left(delta(i,TH)^{sa(i,TH)} \cdot PQD(i,TH)^{1-sa(i,TH)} + \left(1 - delta(i,TH)\right)^{sa(i,TH)} \cdot PIMP(i,TH)^{1-sa(i,TH)}\right)^{\frac{1}{1-sa(i,TH)}}. \qquad (4.49)$$

Price of Export at local currency $PEXP(i,TH)$:

$$PEXP(i,TH) = PQD(i,TH). \qquad (4.50)$$

Exchange Rate $EXR(i,TH)$:

$$\sum_i PEXP(i,TH) \cdot EXP(i,TH)) = \sum_i PIMP(i,TH) * IMP(i,TH)) + INVF(TH). \qquad (4.51)$$

Labor market $L(TH)$:

$$\sum_i L(i,TH) = TLS(TH). \qquad (4.52)$$

Rental rate $R(TH)$:

$$R(TH) = \sum_i (RPS(i,TH) \cdot KS(i,TH))/\sum_i KS(i,TH). \qquad (4.53)$$

Rental rate by commodity $RPS(i,TH)$:

$$K(i,TH) = KS(i,TH). \tag{4.54}$$

Price for Investment $PINVPS(j,TH)$

$$PINVPS(j,TH) = \sum_i (PC(i,TH) \cdot SINVCCPSV(i,j,TH)). \tag{4.55}$$

Investment by commodity before decomposition $INVCCV(i,TH)$:

$$INVCCV(i,TH) = alphai(i,TH) \cdot TINV(TH)/PC(i,TH). \tag{4.56}$$

Decomposition of investment by commodity $INVCCPSV(i,j,TH)$:

$$INVCCPSV(i,j,TH) = SINVCCPSV1(i,j,TH) \cdot INVCCV(i,TH). \tag{4.57}$$

Capital supply by commodity for the base year $KS(j,TH)$:

$$KS(j,TH) = IK(j). \tag{4.58}$$

Cost of commodity $CX(i,TH)$:

$$\begin{gathered} CX(i,TH) = e = (1/AP(i,TH)) \cdot \left(beta(i,TH)^{sp(i,TH)} \cdot PU(i,TH)^{1-sp(i,TH)} + \right. \\ \left. gamma(i,TH)^{sp(i,TH)} \cdot PV(i,TH)^{1-sp(i,TH)}\right)^{1/(1-sp(i,TH))}. \end{gathered} \tag{4.59}$$

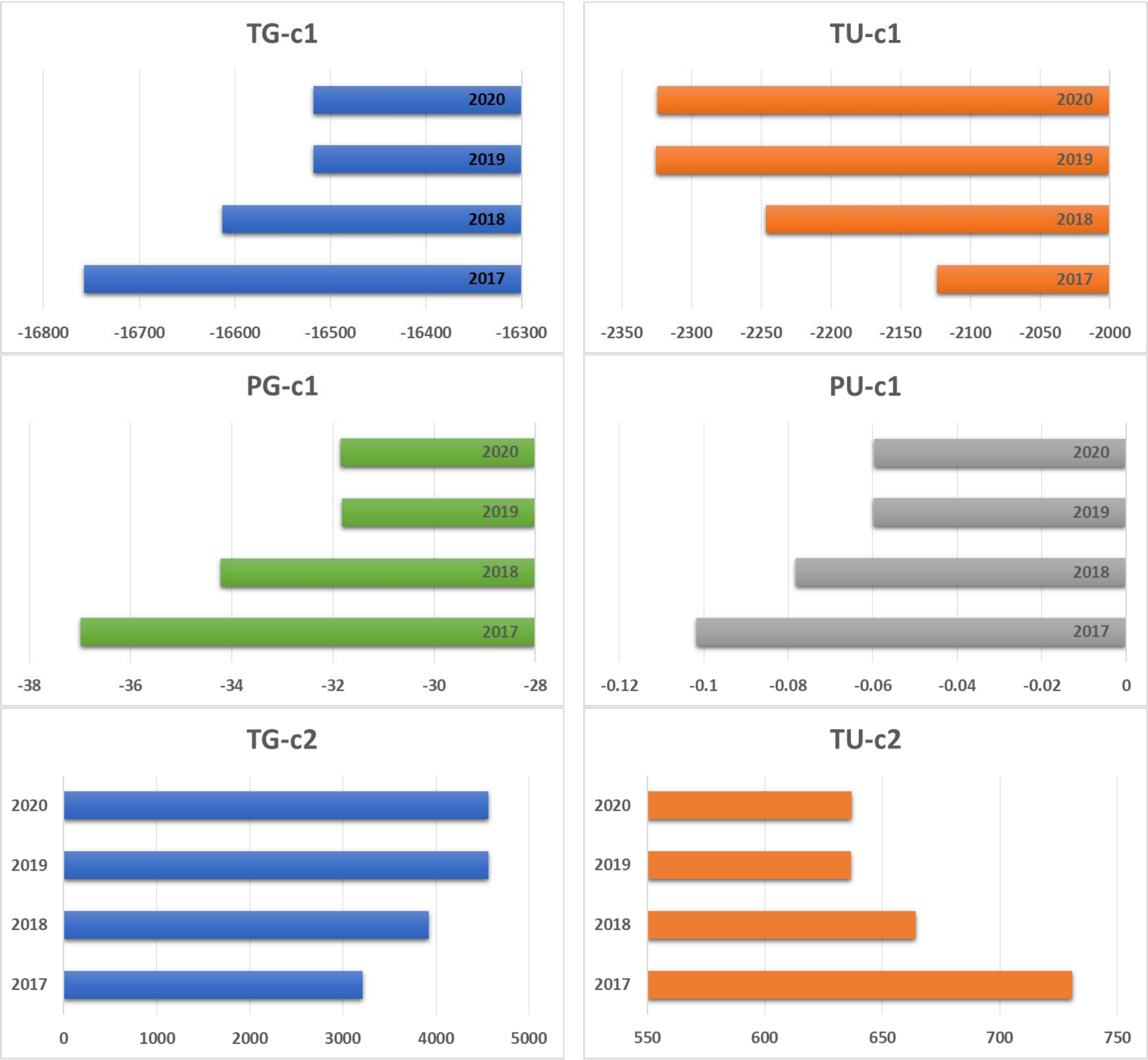
4.2.6 Simulation scenarios

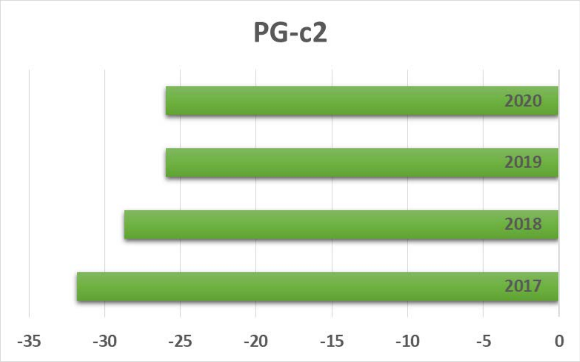
I carried out the simulation analysis on water control policy as an example to harmonize the economic structure, and then applied a DCGE model to gain insight into water management. The simulation also helps identify the sector that requires more attention for a water control policy. The simulation assumptions are summarized as follows. In total, water consumption should not exceed 700 billion m^3 by the year 2030. To reach this goal, I simulated two scenarios wherein the surface water consumption (TG) and groundwater consumption (TU) decrease 10%, respectively. The improvement of the water market is another meaningful water policy that could be beneficial to the Chinese economy. Another two scenarios were considered to estimate the influence of an increasing water price. According to the policy, surface water price (PG) and groundwater price (PU) increase 10%, respectively.

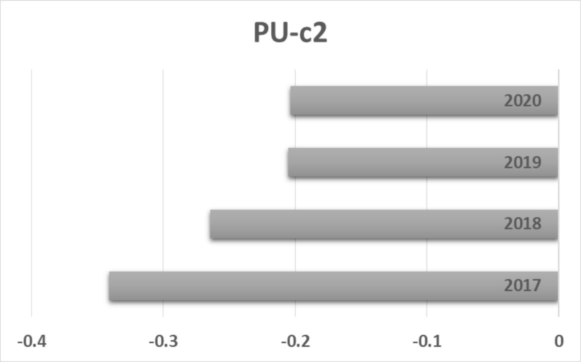
4.3 Results and discussions

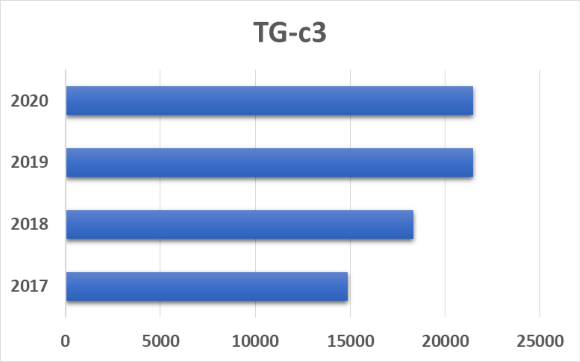
4.3.1 Effect on total output

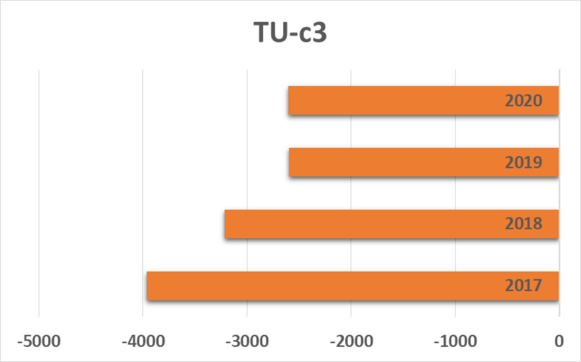
Fig 4.2 shows he effects on total output under the four scenarios. It is obvious that a water control policy has a positive effect on sectors 2 and 5 in the longer term. In contrast, sector 1 shows a decreasing trend. Under the PG and PU scenarios, output declined in sectors 1, 2, 4, and 5 from 2017 to 2020.

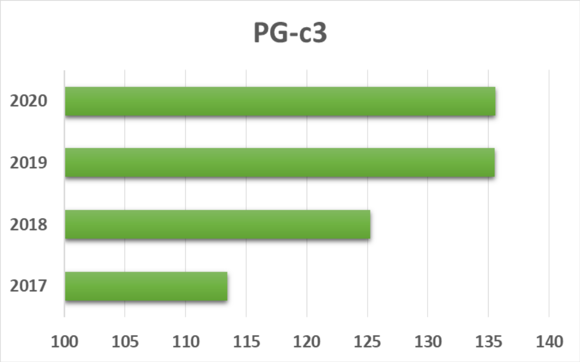


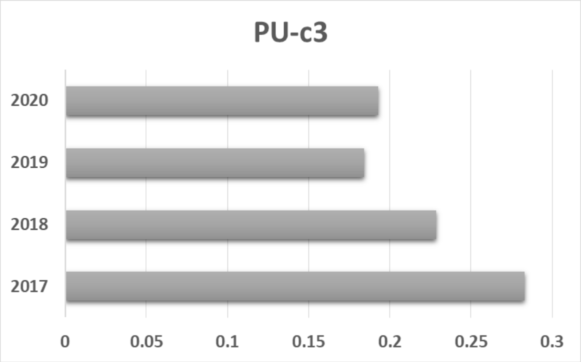

PG-c2
2020
2019
2018
2017
-35
-30
-25
-20
-15
-10
-5
0

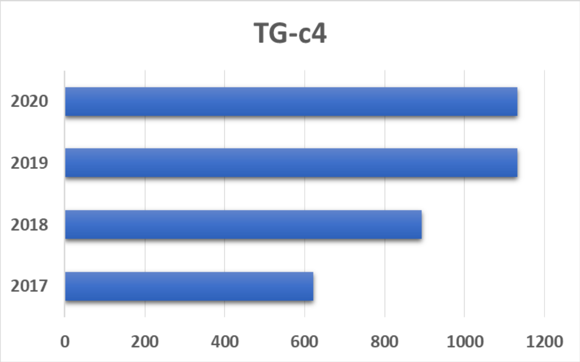

PU-c2
2020
2019
2018
2017
-0.4
-0.3
-0.2
-0.1
0

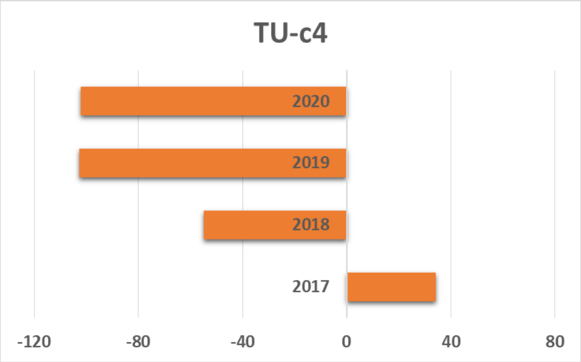

TG-c3
2020
2019
2018
2017
0
5000
10000
15000
20000
25000

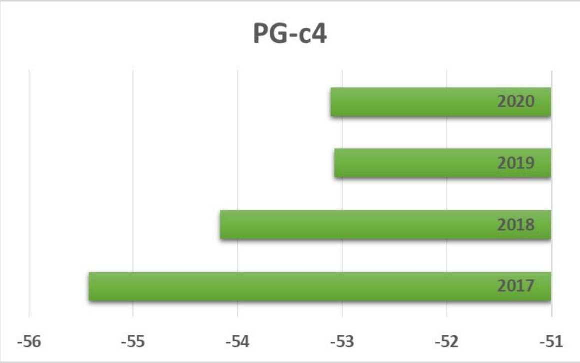

TU-c3
2020
2019
2018
2017
-5000
-4000
-3000
-2000
-1000
0

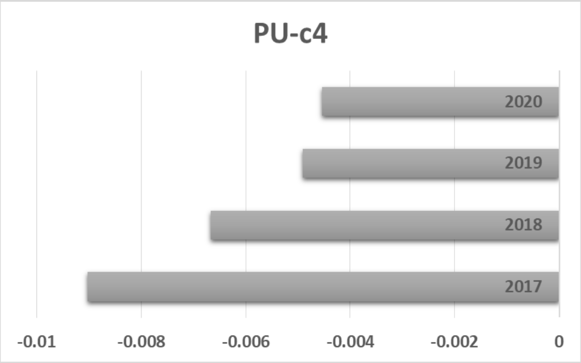

PG-c3
2020
2019
2018
2017
100
105
110
115
120
125
130
135
140


PU-c3
2020
2019
2018
2017
0
0.05
0.1
0.15
0.2
0.25
0.3


TG-c4
2020
2019
2018
2017
0
200
400
600
800
1000
1200


TU-c4
2020
2019
2018
2017
-120
-80
-40
0
40
80


PG-c4
2020
2019
2018
2017
-56
-55
-54
-53
-52
-51


PU-c4
2020
2019
2018
2017
-0.01
-0.008
-0.006
-0.004
-0.002
0

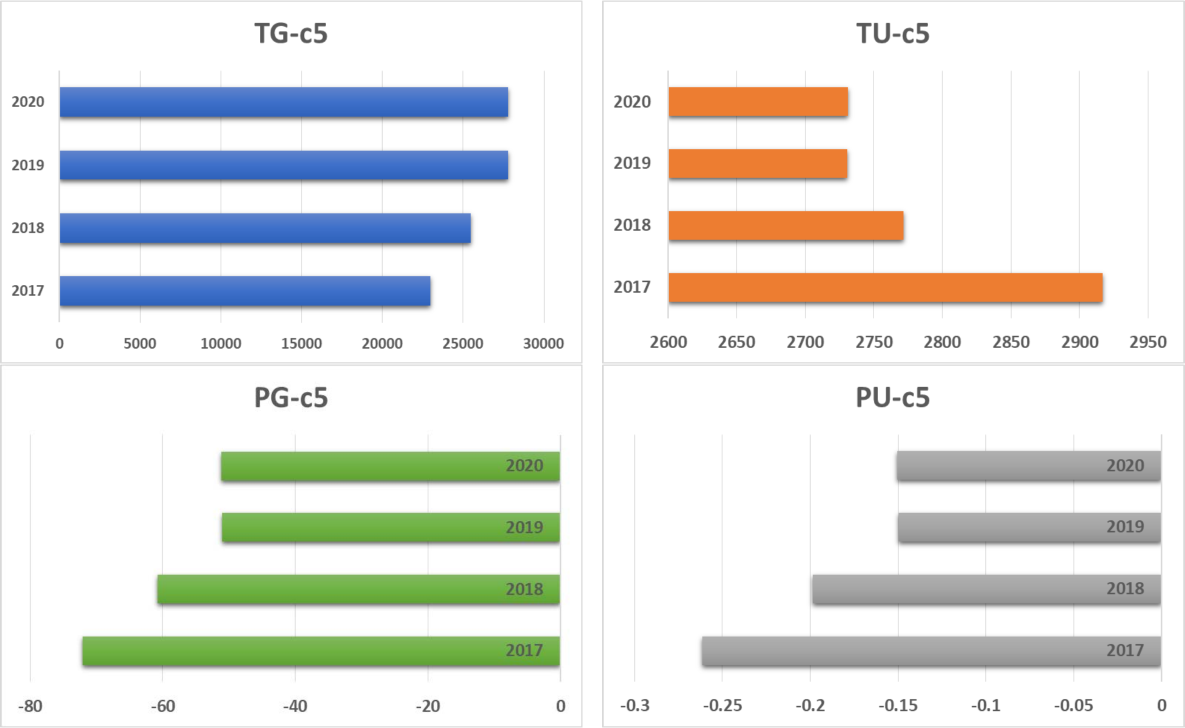


Fig 4.2 The effect of policy on total output
(CN¥ 100 million)

4.3.2 Effect on institutions

Fig 4.3 shows the changes in scenarios for the three institutions, namely, household, firm, and government. Most importantly, water policy may have dramatic effect on each sector in 2017, and all policies have a positive influence on government income in long-run term.

The decreasing groundwater consumption led to the lowest household and firm incomes, which decreased by 0.4% and 0.3% in 2017, respectively. However, the price control policy rose government income up to CN¥ 9,151 million and CN¥ 5,114 million under the PG and PU scenario in 2017, respectively.

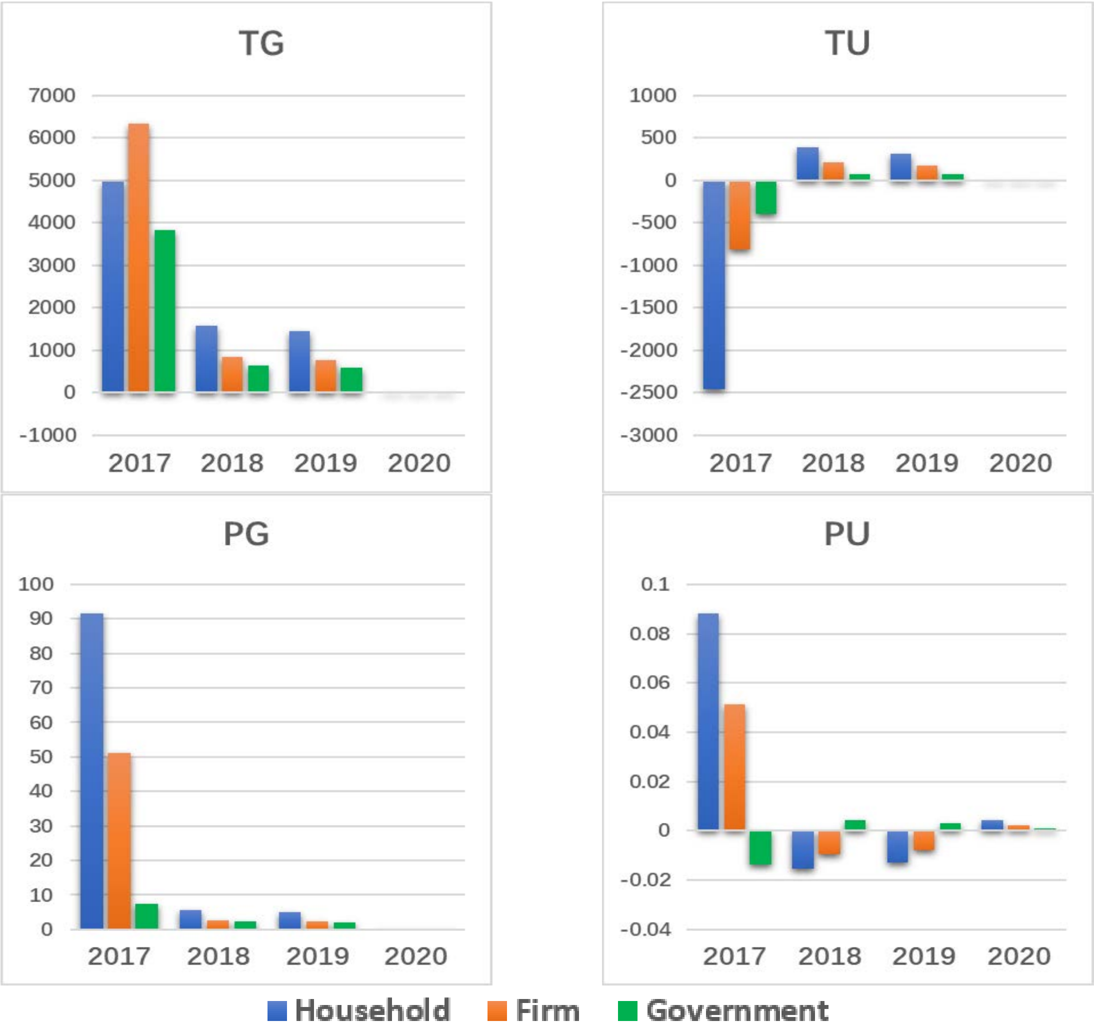


Fig 4.3 The effect of different scenarios on institutions

(CN¥ 100 million)

4.3.3 Effect on Capital

The same scenario reveals a rising trend on the capital stock on all sectors in 2020, and a great change in sector 3 is observable in each year, as shown in Fig 4.4. In the TG scenario, the quantity of capital in c5 rose to the top in 2018 at CN¥ 721,432 million. In the long run, the effect of a water control policy on groundwater is stronger than that of surface water. Meanwhile, the water price policy on groundwater greatly influences capital stock.

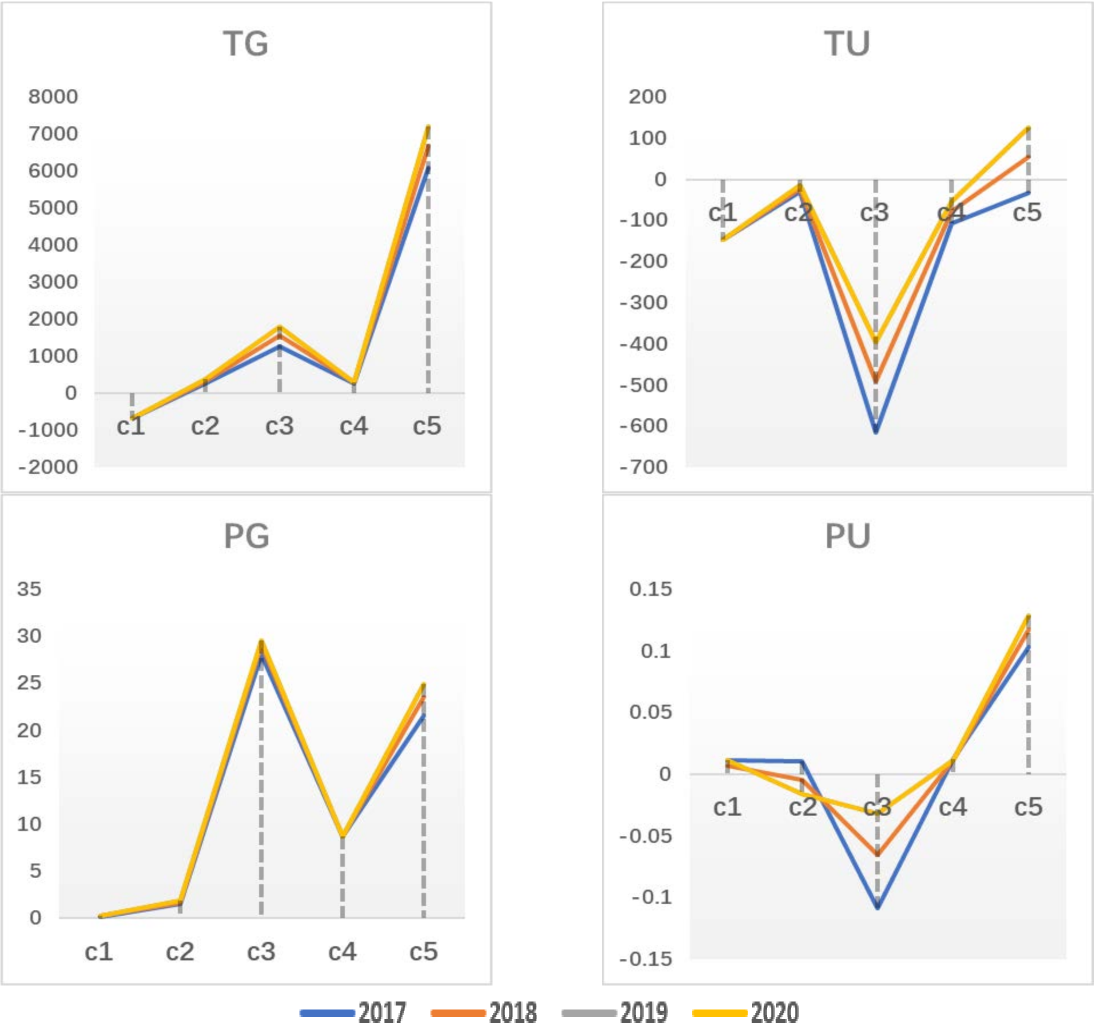


Fig 4.4 The effect of different scenarios on capital
(CN¥ 100 million)

4.3.4 Effect on Water Resource

Under the water control policy, I observe an increasing trend on the demand for surface water. In contrast, there is a small decrease in groundwater, which increases to CN¥ 596 million in 2020, as shown in Fig 4.5. The demand for surface water and groundwater increased at the same time that the policy changed the groundwater price. Importantly, the demand for surface water is more sensitive than that of groundwater in a different policy environment. As for the water resource demand, the decrease trend is attributable to an increase in the groundwater price.

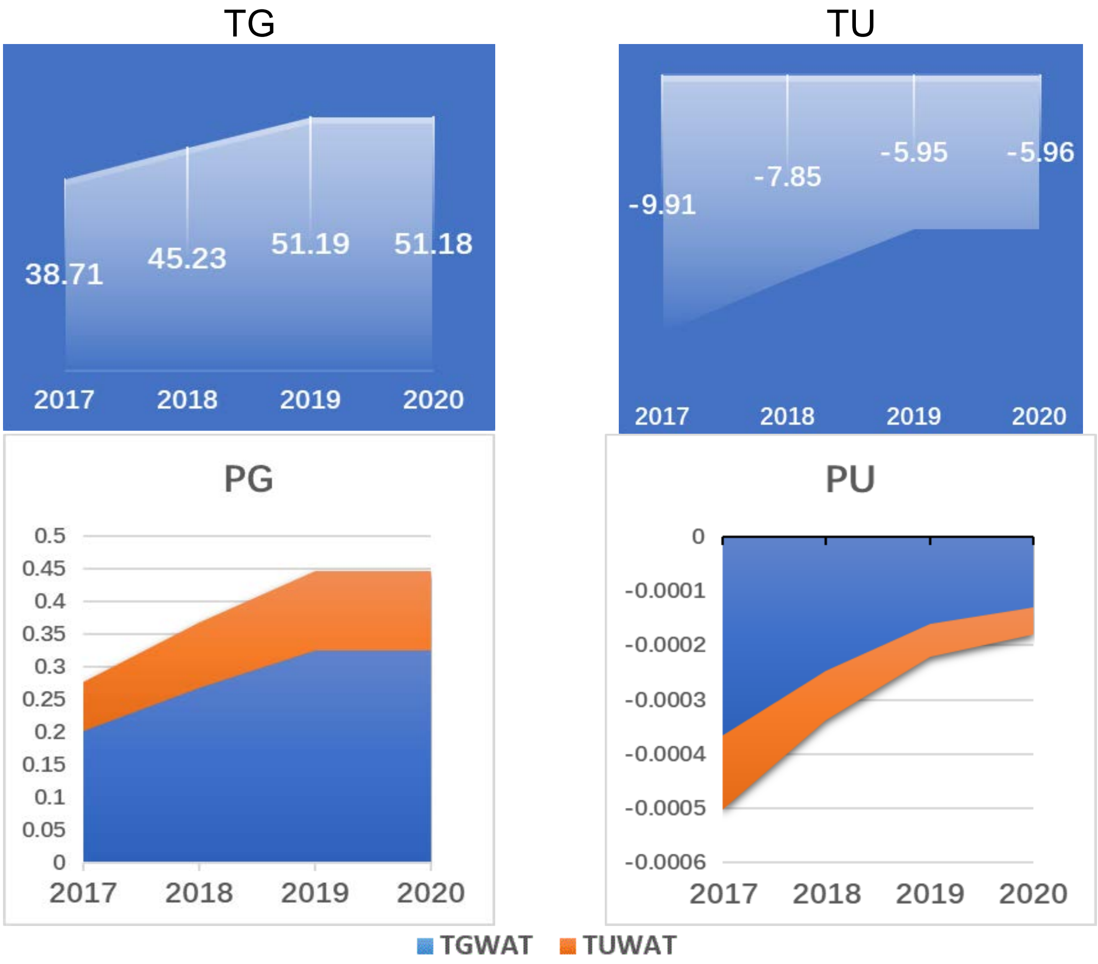


Fig 4.5 Water resource change under 4 scenarios

(CN¥ 100 million)

4.3.5 Sensitivity Analysis

A sensitivity analysis was conducted to investigate the effect of real long-interest rate (RLITR) on the DCGE model. The exact value of the RLITR was changed from 0.02 to 0.04. Table 4.5 shows that the surface water and groundwater use changed as the RLITR was adjusted. Evidently, 0.03 is the most suitable value for minimizing the bias in water demand. The bias increased from 2017 to 2020 when the RLITR was equal to 0.02 and 0.04, respectively.

Table 4.5 Comparison of different real long-interest rates (RLTIR)

	RLTIR = 0.02		RLTIR = 0.03		RLTIR = 0.04	
	Surface water	Groundwater	Surface water	Groundwater	Surface water	Groundwater
2017	5652.00014	2121.00005	5652	2121	5652.00082	2121.00031
2018	5652.00016	2121.00006	5652	2121	5652.00097	2121.00036
2019	5652.00018	2121.00007	5652	2121	5652.00101	2121.00038
2020	5652.00018	2121.00007	5652	2121	5652.00102	2121.00038

4.4 Conclusion

In this chapter, I developed a DCGE model by accounting for water resources in order to explore the effect of water policy on the economic system from 2017 to 2020 at a national level. The DCGE mode is already popular for regional- and prefectural-level analyses. Further, water policy for surface water and groundwater is designed to estimate the economic effect in China. Overall, our findings confirm that water resources should be included in national account under the SEEA framework. Water is an important and sensitive factor in commodity production. The findings show that controlling water use has a more negative effect than improving the price of water, especially for the agriculture industry. I, therefore, suggest that a sound water policy should focus on sectors that are highly dependent on water resources. This way, the price change policy on surface water and groundwater would reveal a large difference on sectors in the long term. Because the demand for water resources will increase with social development, the government should carefully consider its water control policy and the definite negative effect it would have on production.

CHAPTER 5

AGRICULTURE WATER POLICY ANALYSIS USING DCGE MODEL

5.1 Introduction

Agriculture productions are essential to all livelihoods, sustenance of the population and the economic system. They are the fundamental inputs for economic activities (He et al., 2022). China is the fourth largest country in the world, and the top producer of rice and wheat (Briggle et al., 1987). This feat is only possible through massive consumption of water for irrigation—Indeed, agriculture consumes over 60% of China's available freshwater resources every year. Yet, Northern China, which constitutes two-thirds of agriculture output, has access to only one-fifth of acquirable water because of uneven water distribution in the country. Thus, water management is a key issue in the northern regions (Zhong et al., 2015).

To deal with the burgeoning water crisis, the government established a national-level organization for integrated water management that balances environmental sustainability and economic growth (Dalin et al., 2015). For instance, the government standardized water use in

2012. In 2013, to boost agriculture and ease labor burdens, it decided not to charge a water resource fee if the water consumption did not exceed the limited quota (farmer do have to pay water resource fee for the surpassed water use). However, the decrease in cultivated land area and low efficiency of water use in the sector have led to a complex predicament (Zhan et al., 2015), despite the extensive research, exhaustive planning, and extensive measures toward efficient water resource accounting; this has directly affected China's national economic production (Fang et al., 2016).

The SEEA Central Framework, as noted earlier, can effectively track water stock and changes in the ecosystem with respect to the economy. To understand the economic effect of water policy, the SEEA Central Framework based on the SAM table is compiled to trace the water information in economic flow. For the estimation, I again use the PSUTs, MSUTs, and environmental assets in the SEEA to demonstrate the water resource consumption in terms of environment information (Yu et al., 2007). In the next step, I compile the SAM table to summarize water resource data. Then, a DCGE is built to simulate the socioeconomic effect of policies in the long term.

The remaining chapter is organized as follows. In section 5.2, I introduce the structure and content of the SEEA, a descriptive overview of the SAM-based DCGE model, and a description of the model's framework. Then, the results are demonstrated in section 5.3, followed by the conclusions in 5.4 section.

5.2 DCGE model based on SEEA

5.2.1 SAM table based on SEEA

The SAM is an across-the-aboard, economywide data framework capable of representing the overall economy of a nation. Typically, a SAM table is formulated by a square matrix in which the information for sectors, products, and other economic factors such as labor and capital are added to each row and column. Each cell describes the account payment from its column to its row. The SAM table can be compiled to demonstrate the water resource consumption in terms of environment information if we use the PSUTs, MSUTs, and environmental assets. The SEEA provides the measurement and principle for various types of water resources in the PSUTs (United Nations, 2012). Water accounts contain the supply and use tables that track the extraction of water—from the environment to consumptive use. Table 5.1 shows the PSUT[12].

Since 2019, a water use quota system has been active in each prefecture because of the condition of the environment and current water use. This system is a specific standard tool for evaluating water use and improving government water management, and 105 sectors (14 primary industries, 73 secondary industries, and 18 tertiary industries) are included in it. The demand of irrigation water use quota is assessed on agriculture. I use the average of irrigation water use quota for each prefecture for the national quota:

$$m_i = m_w/\eta. \tag{5.1}$$

where m_i is the fixed irrigation water use quota for products, m_w is the quantity of total water consumption, and η is the coefficient of irrigation water use. According to the formula, Table 5.2 shows the water consumption for agriculture products[13].

I can use the DCGE model to investigate the effect of water policy by first summarizing the water resource data and building the SAM table for the economic system. The SAM table is designed based on a multisector input–output relationship. The use–supply coefficient is extracted from the input–output table for production activities and the SAM is assembled based

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[12] System of environmental-economic accounting for water (United nations, 2012)

[13] China agricultural products cost-benefit compilation of information (2018)

on current prices in each year with five components—rice, wheat, potatoes, vegetables, and other. The total output for each product is drawn from the National Bureau of Statistics. Surface water, groundwater, and water resource fee are included in water resource sector. Table 5.3 shows the SAM structure system.

Table 5.1 Physical supply and use table of water resource

Use table		Industries	Household	Rest of World	Total
From the environment	1. Total abstraction (=1.a+1.b=1.i+1.ii)			■	
	1.a. Abstraction for own use			■	
	1.b. Abstraction for distribution			■	
	1.i. From inland water resource:			■	
	1.i.1. Surface water			■	
	1.i.2. Groundwater			■	
	1.i.3. Soil water			■	
	1.ii. Collection of precipitation			■	
	1.iii. Abstraction from the sea			■	
Within the economy	2. Use of water received from other economic units of which:				
	2.a. Reused water				
	2.b. Wastewater to sewerage				
	3. Total use of water (=1+2)				
Supply table		Industries	Household	Rest of World	Total
Within the economy	4. Supply of water to other economic units of which:				
	4.a. Reused water				
	4.b. Wastewater to sewerage				
From the environment	5. Total returns (=5.a+5.b)			■	
	5.a. From inland water resource:			■	
	5.a.1. Surface water			■	
	5.a.2. Groundwater			■	
	5.a.3. Soil water			■	
	5.b. To other source			■	
	6. Total supply of water (=4+5)				
	7. Consumption (=3-6)				

Table 5.2 Water use for each product in 2017

	Rice	Wheat	Potatoes	Vegetable
Sown area (1000 hec)	30747.20	24508	7173	19981
Water use quota ($m^3/1000\ hec$)	466.20	172.70	105.9	136.3
Water Consumption (100 million m^3)	35.42	10.46	2.63	1.07
Surface water (CN¥ million)	29.541	8.721	2.914	0.897
Groundwater (CN¥ million)	21.607	6.378	1.605	0.656
Water Resource fee (CN¥ million)	7.084	2.091	0.526	0.215

Note. hec: Hectare. Potatoes includes potato and sweet potato. Vegetable includes tomato, cucumber, eggplant, cabbage, Chinese cabbage and pepper. Vegetable water use quota is the average value of the tomato, cucumber, and Chinese cabbage water use quota.

Table 5.3 WSAM table for China in 2017

(CN¥ 100 million)

	pro	lab	cap	wr	hh	gov	nc	ns	row	total
pro	656062				552866	193404	191787	4033.41	123539	1721691
lab	299285									299285
cap	422268									422268
wr	8371.04				809.6					9180.64
hh		299285	422268							721553
gov	212166			9180.64						221347
nc					167878	27943				195821
ns							4033.41			4033.41
row	123539									123539
total	1721691	299285	422268	9180.64	721553	221347	195821	4033.41	123539	

Note. pro: production activities; lab: labor; cap: capital; wr: water resource; hh: households; gov: government; nc: new capital from part of investment; ns: new stock from part of investment; row: rest of the world.

5.2.2 DCGE model including agriculture products

The standard CGE model interprets all of the payments incorporated in the SAM table. In the framework, the CGE model is a combination system of simultaneous and nonlinear equations. The mathematical formula is assembled by square data, that is, the number of equations is equal to the number of variables. The equations contain a set of constraints that have to be satisfied by the system for the convergence of the solution. In the nonlinear economic system, the production and consumption decisions are captured by the maximization of profits and utility. In the model, capital is accumulated as the previous capital minus depreciation and the current total investment (Li et al., 2019; Feng et al., 2007; Zhang et al., 2020).

CGE model has been applied to explore the beneficial effects of different policies (Zhou et al., 2018). To solve complex optimization problems and determine the within-period decisions, a DCGE model that includes the time domain was developed based on the foundation of the static CGE model. In this study, the DCGE model is used to explore the effect of water policies on agriculture production and economic development in China from 2017 to 2020. In the structure of production function, water resource is considered a value-added factor. Depending on the supply and demand condition, the surface water formula is expressed below, the same as the groundwater and water resource fee (Su et al., 2018):

$$\left(\sum_j GWAT_{j,TH} * PGWAT_j\right) + HGWAT_j = TGWAT_{TH}. \tag{5.2}$$

Equation (5.2) represents the surface water use. $TGWAT_{TH}$ is the total water demand, $GWAT_{j,TH}$ is the water input of surface water, $PGWAT_j$ is the surface water price, and $HGWAT_j$ is the household surface water consumption. The domestic products $X_{j,TH}$ are represented by the total value of intermediate input $X_{j,TH}$, value added $V_{j,TH}$, tax, and import.

$V_{j,TH}$ and $V_{j,TH}$ are the tax input coefficient and import input coefficient, respectively. Depending on the supply and demand condition, the formula is expressed below:

$$X_{j,TH} = U_{j,TH} + V_{j,TH} + it_{j,TH} * X_{j,TH} + impi_{j,TH} * X_{j,TH}. \tag{5.3}$$

Different from the total output equation, intermediate input $U_{j,TH}$ and value-added $U_{j,TH}$ are represented by a Leontief function in equations (5.4) and (5.5). $gramma$ and $beta$ are the value share of intermediate input and value-added input, respectively. $PV_{j,TH}$ and $PU_{j,TH}$ are the corresponding unit prices.

$$U_{j,TH} = beta * PX_{TH} * X_{j,TH}/PU_{j,TH}. \tag{5.4}$$

$$V_{j,TH} = gramma * PX_{TH} * X_{j,TH}/PV_{j,TH}. \tag{5.5}$$

Labor $L_{j,TH}$ and value-added water $WK_{j,TH}$ are also represented by a Leontief function in equations (5.6) and (5.7). Further, $grammawk$ and $grammal$ are the value share. $PWK_{j,TH}$ is the price of value-added water and W_j is the price of labor.

$$WK_{j,TH} = grammawk * PV_{TH} * V_{j,TH}/PWK_{j,TH}. \tag{5.6}$$

$$L_{j,TH} = grammal * PV_{TH} * V_{j,TH}/W_j . \tag{5.7}$$

Equations (5.8) and (5.9) show the water resource inputs $WAT_{j,TH}$ and capital $K_{j,TH}$ in the Leontief function. Further, $grammawat$ and $grammak$ are the value share. $PWAT_j$ and $RPS_{j,TH}$ are the price of water and capital.

$$WAT_{j,TH} = grammawat * PWK_{TH} * WK_{j,TH}/PWAT_j. \tag{5.8}$$

$$K_{j,TH} = grammak * PWK_{TH} * WK_{j,TH}/RPS_{j,TH}. \tag{5.9}$$

The water resource fee is represented by the Cobb–Douglas function. $watground$ is the value share of surface water input and $PGWAT_j$ is the price of surface water.

$$GWAT_{j,TH} = watground_{j,Th} * PWAT_{TH} * WAT_{j,TH}/PGWAT_{TH}. \tag{5.10}$$

5.2.3 Simulation scenarios

Four scenarios are designed to estimate the effect of water policy on agriculture from 2017 to 2020. It is assumed that the quantity of import rice increased by 10% under the rice import water scenario (IMP). Rice is the most water-consuming agriculture product in China. The greater the proportion of imported rice, the less water needed for irrigation. The second scenario investigates the influence of augmenting investment (INV) by 10%. The Chinese government also stimulated private investment to promote economic development in 2017. Decreasing the household water consumption (HWD) by 10% is another target for sustainable development. Lastly, the government provides subsidies for water use and does not charge for the water resource fee on agriculture products if the water used for irrigation does not exceed its stipulated quota. Therefore, the water resource fee of rice, wheat, potatoes, and vegetables is assumed to be zero in the WRF scenario.

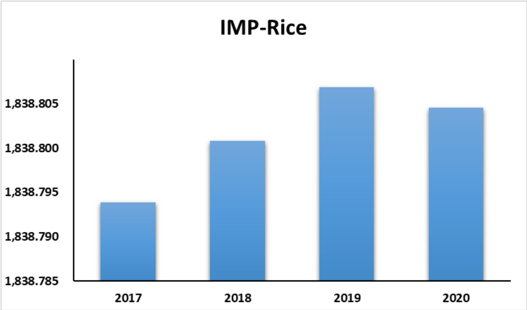
5.3 Results and Discussions

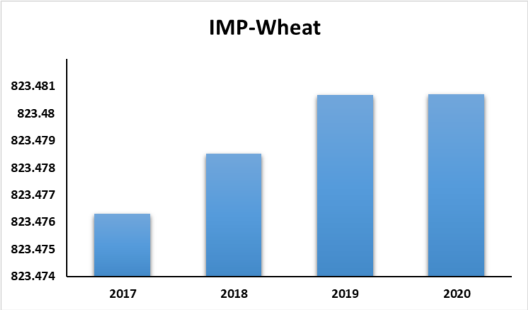
5.3.1 Effect on total output

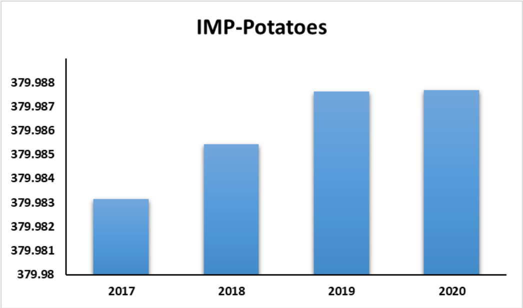
In general, the IMP and WRF scenarios reveal positive effects on all agriculture products, as shown in Fig 5.1. In the IMP scenario, the total output of rice increased from CN¥ 183,879.3 million to CN¥ 183,880.4 million; wheat went up from CN¥ 82,347.6 million to CN¥ 82,348.1 million; potatoes rose from CN¥ 37,998.3 million to CN¥ 37,998.8 million. Vegetables rose from CN¥ 460,503.1 million to CN¥ 460,507.4 million.

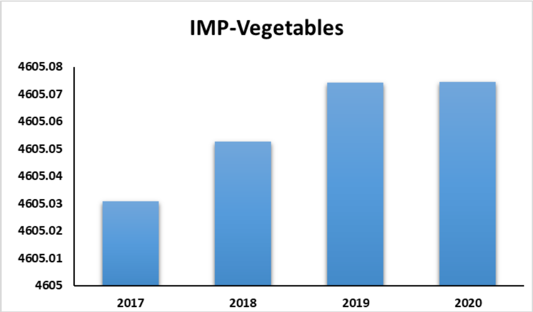
In a similar trend, all agriculture goods' output increased (rice: CN¥ 18,429.5 million; wheat: CN¥ 81,950.8 million; potatoes: CN¥ 382.498 million; vegetables: CN¥ 462,721.2 million) in 2020 in the INV scenario.

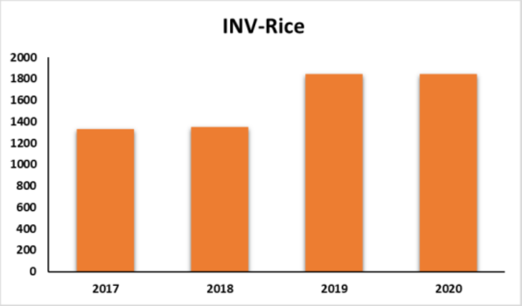
In the HWD scenarios, potato output declined to CN¥ 10 million during the simulation period. However, the output of rice and vegetable increased under same scenario. Compared with wheat and potatoes, rice and vegetables are water-consuming products with higher price. This could be why saving water at the household level has positive effect on rice and vegetables. Although the positive effect holds for the WRF scenario, the different is CN¥ 1.5 million (lower) in each year. According to the Food and Agriculture Organization of the United Nations, the total cereals production and import of crops and livestock products has gradually increased in over three decades. Economic development in China also follows this trend in these simulations.

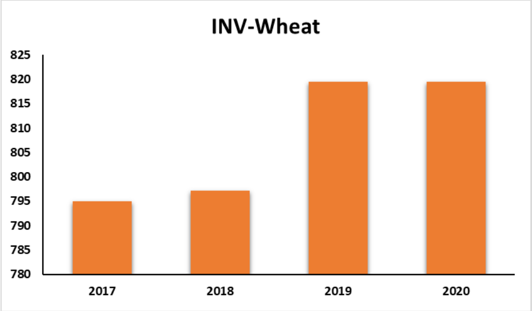


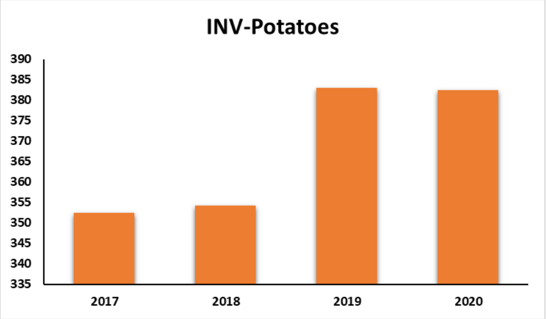


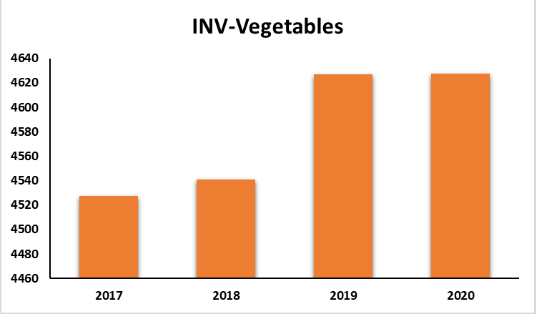


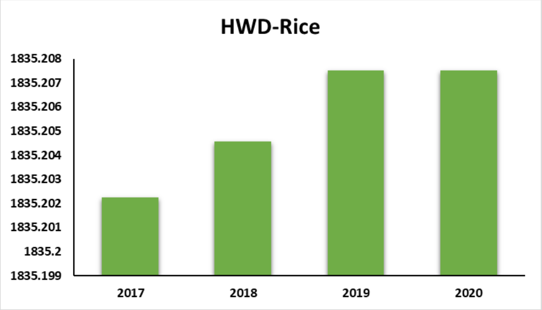


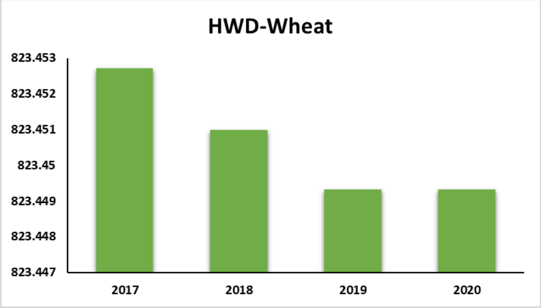

INV-Rice
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2017
2018
2019
2020

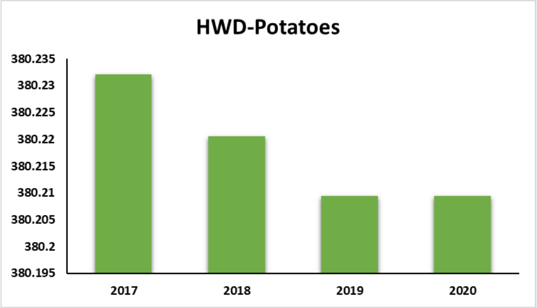

INV-Wheat
825
820
815
810
805
800
795
790
785
780
2017
2018
2019
2020

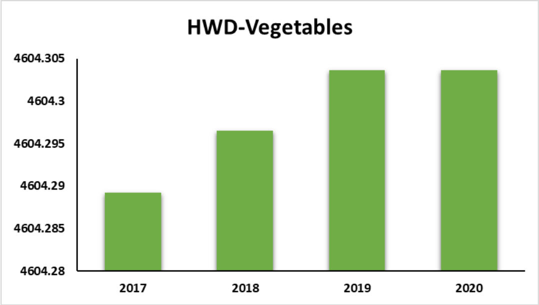

INV-Potatoes
390
385
380
375
370
365
360
355
350
345
340
335
2017
2018
2019
2020

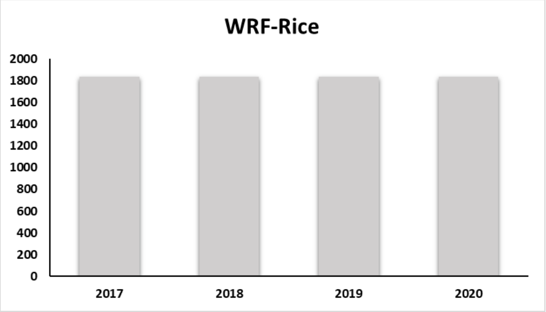

INV-Vegetables
4640
4620
4600
4580
4560
4540
4520
4500
4480
4460
2017
2018
2019
2020

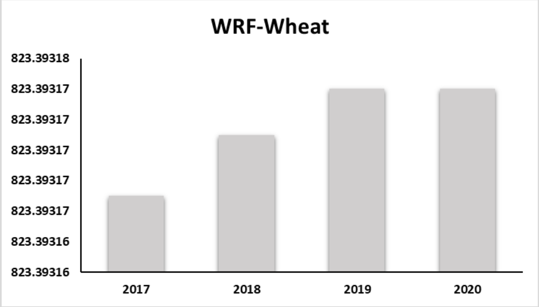

HWD-Rice
1835.208
1835.207
1835.206
1835.205
1835.204
1835.203
1835.202
1835.201
1835.2
1835.199
2017
2018
2019
2020


HWD-Wheat
823.453
823.452
823.451
823.45
823.449
823.448
823.447
2017
2018
2019
2020


HWD-Potatoes
380.235
380.23
380.225
380.22
380.215
380.21
380.205
380.2
380.195
2017
2018
2019
2020


HWD-Vegetables
4604.305
4604.3
4604.295
4604.29
4604.285
4604.28
2017
2018
2019
2020


WRF-Rice
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2017
2018
2019
2020


WRF-Wheat
823.39318
823.39317
823.39317
823.39317
823.39317
823.39317
823.39316
823.39316
2017
2018
2019
2020

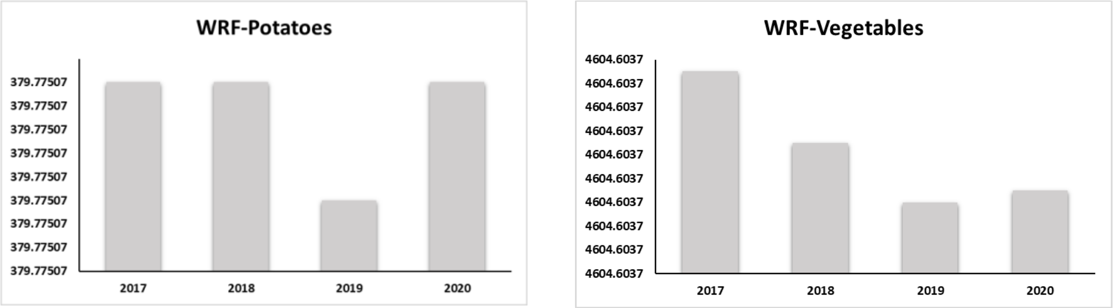


Fig 5.1 Effect of water policy on total output (CN¥ million)

5.3.2 Effect on household and government

Government income and household income follow the same trend under the IMP, HWD, and WRF scenarios, as shown in Fig 5.2. Under the IMP scenario, household income increased from CN¥ 72,169,846.6 million to CN¥ 72,170,245.4 million, while government income rose from CN¥ 22,139,348.4 million to CN¥ 22,139,470.8 million, indicating a positive effect.

On the contrary, after a declining trend in 2018, the income stabilized at CN¥ 72,155,238.9 million and CN¥ 22,134,661.5 million in 2019 and 2020 under the HWD scenarios. Similarly, both incomes declined in 2018, and then again in 2019, before rebounding at CN¥ 72,154,660.1 million and 22,134,751.3 million, respectively, in 2010 under the WRF scenario.

The trends in income change were different for the government and households under the INV scenario. Although higher investments could stimulate economic growth and increase household income in the long term, it is normal for the household income to fluctuate under a simulated shock. Interestingly, the household-level water control policy not only undermines total output, but also restrains the income of both the government and households.

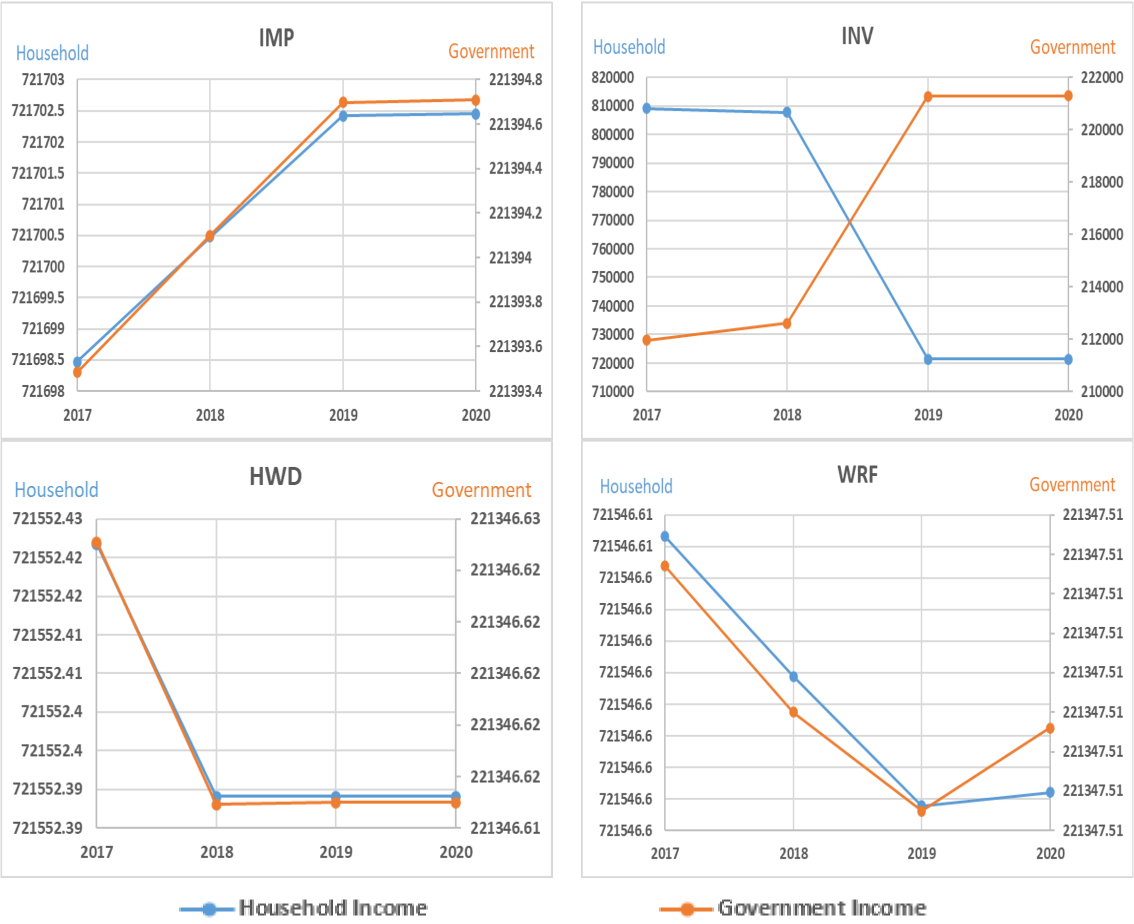
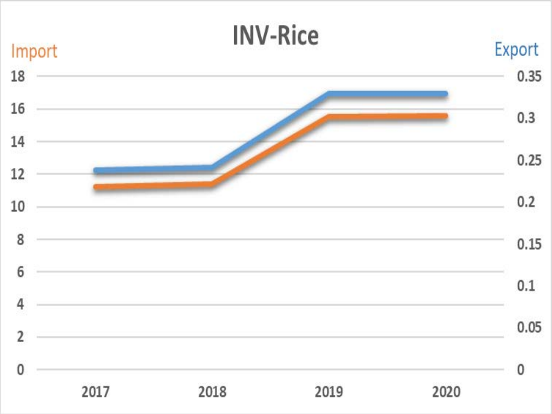


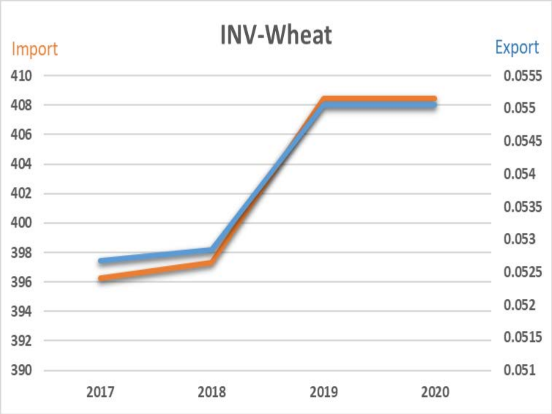
Fig 5.2 Effect of different scenarios on institutions
(CN¥ 100 million)

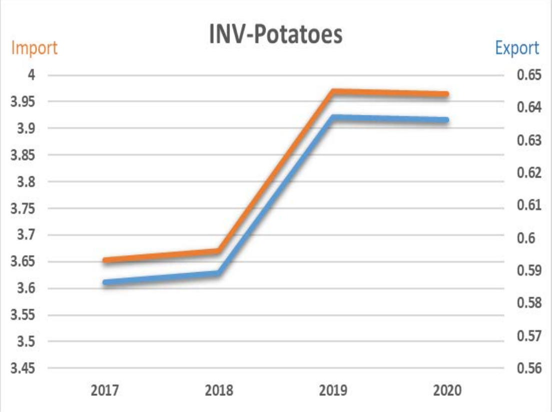
5.3.3 The effect on import and export

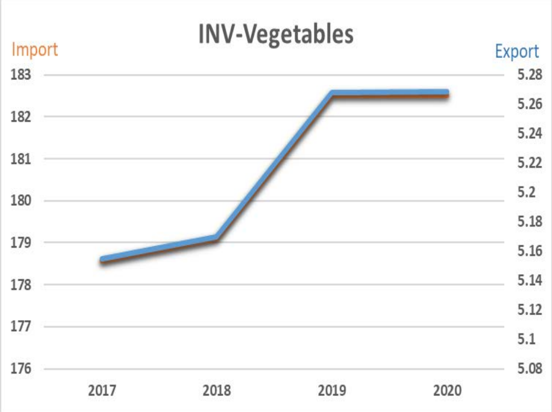
Under the IMP scenario, import of rice is assumed to have increased by 10% in 2017. In the result, the export of rice was maintained at the same level of CN¥ 32.8 million during the simulation period. Naturally, international trade of all agriculture products increased from 2017 to 2020, especially the import of wheat, which increased at CN¥ 41,045.2 million. Meanwhile, vegetables import went up to CN¥ 18,163.8 million and potatoes also rose to CN¥ 393.8 million. Then, under the INV scenario, the export and import climbed higher from 2017 to 2020, with imports leading (rice: CN¥ 1,125.5 to CN¥ 1,556.5 million; wheat: CN¥ 39,623.2 to CN¥ 40,845.7 million; potatoes: CN¥ 365.3 to CN¥ 396.4 million; vegetables: CN¥ 17,858.1

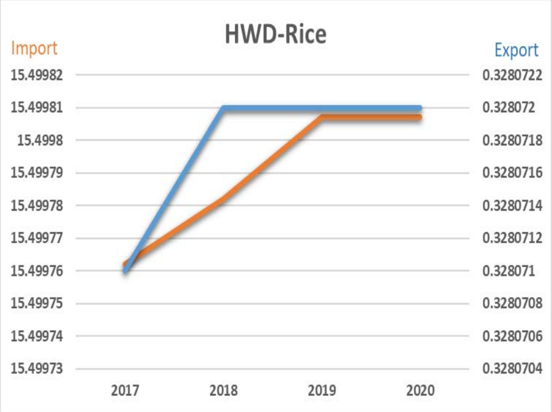
to CN¥ 18,251.2 million). Moreover, the international trade of rice and vegetables shrank, whereas that of wheat and potatoes expanded under the HWD scenario in the long term. A similar change in trend was seen for the total output of all products. The import and export have a weak positive effect under the WRF scenario. All in all, international trade could benefit under the IMP and WRF scenarios, indicating that both import and export increased for all agriculture products. However, the import of wheat reduced 3% under the INV scenario, which has more influence compared with the other scenarios. Fig 5.3 shows how China's international trade depends on import more than export with respect to agriculture goods. Notably, it is difficult to strike an import–export balance across all four scenarios.

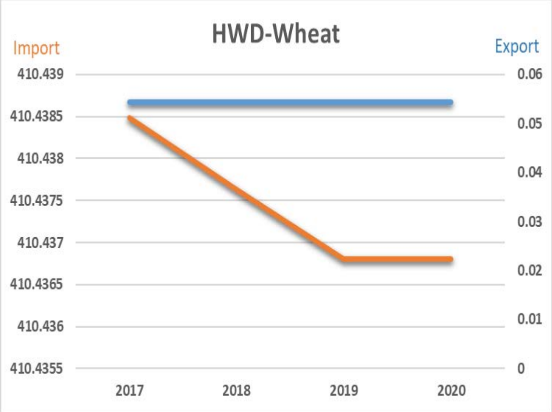

INV-Rice
Import
Export
18
16
14
12
10
8
6
4
2
0
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2017
2018
2019
2020

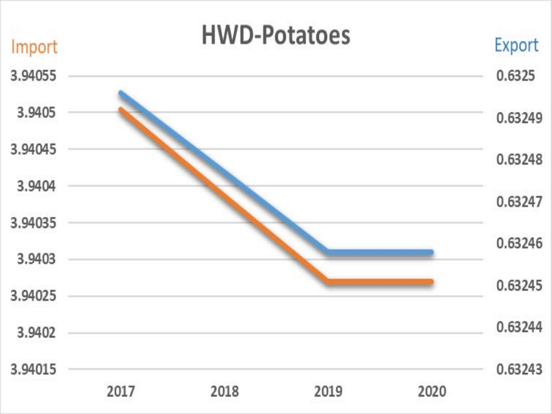

INV-Wheat
Import
Export
410
408
406
404
402
400
398
396
394
392
390
0.0555
0.055
0.0545
0.054
0.0535
0.053
0.0525
0.052
0.0515
0.051
2017
2018
2019
2020


INV-Potatoes
Import
Export
4
3.95
3.9
3.85
3.8
3.75
3.7
3.65
3.6
3.55
3.5
3.45
0.65
0.64
0.63
0.62
0.61
0.6
0.59
0.58
0.57
0.56
2017
2018
2019
2020


INV-Vegetables
Import
Export
183
182
181
180
179
178
177
176
5.28
5.26
5.24
5.22
5.2
5.18
5.16
5.14
5.12
5.1
5.08
2017
2018
2019
2020


HWD-Rice
Import
Export
15.49982
15.49981
15.4998
15.49979
15.49978
15.49977
15.49976
15.49975
15.49974
15.49973
0.3280722
0.328072
0.3280718
0.3280716
0.3280714
0.3280712
0.328071
0.3280708
0.3280706
0.3280704
2017
2018
2019
2020


HWD-Wheat
Import
Export
410.439
410.4385
410.438
410.4375
410.437
410.4365
410.436
410.4355
0.06
0.05
0.04
0.03
0.02
0.01
0
2017
2018
2019
2020


HWD-Potatoes
Import
Export
3.94055
3.9405
3.94045
3.9404
3.94035
3.9403
3.94025
3.9402
3.94015
0.6325
0.63249
0.63248
0.63247
0.63246
0.63245
0.63244
0.63243
2017
2018
2019
2020

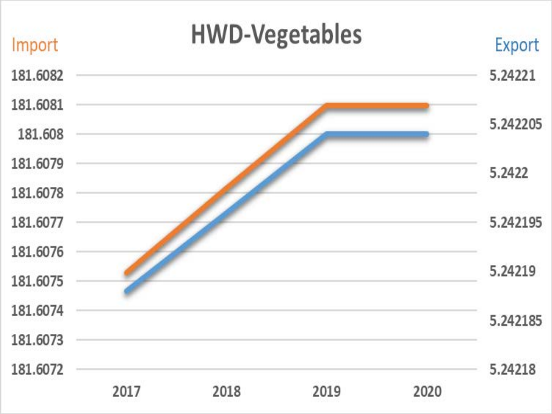

HWD-Vegetables
Import
Export
181.6082
181.6081
181.608
181.6079
181.6078
181.6077
181.6076
181.6075
181.6074
181.6073
181.6072
5.24221
5.242205
5.2422
5.242195
5.24219
5.242185
5.24218
2017
2018
2019
2020

Fig 5.3 Effect of different scenarios on import and export
(CN¥ 100 million)

5.3.4 Effect on water resources

Water use decreased in the INV and HWD scenarios, but increased in the IMP and WRF scenarios, as shown in Table 5.4. In the IMP scenario, surface water increased from CN¥ 565,282.0 million to CN¥ 565,285.2 million; groundwater increased from CN¥ 212,207.7 million to CN¥ 212,208.9 million; and water resource fee increased from CN¥ 140,767.6 million to CN¥ 140,768.4 million in 2020. On the contrary, limiting water consumption is evident in the INV scenarios (surface water: CN¥ 565,010.8 million; groundwater: CN¥ 212,105.6 million; water resource fee: CN¥ 140,700.1 million). The HWD scenario also could help save water resource, which decreased even lower compared with the INV scenario (surface water: CN¥ 565,162.4 million; groundwater: CN¥ 212,162.8 million; water resource fee: CN¥ 140,737.8 million). The demands of surface water went up to CN¥ 565,164.6 million in 2020 in the WRF scenario, whereas those of groundwater declined to CN¥ 212,163.6 million in the last simulation year. Overall, the INV scenario has the stronger effect on all sectors during the estimation period, indicating that changes in water use for agriculture production and economic development occur simultaneously.

Table 5.4 Effect of different scenarios on water resource
(CN¥ 100 million)

	IMP			INV		
	Surface water	Ground water	Water resource fee	Surface water	Ground water	Water resource fee
2017	5652.82036	2122.07686	1407.67642	5412.16840	2031.73577	1347.74880
2018	5652.83608	2122.08276	1407.68034	5428.62900	2037.91512	1351.84786
2019	5652.85134	2122.08849	1407.68414	5649.62131	2120.87593	1406.87979
2020	5652.85162	2122.08859	1407.684211	5650.10830	2121.0587	1407.00106
	HWD			WRF		
	Surface water	Ground water	Water resource fee	Surface water	Ground water	Water resource fee
2017	5651.62392	2121.62771	1407.37848	5651.64550	2121.6358	1407.38386
2018	5651.62366	2121.62762	1407.37842	5651.64550	2121.6358	1407.38386
2019	5651.62366	2121.62762	1407.37842	5651.64550	2121.6358	1407.38386
2020	5651.62366	2121.627621	1407.37842	5651.64550	2121.63582	1407.38386

5.3.5 Sensitive Analysis

A sensitivity analysis is conducted to investigate the influence of changing water price in the DCGE model on water use. In the simulation, the price of water is set to increase and decrease 10%, respectively. Table 5.5 shows the change in water inputs, including the surface water, groundwater, and water resource fee. The demand of water declined when water price increased by 10%, but water inputs increased when the water price decreased by 10% simultaneously.

Table 5.5 Comparison of different water prices

(CN¥ 100 million)

	Water price decreased by 10%			Water price increased by 10%		
	Surface water	Groundwater	Water resource fee	Surface water	Groundwater	Water resource fee
2017	5651.628	2121.629	1407.379	5651.629	2121.63	1407.38
2018	5651.764	2121.68	1407.413	5651.506	2121.584	1407.349
2019	5651.898	2121.731	1407.447	5651.385	2121.538	1407.319
2020	5651.898	2121.731	1407.447	5651.385	2121.538	1407.319

5.4 Conclusion

In this chapter, the DCGE model was applied to investigate the effect of current policy on agriculture production in China's economic system. Integrating water data and compiling the WSAM table under the SEEA framework provides general data to analyze the environmental economics policies through the CGE model. In the simulation, four policies were used to estimate the influence on agriculture. Although the policies of free charge of water resource and increasing imports were beneficial for agriculture production in the long term, increasing investments ultimately had more negative effects on rice and wheat production. Notably, China produces more agriculture products while also increasing it imports. Thus, the results suggest the government's water use quota should not be decreased below 10%.

CHAPTER 6

SUGGESTION AND CONTRIBUTION

6.1 Suggestion

In this article, water data were integrated and a WSAM table under the SEEA framework was compiled to analyze 12 environmental economics policies using the CGE and DCGE models at the national level. I believe the findings herein will be valuable for assessing the effect of current Chinese policy on the economic system and environment stock.

The study found a positive influence of importing rice in the observed period, with a growth of CN¥ 2,600 million, while an increase in investment only serves to reduce imports to CN¥ 52,478 million in 2017 and CN¥ 488,695 million in 2018. The other policies have weak negative effects on the import sector.

A similar export trend in change is observed for all scenarios. Capital goes up with higher rice imports, investment, and groundwater price in the long term, but declines to CN¥ 73,644 million in 2017 owing to household water use control.

For the total output, the decrease in production tax and surface water stimulates economic development, but weaken development with the other 10 policies. Surface water control is the most effective policy for increasing the household income (CN¥ 789,573 million) and government income (CN¥ 506,281 million). Household income changes run opposite to the government trends under the total water control policy, groundwater use control, and discharge water resource fee. Cutting off 10% of the production tax increases water demand for both surface water (CN¥ 94,958 million) and groundwater (CN¥ 275,297 million). The surface water control policy has a water-saving advantage in the long run. The water price change, however, has a marginal effect for water conservation because the demand for groundwater decreases (CN¥ 508 million) but for surface water increases (CN¥ 694 million) simultaneously in 2020. The effect of the production tax and surface water control policies encouraged more water conservation than increasing water consumption through other policies.

The results imply that China could accomplish its plan of water conservation. However, such select and narrow implementation of policy may not be successful in the long run at the scale necessary, especially when development needs still persist.

Overall, the total water controlling policy is the most beneficial in improving water use efficiency, especially among tertiary industries. The water policy could boost the service sector toward sustainable development as well. The model herein presents an opportunity to transform from an extensive pattern to an intensive one for some sectors. Moreover, the price change policy for surface water and groundwater differs markedly by sector in the long term, and the water resource demand will continue to increase as social development progresses.

I strongly recommend the inclusion of water resource as a valuable input in national accounting under the SEEA system. Policies have diverse, often opposing effects, across sectors in an economic system. A policy that is advantageous in one sector, may harm another. Thus, water policy should target individual sectors that are highly dependent on water resources. The government should especially be cautious in implementing policies that could hti the production industry. Most importantly, it must ensure that the water use quota is decrease by no more than 10%.

6.2 Contribution

The SAM table for China reflects the detailed water flow information at the national level based on the SEEA. The WSAM provides economic data based on the SNA by accounting for environmental resource also based on the SEEA. It is a general framework for indicators and captures the effect of policies on economic growth and national wealth. It dynamically treats environmental resource. The static and dynamic CGE model further unveils the economywide effects of projected water management reform and economic structural change on water use and allocation in China under the SEEA framework. Furthermore, the effect of water policy on agriculture products in China were estimated by the DCGE model.

APPENDIX

Export[14]

	WUC	WUE	PDX	WUI	TG				TU				PG				PU				
Agriculture	966.3317	967.3631	967.3833	967.3859	171506.8	171651.1	171745.9	171746.1	186140.2	186017.6	185938.7	185939.5	188227	188229.8	188232.2	188232.2	188263.9	188263.9	188263.9	188263.9	Agriculture industry
Hunting, Forestry and Fishing	229.2086	226.1479	226.065	226.1124	240727.1	241433.9	242078.2	242077.6	238245	238178.2	238150.6	238150.9	237482.2	237485.3	237488	237488	237513.7	237513.7	237513.8	237513.8	Light industry
Mining and Quarrying Food	486.872	487.328	487.5602	487.3662	1118095	1121572	1124716	1124714	1099254	1100004	1100621	1100620	1103333	1103345	1103356	1103356	1103220	1103220	1103220	1103220	Heavy industry
Food, Beverages and Tobacco	3585.413	3585.877	3592.077	3586.004	64140.09	64411.54	64650.52	64650.34	63552.39	63463.12	63415.22	63415.98	63462.58	63463.83	63464.92	63464.89	63517.99	63517.99	63518	63518	Power industry
Textiles, Textile Products and Leather and Footwear	18433.66	18433.83	18387.26	18433.77	837433.8	839972.7	842285	842282.8	817399.9	817254.8	817213.8	817214.4	814410.9	814422.2	814431.9	814431.9	814482.7	814482.8	814482.9	814482.8	Service
Pulp, Paper, Printing and Publishing	957.8927	957.9569	957.9252	957.9602																	
Petroleum, Chemicals and Chemical Products	13385.87	13386.02	13387.75	13386.04																	
Other Non-Metallic Minerals	2883.164	2882.763	2887.109	2882.754	IMP				INV				HWD				WRF				
Basic Metals and Fabricated Metal	10147.6	10148.04	10152.26	10148.06	0.328439	0.32844	0.328441	0.328424	0.238223	0.241007	0.329165	0.329454	0.328071	0.328072	0.328072	0.328072	0.328453	0.328453	0.328453	0.328453	rice
Machinery, Nec	82215.83	82225.36	82158.19	82227.35	0.054295	0.054296	0.054296	0.054296	0.052671	0.052836	0.055056	0.05506	0.054294	0.054294	0.054294	0.054294	0.054525	0.054525	0.054525	0.054525	wheat
Electricity, Gas and Water Supply	95.34088	95.32471	95.35523	95.32593	0.632082	0.632086	0.632089	0.632089	0.586322	0.58925	0.637151	0.63628	0.632496	0.632477	0.632458	0.632458	0.631812	0.631812	0.631812	0.631812	potatoes
Construction	825.2084	825.2467	826.8714	825.2573	5.243032	5.243057	5.243081	5.243081	5.154806	5.170068	5.26803	5.268285	5.242188	5.242196	5.242204	5.242204	5.243292	5.243292	5.243291	5.243292	vegetables
Service	29626.27	29625.51	29619.6	29625.34	123558.3	123558.7	123559	123559	118285.7	118645.5	123485.7	123496.4	123532.2	123532.1	123532.1	123532.1	123532.8	123532.8	123532.8	123532.8	other
					2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	

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[14] Collection of all simulation results of export

Import[15]

	WUC	WUE	PDX	WUI
Agriculture	4345.86	4344.895	4344.905	4344.874
Hunting, Forestry and Fishing	1668.72	1670.983	1669.965	1671.011
Mining and Quarrying Food	23291.49	23290.99	23301.39	23290.96
Food, Beverages and Tobacco	5857.215	5856.786	5866.804	5856.66
Textiles, Textile Products and Leather and Footwear	3080.369	3080.015	3072.317	3080.077
Pulp, Paper, Printing and Publishing	1333.13	1332.459	1332.405	1332.454
Petroleum, Chemicals and Chemical Products	18939.7	18941.45	18943.91	18941.46
Other Non-Metallic Minerals	1010.388	1010.157	1011.682	1010.147
Basic Metals and Fabricated Metal	8864.158	8863.138	8866.799	8863.096
Machinery, Nec	58035.06	58045.25	57997.81	58046.71
Electricity, Gas and Water Supply	21.44627	20.9529	20.94476	20.91324
Construction	584.0671	583.5106	584.6268	583.3849
Service	22228.27	22227.85	22223.49	22227.79

	TG				TU				PG				PU			
	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020
Agriculture industry	171506.8	171651.1	171745.9	171746.1	186140.2	186017.6	185938.7	185939.5	188227	188229.8	188232.2	188232.2	188263.9	188263.9	188263.9	188263.9
Light industry	240727.1	241433.9	242078.2	242077.6	238245	238178.2	238150.6	238150.9	237482.2	237485.3	237488	237488	237513.7	237513.7	237513.8	237513.8
Heavy industry	1118095	1121572	1124716	1124714	1099254	1100004	1100621	1100620	1103333	1103345	1103356	1103356	1103220	1103220	1103220	1103220
Power industry	64140.09	64411.54	64650.52	64650.34	63552.39	63463.12	63415.22	63415.98	63462.58	63463.83	63464.92	63464.89	63517.99	63517.99	63518	63518
Service	837433.8	839972.7	842285	842282.8	817399.9	817254.8	817213.8	817214.4	814410.9	814422.2	814431.9	814431.9	814482.7	814482.8	814482.9	814482.8

	IMP				INV				HWD				WRF			
	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020
rice	17.05095	17.05095	17.05095	17.05095	11.2552	11.38402	15.55159	15.56522	15.49976	15.49978	15.49981	15.49981	15.5013	15.5013	15.5013	15.5013
wheat	410.4503	410.4514	410.4524	410.4524	396.2319	397.3372	408.446	408.4569	410.4385	410.4376	410.4368	410.4368	410.409	410.409	410.409	410.409
potatoes	3.937925	3.937949	3.937971	3.937972	3.652853	3.671065	3.969405	3.963973	3.940504	3.940386	3.94027	3.94027	3.935849	3.935849	3.935849	3.935849
vegetables	181.6368	181.6376	181.6385	181.6385	178.5807	179.1088	182.5028	182.5117	181.6075	181.6078	181.6081	181.6081	181.6207	181.6207	181.6207	181.6207
other	122953	122953.3	122953.7	122953.7	117706.2	118064.2	122880.8	122891.4	122927	122926.9	122926.9	122926.9	122927.7	122927.7	122927.7	122927.7

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[15] Collection of all simulation results of import

Capital[16]

	WUC	WUE	PDX	WUI	TG				TU				PG				PU				
Agriculture	2570	2570	2570	2570	7955	7955	7955	7955	7955	7955	7955	7955	7955	7955	7955	7955	7955	7955	7955	7955	Agriculture
	.02	.04	.05	.07	.135	.229	.293	.293					.135	.229	.293	.293	.011	.007	.011	.011	industry
Hunting, Forestry and Fishing	1265	1265	1264	1265	1903	1903	1903	1903	1903	1903	1903	1903	1903	1903	1903	1903	1903	1903	1903	1903	Light
	.644	.533	.793	.578	9.47	9.69	9.84	9.84	8	8	8	8	9.47	9.69	9.84	9.84	8.01	8	7.98	7.98	industry
Mining and Quarrying Food	9259	9259	9263	9259	8966	8966	8966	8966	8963	8963	8963	8963	8966	8966	8966	8966	8963	8963	8963	8963	Heavy
	.097	.074	.211	.074	7.09	8.14	8.51	8.51	9	9	9	9	7.09	8.14	8.51	8.51	8.89	8.93	8.97	8.97	industry
Food, Beverages and Tobacco	1111	1111	1113	1111	1065	1065	1065	1065	1064	1064	1064	1064	1065	1065	1065	1065	1064	1064	1064	1064	Power
	6.75	6.75	5.85	6.76	5.71	5.75	5.75	5.75	7	7	7	7	5.71	5.75	5.75	5.75	7.01	7.01	7.01	7.01	industry
Textiles, Textile Products and	5211	5211	5198	5211	1720	1720	1720	1720	1720	1720	1720	1720	1720	1720	1720	1720	1720	1720	1720	1720	Service
Leather and Footwear	.245	.246	.101	.246	28.5	30.5	31.9	31.9	07	07	07	07	28.5	30.5	31.9	31.9	07.1	07.1	07.1	07.1	
Pulp, Paper, Printing and	2709	2709	2709	2709																	
Publishing	.799	.804	.707	.804																	
Petroleum, Chemicals and	1772	1772	1772	1772																	
Chemical Products	4.46	4.46	6.76	4.46																	
Other Non-Metallic Minerals	9360	9360	9374	9360	IMP				INV				HWD				WRF				
	.78	.755	.895	.755																	
Basic Metals and Fabricated	1642	1642	1643	1642	1838	1838	1838	1838	1332	1347	1841	1842	1835	1835	1835	1835	1835	1835	1835	1835	rice
Metal	2.62	3.29	0.12	3.31	.794	.801	.807	.805	.639	.896	.339	.953	.202	.205	.208	.208	.34	.34	.34	.34	
Machinery, Nec	3317	3318	3315	3318	823.	823.	823.	823.	794.	797.	819.	819.	823.	823.	823.	823.	823.	823.	823.	823.	wheat
	7.15	1.22	4.11	2.02	4763	4785	4807	4807	9581	176	4858	5077	4527	451	4493	4493	3932	3932	3932	3932	
Electricity, Gas and Water	1064	1064	1065	1064	379.	379.	379.	379.	352.	354.	383.	382.	380.	380.	380.	380.	379.	379.	379.	379.	potatoes
Supply	8.31	7.13	0.49	7.2	9831	9854	9876	9877	4756	2332	0217	4976	232	2206	2095	2095	7751	7751	7751	7751	
Construction	1294	1294	1297	1294	4605	4605	4605	4605	4527	4540	4626	4627	4604	4604	4604	4604	4604	4604	4604	4604	vegetables
	9.08	9.07	4.6	9.16	.031	.053	.074	.074	.551	.938	.987	.212	.289	.296	.304	.304	.604	.604	.604	.604	
Service	1720	1720	1719	1720	1714	1714	1714	1714	1641	1646	1713	1713	1714	1714	1714	1714	1714	1714	1714	1714	other
	10.2	06.7	72.4	05.7	410	415	419	419	250	243	403	551	046	046	046	046	053	053	053	053	
					2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	

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[16] Collection of all simulation results of capital

Total output[17]

	WUC	WUE	PDX	WUI	TG				TU				PG				PU				
Agriculture	6300	6300	6300	6300	1715	1716	1717	1717	1861	1860	1859	1859	1882	1882	1882	1882	1882	1882	1882	1882	Agriculture
	6.55	6.7	7.04	6.7	06.8	51.1	45.9	46.1	40.2	17.6	38.7	39.5	27	29.8	32.2	32.2	63.9	63.9	63.9	63.9	industry
Hunting, Forestry and Fishing	4777	4778	4775	4778	2407	2414	2420	2420	2382	2381	2381	2381	2374	2374	2374	2374	2375	2375	2375	2375	Light
	9.92	0.03	2.06	0.04	27.1	33.9	78.2	77.6	45	78.2	50.6	50.9	82.2	85.3	88	88	13.7	13.7	13.8	13.8	industry
Mining and Quarrying Food	7747	7747	7751	7747	1118	1121	1124	1124	1099	1100	1100	1100	1103	1103	1103	1103	1103	1103	1103	1103	Heavy
	7.64	7.28	1.9	7.28	095	572	716	714	254	004	621	620	333	345	356	356	220	220	220	220	industry
Food, Beverages and Tobacco	1320	1320	1322	1320	6414	6441	6465	6465	6355	6346	6341	6341	6346	6346	6346	6346	6351	6351	6351	6351	Power
	64.4	64.3	91.2	64.4	0.09	1.54	0.52	0.34	2.39	3.12	5.22	5.98	2.58	3.83	4.92	4.89	7.99	7.99	8	8	industry
Textiles, Textile Products and	7882	7882	7862	7882	8374	8399	8422	8422	8173	8172	8172	8172	8144	8144	8144	8144	8144	8144	8144	8144	Service
Leather and Footwear	3.86	3.98	5.15	3.98	33.8	72.7	85	82.8	99.9	54.8	13.8	14.4	10.9	22.2	31.9	31.9	82.7	82.8	82.9	82.8	
Pulp, Paper, Printing and	2662	2662	2662	2662																	
Publishing	5.02	5.05	4.1	5.05																	
Petroleum, Chemicals and	2055	2055	2056	2055																	
Chemical Products	93.9	94	20.7	94																	
Other Non-Metallic Minerals	6595	6595	6605	6595	IMP				INV				HWD				WRF				
	6.13	5.91	5.54	5.9																	
Basic Metals and Fabricated	1563	1563	1564	1563	1838	1838	1838	1838	1332	1347	1841	1842	1835	1835	1835	1835	1835	1835	1835	1835	rice
Metal	37.7	44.3	09.3	44.5	.794	.801	.807	.805	.639	.896	.339	.953	.202	.205	.208	.208	.34	.34	.34	.34	
Machinery, Nec	4459	4459	4455	4459	823.	823.	823.	823.	794.	797.	819.	819.	823.	823.	823.	823.	823.	823.	823.	823.	wheat
	05.1	56.9	92.6	67.7	4763	4785	4807	4807	9581	176	4858	5077	4527	451	4493	4493	3932	3932	3932	3932	
Electricity, Gas and Water	6352	6351	6353	6351	379.	379.	379.	379.	352.	354.	383.	382.	380.	380.	380.	380.	379.	379.	379.	379.	potatoes
Supply	6.61	9.54	9.56	9.98	9831	9854	9876	9877	4756	2332	0217	4976	232	2206	2095	2095	7751	7751	7751	7751	
Construction	2293	2293	2298	2293	4605	4605	4605	4605	4527	4540	4626	4627	4604	4604	4604	4604	4604	4604	4604	4604	vegetables
	68.2	69.3	21.6	71.3	.031	.053	.074	.074	.551	.938	.987	.212	.289	.296	.304	.304	.604	.604	.604	.604	
Service	8145	8144	8143	8144	1714	1714	1714	1714	1641	1646	1713	1713	1714	1714	1714	1714	1714	1714	1714	1714	other
	00.6	84.5	22	79.7	410	415	419	419	250	243	403	551	046	046	046	046	053	053	053	053	
					2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	

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[17] Collection of all simulation results of total output

Water resource[18]

	WUC	WUE	PDX	WUI				
Surface water	5608.105675	5651.456102	6601.586827	5654.425235				
Groundwater	2156.88271	2122.067162	4873.972568	2114.726389				
	TG	TU	PG		PU			
2017	2159.707983	5642.088652	5652.200748	2121.075334	5652.200748	2121.07533		
2018	2166.23452	5644.150072	5652.267057	2121.100217	5652.267057	2121.10022		
2019	2172.187614	5646.046752	5652.324554	2121.121794	5652.324554	2121.12179		
2020	2172.183963	5646.042397	5652.324711	2121.121853	5652.324711	2121.12185		
	Groundwater	Surface water	Surface water	Groundwater	Surface water	Groundwater		
	IMP		INV		HWD		WRF	
2017	5652.820362	2122.076864	5412.168407	2031.735775	5651.623921	2121.62772	5651.645505	2121.63582
2018	5652.836087	2122.082767	5428.629041	2037.91512	5651.623661	2121.62762	5651.645504	2121.63582
2019	5652.851346	2122.088495	5649.621318	2120.875938	5651.623663	2121.62762	5651.645504	2121.63582
2020	5652.851623	2122.088599	5650.108309	2121.058755	5651.623663	2121.62762	5651.645504	2121.63582
	Surface water	Groundwater	Surface water	Groundwater	Surface water	Groundwater	Surface water	Groundwater

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[18] Collection of all simulation results of water resource

Household income and government income[19]

	WUC	WUE	PDX	WUI
Household income	209810.22	209795.166	214419.038	209807.392
Government income	559037	559235.884	566237.803	559276.2946

	TG		TU		PG		PU	
2017	564210.14	213622.441	556776.708	209395.366	559328.51	209802.451	559237.09	209794.986
2018	565782.27	214268.801	557167.581	209471.9686	559334.28	209804.913	559237.07	209794.991
2019	567223.48	214858.161	557477.475	209542.437	559339.28	209807.047	559237.06	209794.994
2020	567222.73	214857.817	557476.308	209542.2632	559339.34	209807.053	559237.06	209794.995
	Household income	Government income	Household income	Government income	Household income	Government income	Household income	Government income

	IMP		INV		HWD		WRF	
2017	721698.47	221393.484	809108.992	211968.3151	721552.42	221346.625	721546.61	221347.513
2018	721700.47	221394.1	807810.951	212613.0075	721552.39	221346.615	721546.6	221347.513
2019	721702.42	221394.697	721370.747	221268.1953	721552.39	221346.615	721546.6	221347.513
2020	721702.45	221394.708	721435.577	221287.2684	721552.39	221346.615	721546.6	221347.513
	Household income	Government income	Household income	Government income	Household income	Government income	Household income	Government income

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[19] Collection of all simulation results of household income and government income

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