Water **2015**, *7*, 3431-3465; doi:10.3390/w7073431

OPEN ACCESS

water

ISSN 2073-4441
www.mdpi.com/journal/water

Article

Assessing the Water Parallel Pricing System against Drought in China: A Study Based on a CGE Model with Multi-Provincial Irrigation Water

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Academic Editor: Markus Disse

Received: 12 January 2015 / Accepted: 10 June 2015 / Published: 30 June 2015

Abstract: The reform of water management in China is still in progress, and the pricing of water resources is undertaken in parallel, with a divide between irrigation water and pipe water associated with different users: The supply of irrigation water is regulated by local government and that of pipe water is operated by the production sector of pipe water. Based on a literature review and an interview survey of farmers, this study incorporated the water parallel pricing system of China within a computable general equilibrium (CGE) model, where the drought of 2000 is simulated. The 16 provincial irrigation water supplies and their subsidies were also estimated and introduced into this CGE model. The results demonstrated that the effects on the macro-economy were insignificant. However, the effects on agricultural production, particularly on farming production mainly cultivated in northern areas, were significant. Most farming production sectors employed more capital and labor to prevent losses in output from drought. Agricultural labor was shifted from non-farming agricultural production sectors into farming. Both urban and rural households suffered severe losses in welfare and food consumption, even though they benefited from the additional income. Moreover, rural households suffering the worst losses were located in both northern and southern areas.

Keywords: water parallel pricing system; multi-provincial irrigation water; CGE model; drought; China

1. Introduction

Irrigation is an essential factor allowing China to be able to support the largest population in the world with only 6% of the world's renewable water resources and 9% of the world's arable land, guaranteeing agricultural production, food security and also economic and social stability [1]. However, it is projected that the 1 °C rise in air temperature expected by 2020 will increase in the need for irrigation water by 6%–10% in East Asia [2]. Indeed, this problem is already emerging in Northern China generally where temperatures have become higher [3] and more droughts have occurred than in the past [4]. Moreover, the share of agricultural water declined from 97% to 65%, while the share of industrial water increased from 2% to 22% during the period of 1949–2004 [5] and to 24% in 2011 [6]. Accordingly, drought will make irrigation more expensive [7]. Water availability will play a significant limiting role in future agricultural production and economic growth. The combined effects between higher crop water requirements (due to climate change) and increasing demand for non-agricultural water use (due to socio-economic development) should be paid more attention [8].

Water pricing plays as a key role in coordinating water use and economic growth. However, water prices in China are determined by top-down administrative commands rather than by the market. Moreover, the system of water resources management is notoriously fragmented and involves a series of government agencies from both vertical and horizontal levels [9]. To promote industrialization, the Ministry of Water Resources (MWR) prioritizes water allocation to urban-industrial uses over irrigation, which has resulted in serious competition for water between agriculture and industry [10]. After introducing the pricing method based on the marginal opportunity costs [11], water tariffs imposed by the government almost cover at least the operation and maintenance costs of most water supply utilities, even in several rural communities [12]. However, from the water parallel pricing system, it can be observed that the charges of irrigation water are related to the irrigated area instead of the volume of water that the progressive volumetric pricing has introduced in urban areas [13,14]. As a result, the main divide of water resources in China is between irrigation water, which is used in the agricultural production sectors, and pipe water, which is consumed by the urban-industrial sectors.

Based on a literature review and an interview survey of farmers in Jilin and Liaoning provinces, China, attempts have focused on incorporating the water parallel pricing system within a computable general equilibrium (CGE) model. This paper is organized around the following three objectives.

The first objective is to discuss the water parallel pricing system based on an interview survey, and to calculate irrigation water and its subsidy at the multi-provincial level, which are used to construct a social accounting matrix (SAM). The second objective is to introduce the water parallel pricing into CGE model, where the irrigation water and its subsidy from different provinces are employed to production function. The third objective is to simulate the drought of 2000, which was the most widespread in years, under the water parallel pricing system, and the effect of this drought on agricultural production and rural households are measured.

2. Background to the Drought of 2000 and the Water Parallel Pricing System

2.1. The Drought of 2000

The drought of 2000 was the most serious in nearly 15 years and the total drought affected rate in the cultivated areas reached 17.14%. The water employed in agriculture in 2000 (only 378.35 billion m^3) was less than that utilized in the preceding (386.92 billion m^3 in 1999) and subsequent years (382.57 billion m^3 in 2001) [15]. The detailed affected levels are presented in Figure 1, where provinces with the drought affected rates greater than 50% were Jilin, Liaoning and Qinghai, followed by Shanxi, Inner Mongolia and Ningxia and finally, Gansu, Shaanxi, Anhui and Heilongjiang.

Figure 1. Drought-affected level ineach province of year 2000. Data source: China Rural Statistics Yearbook 2001 [15]. Note: "Affected" defines those cultivated areas where yields are reduced by more than 30% [16].

2.2. The Water Parallel Pricing System and Water Price Distortion

2.2.1. The Water Parallel Pricing System Observed from an Interview Survey

We conducted an interview survey of some farmers in Jilin and Liaoning provinces, where the drought usually becomes more serious than in other provinces. Those famers described the current management system of water resources as presented in Figures 2 and 3.

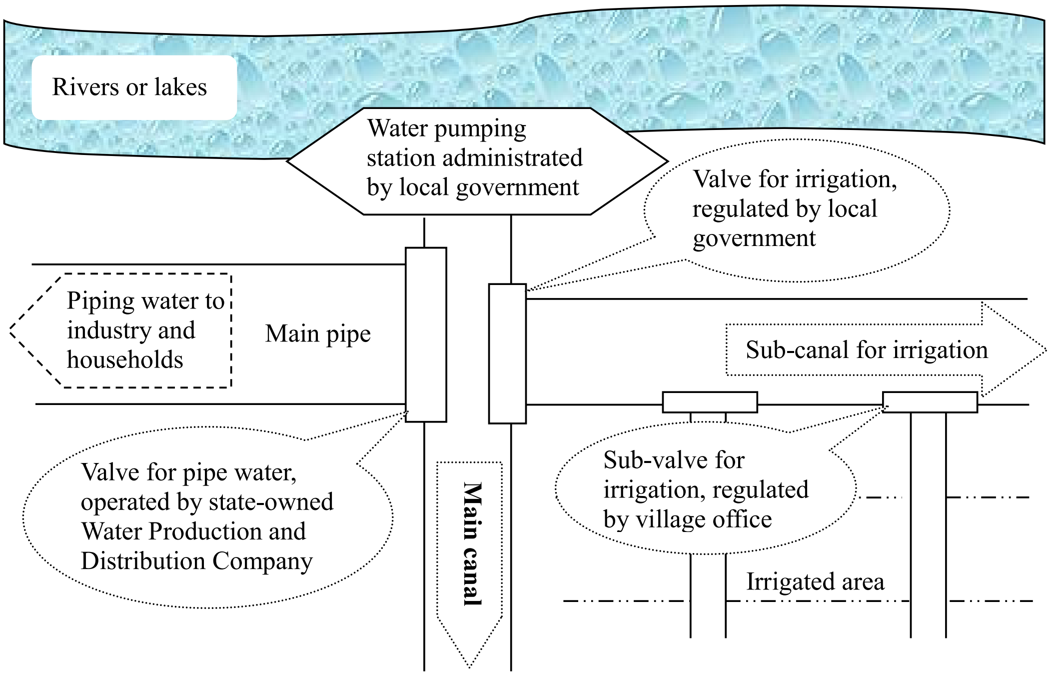


Figure 2. Surface water distributions between irrigation water and pipe water.

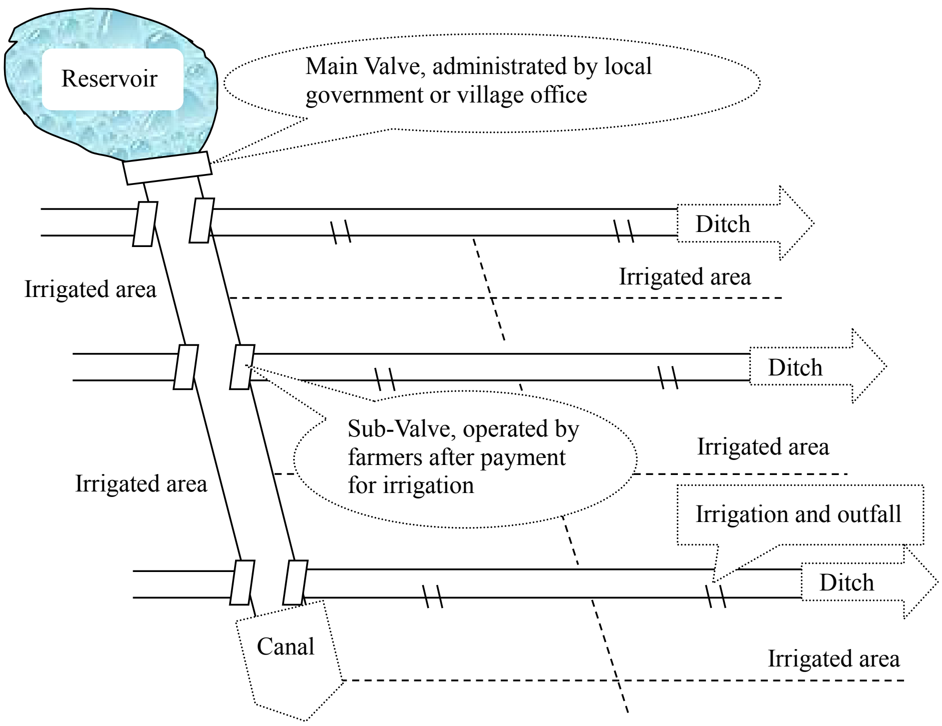


Figure 3. Reservoir irrigation systems at village level.

Figure 2 presents a simplified depiction of the structure of the water distribution between pipe water and irrigation water. There is a water pumping station near rivers or lakes constructed by the government. This pumping station transports water from rivers or lakes to the main canal, where water is distributed as pipe water by a main pipe and as irrigation water by a sub-canal. The main pipe is operated by the state-owned water production and distribution company, and the sub-canal is regulated by several village offices. The pipe water users, which mainly include the industrial and service sectors as well as households, must pay the price to the water company according to the amount of water they used. In contrast, farmers must pay the irrigation cost to the village office according to the size of their irrigated areas. As a result, pipe water and irrigation water are formulated by volumetric and non-volumetric pricing (or called area pricing), respectively, which has generated the water parallel pricing system.

In rural areas, water authorities directly collect payment from farmers who utilize the water for irrigation. Figure 3 presents the basic structure of the reservoir irrigation system at the village level. This reservoir, especially for those with large-scale irrigated areas, is basically funded by the local government. Thus, the local government imposes an irrigation cost to obtain a return on initial investment and to maintain the daily operation of the irrigation system. Specifically, the local government manages the main valve of the reservoir. Farmers must pay the irrigation cost for operating the sub-valve when they need water for irrigation. The irrigation cost is formulated according to the size of the irrigated area (Yuan per mu) and is changed in relation to the weather and cultivated crops. Indeed, this irrigation cost only reflects the variable cost of the total irrigation cost. In contrast, the fixed cost of the infrastructure is supported by the government, acting as a subsidy for farmers to lower costs.

2.2.2. Water Price Distortion and Equilibrium Irrigation Water Inputs

In this study, we selected 15 provinces and also an "other provinces" entity as the main crop-producing areas in China. The irrigation cost of ten crops cultivated in those provinces was collected from the official database, the National Agricultural Production Cost and Revenue Information Summary 2008 [17]. Accordingly, we estimated the irrigation water input costs employing the Equation (1).

$$Irrigation\ water\ input\ cost\left(yuan\right)_{ij} = Irrigation\ cost\left(\frac{yuan}{mu}\right)_{ij} \times Cultivated\ area\left(mu\right)_{ij} \tag{1}$$

where i = crops; j = provinces, same as in Equations (2)–(4).

To present the price distortion between irrigation water and pipe water, the volumetric pricing method (water use (Yuan) divided by water withdrawal (m^3)) was employed to derive the average prices of irrigation water and pipe water. However, China's official database does not contain detailed information for irrigation water use and withdrawal; Rather, it provides data for agricultural water, which indicates the water consumed by all agricultural sectors, including farming, forestry, animal husbandry, fishery and the agriculture services. Furthermore, according to the Input-Output Tables of China 2007 [18] and the China Regional Input-Output Tables 2007 [19], where the production sector of pipe water is represented by the water production and distribution sector, pipe water is also consumed by the agricultural sectors, although this consumption is not very high. In fact, the use of pipe water for irrigation is limited to those rural areas very near to urban areas. The main portion of irrigation water still comes from the local irrigation system. Moreover, the water withdrawal data are given by the China Statistical Yearbook on the Environment 2008 [20] (see Table 1).

Table 1. Water volumetric pricing and provincial water price distortions in 2007.

Provincial Level	Water Uses (100 Million Yuan)		Water Withdrawals (100 million m^3) ***		Water Prices (Yuan/m^3) ****		Subsidy Rates ****
	Agricultural *	Industrial, Service and Households **	Agricultural	Industrial and Residential	Agricultural (= Irrigation Water Price)	Industrial, Service and Households (= Pipe Water Price)	
National level	166.73	1199.87	3599.51	2219.16	0.05	0.54	−0.91
Guangdong	7.13	255.24	224.84	237.67	0.03	1.07	−0.97
Jiangxi	4.73	48.79	151.35	83.52	0.03	0.58	−0.95
Hainan	1.95	5.56	35.84	10.85	0.05	0.51	−0.89
Yunnan	6.61	12.72	105.95	44.08	0.06	0.29	−0.78
Guangxi	5.89	27.31	208.39	102.01	0.03	0.27	−0.89
Henan	18.20	26.03	120.07	89.21	0.15	0.29	−0.48
Jilin	4.72	38.41	67.53	33.25	0.07	1.16	−0.94
Anhui	6.68	68.21	120.56	111.49	0.06	0.61	−0.91
Heilongjiang	15.22	54.86	214.75	76.62	0.07	0.72	−0.90
Hebei	15.66	33.78	151.59	50.91	0.10	0.66	−0.84
Hubei	6.20	70.38	132.65	126.09	0.05	0.56	−0.92
Chongqing	2.42	21.53	18.75	58.67	0.13	0.37	−0.65
Sichuan	11.62	42.19	118.71	95.27	0.10	0.44	−0.78
Inner Mongolia	11.34	19.52	141.77	38.27	0.08	0.51	−0.84
Shandong	10.40	105.38	159.71	59.83	0.07	1.76	−0.96
Other provinces	37.95	369.97	1627.03	1001.43	0.02	0.37	−0.93

Notes: Source: * The estimated irrigation water input costs plus the pipe water inputs; ** Input-Output Tables of China 2007 [18] and China Regional Input-Output Tables 2007 [19]; *** China Statistic Yearbook on Environment 2008 [20]; **** Estimated by authors.

By relying on these data, we estimated the agricultural water price and the pipe water price, assuming that the agricultural water price is equal to the irrigation water price. In detail, the agricultural water use was defined to be equal to the sum of sectoral irrigation water input costs plus the pipe water used in agricultural water sectors. It was also assumed that different sectors in the same provinces share the same agricultural water price and pipe water price. As presented in Table 1, the two water prices were significantly different across provinces.

The differences between the irrigation water price (represented by the agricultural water price) and pipe water price can be regarded as the subsidy on irrigation water. Accordingly, the equilibrium irrigation water input costs and their subsidies were estimated according to Equations (2) and (3), and the results are exhibited in Tables 2 and 3:

$$\text{Equilibrium irrigation water input costs}\left(yuan\right)_{ij} = \text{Irrigation water input costs}\left(yuan\right)_{ij} \times \frac{\text{Pipe water price }\left(yuan/m^3\right)_j}{\text{Irrigation water price}\left(yuan/m^3\right)_j} \quad (2)$$

$$\text{Subsidy for irrigation water}\left(yuan\right)_{ij} = \text{Irrigation water input costs}\left(yuan\right)_{ij} - \text{Equilibrium irrigation water input costs}\left(yuan\right)_{ij} \quad (3)$$

It should be noted that the sectoral equilibrium irrigation water input costs of "other provinces" are equal to the differences between the national level and the sum of the given 15 provinces.

The subsidy rates recorded in the last column of Table 1 was derived using Equation (4):

$$\text{Subsidy rate for irrigation water}_{ij} = \frac{\text{Subsidy for irrigation water}\left(yuan\right)_{ij}}{\text{Equilibrium irrigation water input costs}\left(yuan\right)_{ij}} \quad (4)$$

Table 2. Equilibrium irrigation water input costs at the provincial and sectoral levels.

Unit: 10 thousand Yuan	Paddy	Wheat	Corn	Vegetables	Fruits	Oil Seeds	Sugarcane	Potato	Sorghum	Other Crops	Total
National level	5,523,673	1,979,392	2,705,227	5,227,817	521,447	514,332	84,459	376,607	72,921	1,220,047	18,225,922
Guangdong	333,811	244	35,676	1,089,802	30,373	86,123	58,651	43,323	85	57,686	1,735,773
Jiangxi	670,855	1511	2299	86,829	25,978	12,353	715	10,137	377	44,426	855,479
Hainan	30,361	0	1317	139,560	5118	656	188	3044	0	2820	183,064
Yunnan	83,997	6572	14,851	152,402	2056	2423	6793	10,465	151	25,972	305,681
Guangxi	212,919	267	36,867	231,290	12,332	8881	7769	7890	298	20,365	538,879
Henan	23,692	176,274	6099	103,139	12,597	15,306	20	2172	80	10,909	350,288
Jilin	357,383	643	140,650	169,510	20,434	15,781	0	6626	14,001	39,651	764,680
Anhui	333,409	56,341	3882	173,428	38,600	29,198	211	7304	139	59,715	702,226
Heilongjiang	923,240	35,320	60,049	296,147	21,532	7010	0	8766	6176	150,424	1,508,664
Hebei	25,019	9298	28,133	877,554	13,480	12,579	0	6664	1951	28,951	1,003,628
Hubei	240,074	17,472	41,331	33,334	22,735	31,578	152	10,544	436	44,795	442,452
Chongqing	30,822	4090	10,220	5161	1194	2152	29	7782	315	7040	68,804
Sichuan	233,749	64,057	116,539	40,314	4592	17,707	524	20,133	2040	25,879	525,535
Inner Mongolia	7743	24,544	405,269	125,405	6041	13,347	0	15,993	8606	57,285	664,234
Shandong	34,559	343,945	310,213	1,390,362	140,928	7481	0	25,249	2351	110,911	2,365,998
Other provinces	1,982,039	1,238,813	1,491,833	313,580	163,458	251,758	9406	190,515	35,914	533,221	6,210,537

Note: Sources: Estimated by authors.

Table 3. Subsidy for irrigation water at the provincial and sectoral levels.

Unit: 10 Thousand Yuan	Paddy	Wheat	Corn	Vegetables	Fruits	Oil Seeds	Sugarcane	Potato	Sorghum	Other Crops	Total
National level	−5,046,075	−1,808,246	−2,471,323	−4,775,801	−476,361	−469,861	−77,156	−344,044	−66,616	−1,114,557	−16,650,041
Guangdong	−323,951	−237	−34,622	−1,057,612	−29,475	−83,579	−56,919	−42,043	−83	−55,982	−1,684,504
Jiangxi	−634,967	−1430	−2176	−82,184	−24,589	−11,692	−676	−9595	−357	−42,049	−809,715
Hainan	−27,142	0	−1177	−124,762	−4575	−587	−168	−2721	0	−2521	−163,653
Yunnan	−65,832	−5151	−11,639	−119,444	−1611	−1899	−5324	−8201	−119	−20,355	−239,574
Guangxi	−190,446	−238	−32,975	−206,877	−11,030	−7944	−6949	−7057	−267	−18,216	−482,000
Henan	−11,384	−84,702	−2931	−49,560	−6053	−7355	−10	−1044	−38	−5242	−168,319
Jilin	−335,738	−604	−132,132	−159,244	−19,196	−14,826	0	−6225	−13,153	−37,249	−718,368
Anhui	−303,209	−51,237	−3531	−157,718	−35,103	−26,553	−192	−6642	−127	−54,306	−638,618
Heilongjiang	−831,884	−31,825	−54,107	−266,843	−19,402	−6316	0	−7899	−5565	−135,539	−1,359,379
Hebei	−21,124	−7850	−23,753	−740,936	−11,382	−10,621	0	−5627	−1647	−24,444	−847,383
Hubei	−219,965	−16,009	−37,869	−30,542	−20,831	−28,933	−139	−9660	−400	−41,043	−405,391
Chongqing	−19,964	−2649	−6620	−3343	−773	−1394	−19	−5041	−204	−4560	−44,566
Sichuan	−182,070	−49,895	−90,774	−31,401	−3577	−13,792	−408	−15,682	−1589	−20,157	−409,346
Inner Mongolia	−6529	−20,696	−341,724	−105,742	−5094	−11,254	0	−13,485	−7257	−48,303	−560,084
Shandong	−33,281	−331,224	−298,739	−1,338,936	−135,715	−7204	0	−24,315	−2264	−106,808	−2,278,487
Other provinces	−1,838,589	−1,204,498	−1,396,554	−300,656	−147,955	−235,914	−6351	−178,806	−33,548	−497,783	−5,840,655

Note: Sources: Estimated by authors.

3. A CGE Model with the Water Parallel Pricing System

3.1. Previous CGE Model Focusing on China's Water Resources

The CGE Model as a good economic method for policy evaluation has been applied in many areas of water resource management and water pricing in China. The key question for employing the CGE model in these areas is how to make a connection between water resources and the whole social-economic system [21]. The CGE models for water issues (water-CGE model) are generally developed from the classical CGE models, such as ORANI [22], GTAP [23,24] and TERM [25,26]. There are quite a few water-CGE models in the literature. For example, Diao and Roe (2003) [27] developed an inter-temporal CGE model for Morocco focusing on water and trade policies. Gómez, Tirado and Rey-Maquieira (2004) [28] analyzed the welfare gains by improved allocation of water rights for the Balearic Islands. Horridge, Madden and Wittwer (2005) [29] modeled the 2002–2003 Australian drought by employing the TERM and developed an estimation formula that computed the productivity loss for each agricultural industry in each region. Calzadilla, Rehdanz, and Tol (2008) [23] considered the impact of increasing irrigation efficiency on global economic system based on the new version of GTAP-W. Watson and Davies (2011) [30] examined the effects of medium-run, exogenously projected population and economic growth on the water demand in the economically large and diverse region of the South Platte River Basin in Colorado, Wittwer and Dixon (2012) [26] made an analysis of the economic benefits of infrastructure upgrades or the economic costs of water buybacks based on TERM-H2O CGE modeling.

For water-CGE modeling studies in China, water resources are regarded as a constraint on production in estimating the marginal price of water by simulating the change in water supply [31], or acts as the factor defined in the production function to evaluate the effects of water scarcity [32]. Great potential in agricultural water saving was demonstrated in a case study of Jiangxi Province which defined water production and supply as a sector and water resources as factors with consideration of the subsidy of productive water [33]. Water saving could be achieved by controlling the export of farming products [34] or by raising water prices [35]. Chou, Hsu, Huang *et al.* (2001) [22] constructed a WATERGEM model based on ORANI, where municipal water, surface water and ground water were involved; Berrittella, Rehdanz and Tol (2006) [36] defined a "non-market solution" and "market solution" by contrasting three alternative groups to estimate the impacts of the South-North Water Transfer Project on the economy of China and the rest of the world. Feng *et al.* (2007) [37] used a recursive dynamic CGE model to assess the economic implications of the same project. Yu and Shen (2014) [38] summarized the water-CGE studies and indicated that there are four types of formulating the water in CGE model: (1) Water as a constrain condition in production and/or consumption (e.g., [31]); (2) Water as a factor (e.g., [32]); (3) Water as an intermediate input (e.g., [33]); and (4) Water as a factor and as an intermediate input according to different users (integrated formulation, e.g., [30]).

The reform of China's water management is still in progress, and the pricing system is inadequate to the representation of the commodity attributes of water [38]. The price distortion between agricultural water and non-agricultural water is usually neglected in previous water-CGE models of China. Moreover, little attention has been paid to China's fragmented water management system, which is the main reason for the parallel pricing and separated supply for irrigation and pipe water. Previous CGE modeling studies involved China's pricing system for water resources are rarely found in the literature.

3.2. Data and Modeling Framework

The water parallel pricing system is defined in both the dataset and model. This dataset essentially has the form of the 2007 Social Accounting Matrix (SAM) for China, which was contributed by Ge and Tokunaga (2011) [39]. We introduced the 16 province's equilibrium irrigation water inputs (from Table 2) and their subsidies (from Table 3) and also the production sector of pipe water into the SAM to construct the SAM with the irrigation waterfrom 16 provinces (SAM-16P, see S1 in Supplementary Material File; for a simplified diagram, see Table 4).

This model also refers to some agricultural CGE models to address the connection between agriculture and water, stated by Zhong, Okiyama and Tokunaga (2014) [40], Akune, Okiyama and Tokunaga (2011) [41], Okiyama and Tokunaga (2010) [42] and Tokunaga *et al.* (2003) [43]. The detailed mathematical functions of this static CGE model with irrigation water from16 provinces (SCGE-16P) are presented in Appendix.

The production module consists of 34 sectors, which were divided into two categories: (i) Agricultural sectors including farming and non-farming, allocated across agricultural labor, croplands and irrigation water from 16 provinces; (ii) Other sectors including industrial, construction and services, where pipe water are the inputs. It should be noted that non-farming agricultural sectors only employ agricultural labor but not croplands and irrigation water; and other non-agricultural sectors only employ non-agricultural labor and capital. The nested constant elasticity of substitution (CES) production structure is applied to all production sectors. Most of parameters in the SCGE-16P as in the standard CGE model were derived from calibration, with the exception of substitution elasticity (σ) [44].

Table 4. Simplified social accounting matrix (SAM)-16P. Note: AGR = Agricultural sectors as activities/commodities, including paddy, wheat, corn, vegetable, fruit, oil seed, sugarcane, potato, sorghum and other crops and also animal husbandry, forestry, fishery and agriculture services; OTH = Other sectors as activities/commodities; WAP = Pipe water production sector as one of activities/commodities; 16WAR = 16 Provinces' irrigation water as factor inputs; 16LAND = 16 Provinces' croplands as factor inputs; 16AGRLB = 16 Provinces' agricultural labor as factor inputs; NAGRLB = Non-agricultural labor as a factor input; CAP = Capital as a factor input; 16HHDRUAL = 16 provinces' rural households; HHDURBN = Urban households; GOV = Government; ENT = Enterprise; S-I = Savings and Investment; DTAX = Direct tax; INDTAX = Indirect tax; 16SUBWAR = 16 Provinces' subsidy for irrigation water; TAR = Tariff; ROW = Rest of the world.

Unit: 0.1 billion yuan		**Activities and Commodities**			**Factors**					**Institutions**				**Others**						**Total**
		AGR	OTH	WAP	16WAR	16LAND	16AGRLB	NAGRLB	CAP	16HHDRUAL	HHDURBN	GOV	ENT	S-I	DTAX	INDTAX	16SUBWAR	TAR	ROW	
Activities and Commodities	AGR	6877	27,514	0						6013	6301	342		3581					666	51,294
	OTH	13,348	503,647	590						19,106	65,968	34,849		109,503					94,875	841,886
	WAP	9	837	41						52	270			−30						1179
Factors	16WAR	1823																		1823
	16LAND	157																		157
	16AGRLB	26,564																		26,564
	NAGRLB	618	82621	244																83,484
	CAP	1115	115,819	229																117,163
Institutions	16HHDRUAL					157	26,564	5036	6651			793	8105						905	48,211
	HHDURBN							78,448	2328			5602	20,512						2008	108,898
	GOV				1823									5700	11,965	38,519	−1665	1433	-12	57,761
	ENT								106,560											106,560
Others	S-I									22,013	34,199	16,053	69,163						−22,675	118,754
	DTAX									1027	2158		8779							11,965
	INDTAX	48	38,396	75																38,519
	16SUBWAR	−1665																		−1665
	TAR	73	1360	0																1433
	ROW	2328	71693	0					1623			122								75,766
Total		51,294	841,886	1179	1823	157	26,564	83,484	117,163	48,211	108,898	57,761	106,560	118,754	11,965	38,519	-1665	1433	75,766	

Previous CGE models have provided a useful reference work for this study. Based on the CGE model with the croplands of 16 provinces [39,45], we incorporated irrigation water and pipe water by modeling the water parallel pricing system by means of integrated formulation where irrigation water acts as one of the factor inputs in the farming sectors and pipe water is consumed by all production sectors as an intermediate input and by households through their demand functions. Compared to previous CGE models, this model incorporates irrigation subsidy to indicate the price distortion between irrigation water and pipe water; irrigation water input and its subsidy are disaggregated into 16 groups for each of the 16 provinces. This gives the pipe water consumption of rural households. Thus, the water parallel pricing system is introduced into this model, in which irrigation water price is given at the level for which farmers are willing to pay and the subsidy is included. The supply of irrigation water is regulated by local government. Pipe water price is equal to the marginal cost of production, and pipe water supply is operated by its production sector. Therefore, the water parallel pricing system is represented by the parallel pricing processes of irrigation water and pipe water.

In China's CGE modeling studies, the Cobb-Douglas function has been widely applied to represent the substitution between labor and capital in agricultural production (e.g., [31,32]); while in other production, the CES function is employed and its elasticity of this substitution has been estimated (e.g., [46–48]). For the substitution between labor and capital (σ_{F}), agricultural sectors have the Cobb-Douglas function, while non-agricultural sectors have the CES function with the elasticity given by Zhao and Wang (2008) [46]. The substitution between non-agricultural labor and agricultural labor (σ_{LB}), as well as that among regional agricultural labor (σ_{RLB}), are referred to Ge, Lei and Tokunaga (2014) [45]. Furthermore, farming sectors employ the combinations of cropland and irrigation water (the land-water bundles) from 16 provinces following the Cobb-Douglas assumption [45], and the irrigation subsidy is included in irrigation water price (see Figure 4). We set $\sigma_{RLW} = 0.2$ to denote that water pricing not a valid means of significantly reducing agricultural water consumption under water parallel pricing system [49,50]. Pipe water is combined with value-added input within the production function of non-farming agricultural sectors and other sectors, which faithfully reflects the characteristics of water-use efficiency in China. Water-use efficiency is highly relevant to value-added input, especially in industry, and therefore "water-use per unit of industrial value added" is used to represent water-use efficiency [6] (see Figure 5). We set $\sigma_{VAW} = 0.5$ to represent a more direct influence of water pricing policy on the industrial production [13]. The pipe water input in the farming sectors along with the irrigation water of "Other provinces" becomes the composite water demand of "Other provinces". The reason for this setting is that those rural areas using pipe water for irrigation are very close to urban areas and thus were classified within "Other provinces". We set $\sigma_{WARP} = 30$ to assume that there is no difference between pipe water and irrigation water for farming production.

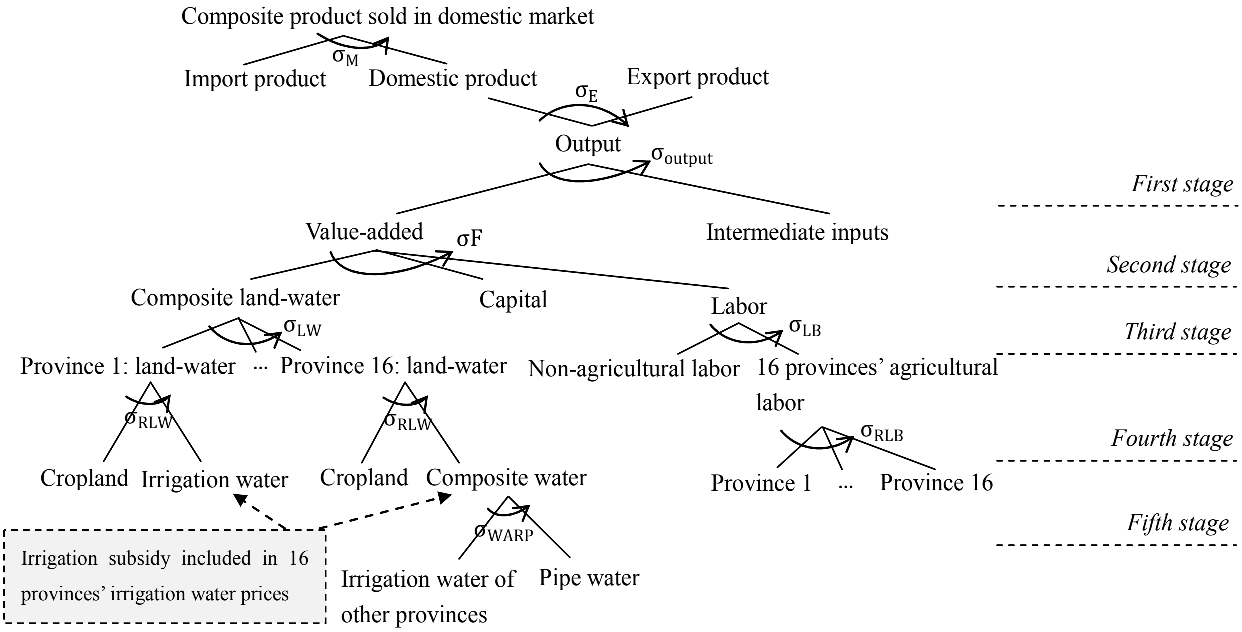
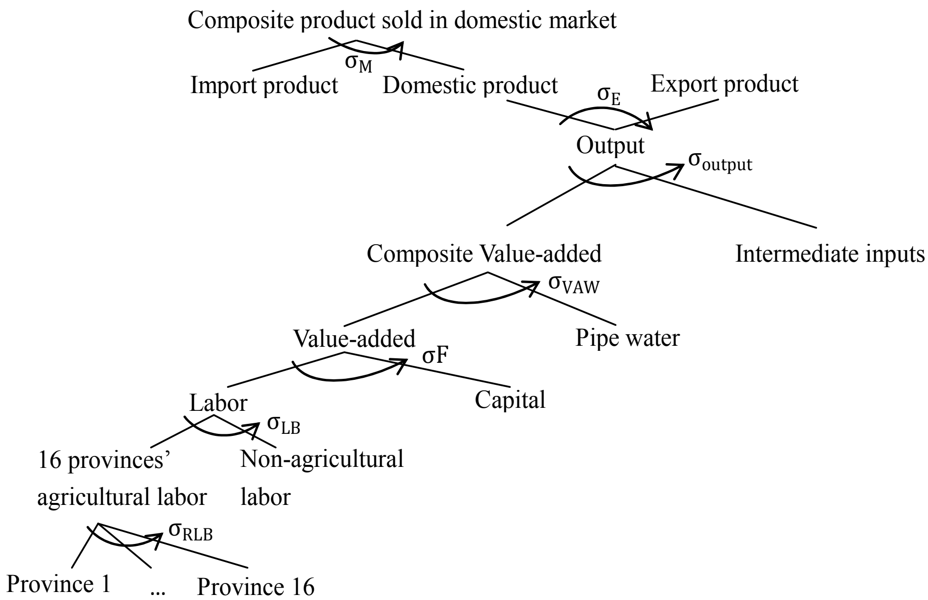
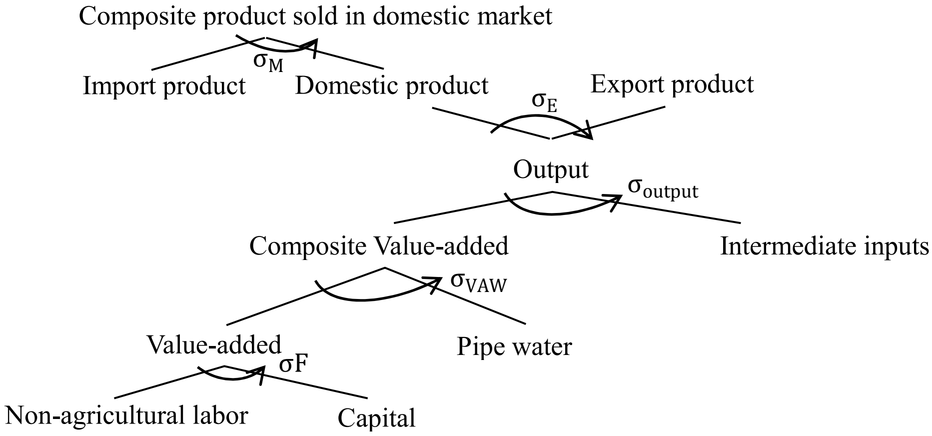


Figure 4. Nested constant elasticity of substitution (CES) production structure of farming sectors. Notes: Province 1 = Guangdong; Province 2 = Jiangxi; Province 3 = Hainan; Province 4 = Yunnan; Province 5 = Guangxi; Province 6 = Henan; Province 7 = Jilin; Province 8 = Anhui; Province 9 = Heilongjiang; Province 10 = Hebei; Province 11 = Hubei; Province 12 = Chongqing; Province 13 = Sichuan; Province 14 = Inner Mongolia; Province 15 = Shandong; Province 16 = Other Provinces.



(**A**)

Figure 5. *Cont.*



(**B**)

Figure 5. Nested CES production structure of non-farming sectors. Note: Non-farming sectors including non-farming agricultural sectors (**A**) and Other sectors (**B**).

The total supply of irrigation water is exogenous to presenting the resource endowment owned by the government, and so the government receives total payments of the irrigation water supply from 16 provinces as a source of income. Total subsidies of irrigation water are also entered into the income function of the government with a negative value. However, pipe water supply is equal to the sum of the sectoral demand defined by a market clearing function.

Households are grouped by urban and the 16 province's rural households (corresponding to the water, agricultural labor and land provinces). Their income comes from the payments of agricultural and non-agricultural labor, capital return, cropland's return and the transfers from government and enterprises and also foreign countries. Their consumption behavior follows the Cobb-Douglas assumption. The Hicksian equivalent variation (EV) measures the changes in household welfare: if EV is positive, the simulation increases welfare; and if it is negative, the simulation decreases welfare.

SCGE-16P as an open-economy model follows a small-country assumption regarding that the world prices of imports and exports are exogenous. The domestic prices of imports and exports are in Chinese Yuan (RMB). Similar to most CGE models, domestic production of each commodity is divided into domestic and export products through a constant elasticity of transformation (CET) function (σ_E, obtained from Zhai and Hertel (2005) [47], is presented in Figures 4 and 5). The domestic consumption of each commodity is composed of domestic and import products based on the Armington assumption (1969) [51] (σ_M, obtained from Willenbockel (2006) [48], is presented in Figures 4 and 5). Moreover, domestic consumption is separated by households, government and investment following the Cobb-Douglas assumption, respectively. Total investment is the sum of the savings obtained from households, enterprises and government, respectively. In particular, the model structure of farming products within the SCGE-16P is presented in Figure 6.

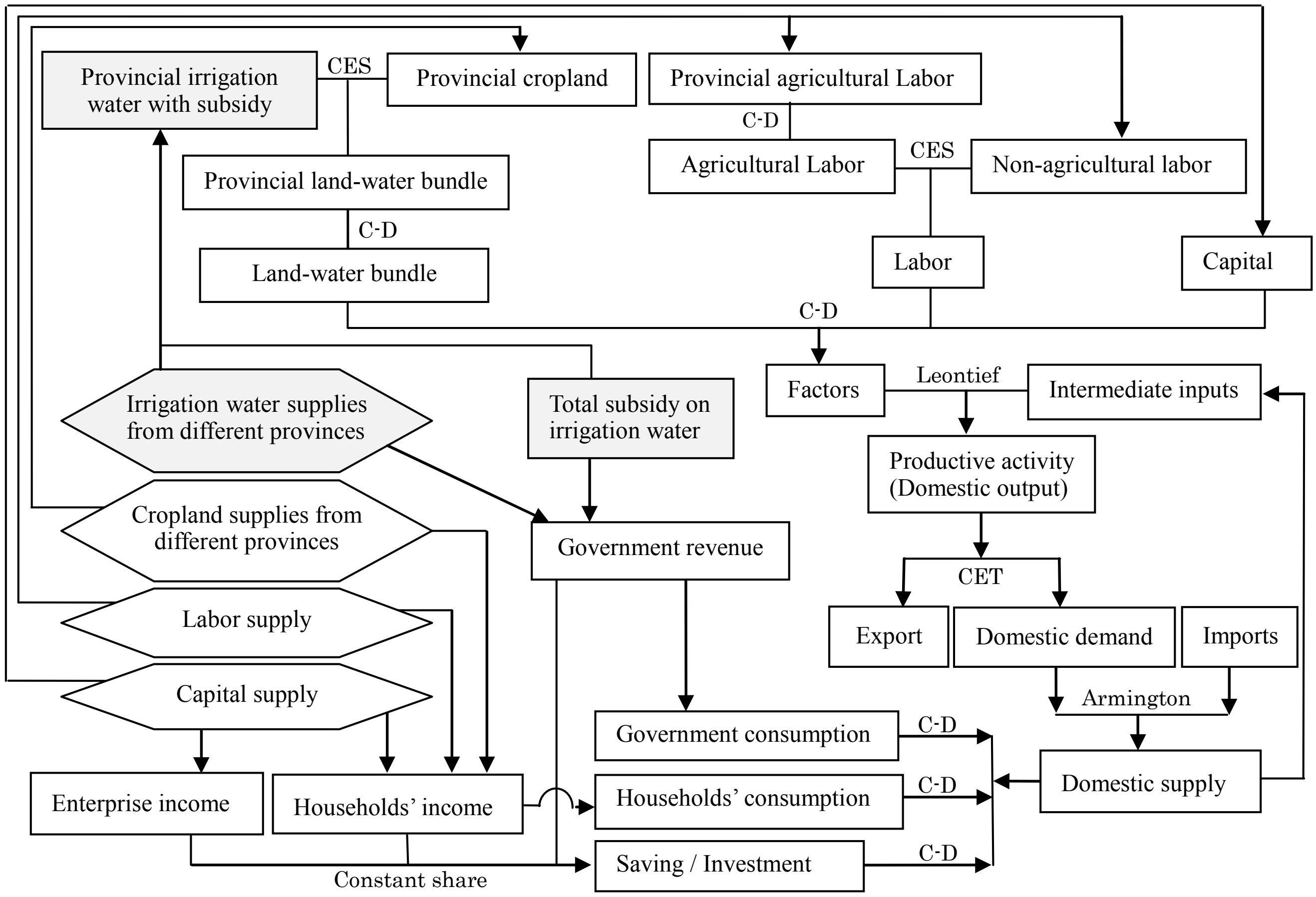


Figure 6. Model structure for farming products in the SCGE-16P. Notes: C–D = Cobb–Douglas function; Leontief = Leontief function; CES (Armington) = the constant elasticity of substitution function; CET = the constant elasticity of transformation function; exogenous variables are circled by ⬡; endogenous variables are circled by ▭.

Other assumptions are same as those for the standard CGE model [44]. Moreover, all prices of commodities and factors in the base year are assumed to equal one. We excluded the non-agricultural labor market to follow Walras' law, and the wage of non-agricultural labor is exogenously fixed as the numeraire price index. Sensitivity analysis, where abnormalities were not observed from the results, can be obtained from the authors upon request for the sake of brevity. This model was conducted within the GAMS (Generalized Algebraic Modeling System) software, and the GAMS codes can be found in another one of Supplementary Material File, S2.

4. Simulation Results and Discussion

4.1. Simulation on the Drought of 2000

To simulate the drought of 2000, the modeling of farming production is suitable for considering the changes in cropland supply and irrigation water supply for different crops in different provinces. The changes in agricultural water represent the changes in irrigation water supply due to data limitation. Moreover, the year 2007 served as the baseline to the drought of 2000, and the simulated rates of the provincial cropland supply and the irrigation water supply were introduced into the SCGE-16P (see Table 5).

Table 5. Simulated rates for the regional supplies of croplands and irrigation water.

Provincial Level	Simulating Cropland Supply			Simulating Irrigation Water Supply		
	Cultivated Area of Farming 2007, Unit: 1000 ha *	Affected Rate of 2000 Drought **	Simulated Rate *****	Water Withdrawals in Agriculture 2007 Unit: 0.1 billion m^3***	Water Withdrawals in Agriculture 2000 Unit: 0.1 billion m^3****	Simulated Rate *****
Guangdong	4363.10	1.551%	0.995	224.84	258.42	1.028
Jiangxi	5245.10	11.096%	0.967	151.35	152.79	1.067
Hainan	754.30	0.000%	1.000	35.84	35.43	1.215
Yunnan	5801.90	1.953%	0.994	105.95	111.80	0.945
Guangxi	5594.40	8.641%	0.974	208.39	224.70	1.038
Henan	14,087.80	10.048%	0.970	120.07	134.10	0.835
Jilin	4944.00	54.819%	0.836	67.53	85.42	0.726
Anhui	8853.90	24.984%	0.925	120.56	121.31	1.011
Heilongjiang	11,898.50	23.999%	0.928	214.75	185.58	0.907
Hebei	8652.70	18.173%	0.945	151.59	161.74	0.978
Hubei	7030.00	19.383%	0.942	132.65	164.90	0.868
Chongqing	3134.70	5.291%	0.984	18.75	18.54	1.158
Sichuan	9278.20	7.940%	0.976	118.71	132.30	0.929
Inner Mongolia	6761.50	37.197%	0.888	141.77	155.13	0.799
Shandong	10,724.40	18.892%	0.943	159.71	175.92	0.944
Other provinces	46,339.40	17.632%	0.947	1627.03	1665.45	1.047

Notes: Data source: * China Agricultural Yearbook 2008 [52]; ** China Agricultural Yearbook 2001 [53] *** China Statistic Yearbook on Environment 2008 [20]; **** China Water Resources Bulletin 2000 [54] ***** Estimated by authors.

Table 5 reflects the fact that the drought of 2000 primarily occurred in the northern part of China, with Jilin being the most affected province. In Jilin, agricultural water declined by 27.4% compared with its 2007 level. Inner Mongolia and Henan were the second and third most affected provinces because their agricultural water declined by 20.1% and 16.5%, respectively. However, it should be noted that there were seven provinces in the southern areas in which the agricultural water supplies in 2000 exceeded those in 2007, including Guangdong, Jiangxi, Hainan, Guangxi, Anhui, Chongqing and the "Other provinces". Thus, this year was not the worst year of drought for these provinces.

4.2. Effects of the 2000 Drought on the Agricultural Economy

The simulation predicted an insignificant effect on the nominal and real values of the national gross domestic product (GDP). The worst effect occurred in the total output of farming products and also agricultural outputs, which decreased by 0.078% and 0.052%, respectively. Total consumption, including food consumption, was also negatively affected. One projected positive value was the consumer price index, which was the primary reason for the decrease in consumption. The effects on the irrigation water prices of the 16 provinces were closely related to the changes in their irrigation water supply: A decrease in irrigation water supply increases price and vice versa (see Table 6).

Table 6. Changes in the macro economy and price indexes.

	Changes in Macro Indexes	**Level**
	Nominal GDP, %	0.013
	Real GDP, %	−0.001
	Total output of farming, %	−0.078
	Total output of agriculture, %	−0.052
	Total consumption, %	−0.012
	Total food consumption, %	−0.068
	Total change in welfare of households, 10 million Yuan	−116.036
	Consumer price index, %	0.028
	Capital return, %	0.009
	Exchange rate, %	0.010
	Pipe water price, %	0.006
Provincial Prices of Irrigation Water, %	Guangdong	−5.43
	Jiangxi	−19.87
	Hainan	−23.68
	Yunnan	9.68
	Guangxi	−12.96
	Henan	38.64
	Jilin	51.80
	Anhui	−9.79
	Heilongjiang	11.18
	Hebei	1.50
	Hubei	26.20
	Chongqing	−32.06
	Sichuan	11.46
	Inner Mongolia	38.59
	Shandong	6.03
	Other provinces	−14.74

Notes: (1) Sources: derived from simulation; (2) "Food" includes the 10 crops and the food products provided by food industries, including the following six types: meat, milk, vegetable oil, gain, sugar, and other food.

The three most affected crops in terms of output were sorghum, wheat and oil seed, which decreased by 2.278%, 0.407% and 0.295%, respectively, as they are mainly cultivated in the northern area of China. Their imports thus increased more significantly than those of other crops. Obviously, the decline in their inputs of composite land and water was the main reason for their decrease in output and their increases in the inputs of capital and labor. Therefore, at the national level, drought significantly reduced the output and export of crops, leading to increased imports. As a result, their producer prices increased significantly; the greatest increases were observed for sorghum, wheat and corn, whose prices rose by 0.974%, 0.385% and 0.338%, respectively. Furthermore, agricultural labor was reallocated from the non-farming agricultural production sectors into farming, with the exceptions of production of sorghum, oil seed and other crops, whose imports increased instead (see Table 7).

Table 7. Effects on agricultural production sectors.

Unit: %	Producer Prices	Outputs	Exports	Imports	Capital Inputs	Composite Agricultural Labor Inputs	Non-Agricultural Labor Inputs	Composite Land and Water Inputs
Paddy	0.156	−0.114	−0.636	0.645	0.172	0.132	0.172	−2.875
Wheat	0.385	−0.407	−1.741	1.454	0.349	0.306	0.348	−8.882
Corn	0.338	−0.084	−1.255	0.512	0.403	0.360	0.402	−5.864
Vegetable	0.223	−0.196	−0.958	0.371	0.044	0.004	0.043	−6.252
Fruit	0.066	−0.064	−0.265	0.099	0.098	0.058	0.098	−4.365
Oil seed	0.129	−0.295	−0.722	0.061	−0.113	−0.153	−0.113	−4.075
Sugarcane	0.075	−0.024		0.139	0.077	0.040	0.077	−2.600
Potato	0.189	−0.150	−0.791	0.327	0.045	0.005	0.045	−4.469
Sorghum	0.974	−2.278	−5.595	2.648	−1.252	−1.292	−1.252	−9.220
Other crops	0.044	−0.017	−0.140	0.071	0.029	−0.012	0.028	−1.848
Animal Husbandry	0.061	−0.030	−0.213	0.048	0.006	−0.033	0.006	
Forestry	0.038	−0.017	−0.116	0.052	0.020	−0.020	0.020	
Fishery	0.042	−0.021	−0.134	0.023	0.014	−0.023	0.014	

Note: Sources: Derived from simulation.

Both urban and rural households were projected to suffer significant reductions in their welfare, total consumption and food consumption, despite the fact that most of them benefited from additional income. The higher consumer price indexes, especially the higher prices of agricultural products, were the main reasons for these reductions. Moreover, rural households from Henan, Sichuan, Hubei, Guangdong, Inner Mongolia, Yunnan and Jilin experienced the worst declines in welfare, with the decreases amounting to more than 10 million Yuan. These rural households were part of both northern and southern areas of China. Furthermore, significant negative effects on food consumption to all rural households were found, particularly in Hubei, Jilin, Sichuan, Inner Mongolia, Guangdong and Yunnan, with the decreases amounting to more than 0.1%. This demonstrates that rural households that were experiencing declines in welfare were marked by an analogous change in their food consumption. In particular, the losses of food consumption in rural households were more serious than those in urban households at the national level (see Table 8).

Figure 7 presents a chart summarizing the impacts of the drought of 2000 on rural households. When the drought occurred and reduced the supplies of irrigation water and cropland, agricultural outputs decreased, and then, the prices of agricultural products increased. Rural households lowered their food consumption so that their utility levels and also their welfare decreased. Decreasing supplies of cropland and irrigation water increased the return of cropland. Meanwhile, labor wages were also higher because of the increasing demand of labor; thus, rural households benefited from higher income. However, additional income could not compensate for their losses in consumption.

Table 8. Changes in welfare, income and consumption of urban and rural households.

	Unit: for Welfare, 10 million Yuan; for Income and Consumption, %	Welfare	Income	Consumption	Food Consumption
16 Provincial Rural Households	Guangdong	−3.754	0.033	−0.026	−0.103
	Jiangxi	−0.638	0.064	−0.007	−0.099
	Hainan	0.125	0.080	0.009	−0.077
	Yunnan	−1.985	0.037	−0.024	−0.103
	Guangxi	−0.571	0.061	−0.006	−0.091
	Henan	−9.280	−0.053	−0.069	−0.087
	Jilin	−1.970	0.008	−0.041	−0.127
	Anhui	0.566	0.053	0.005	−0.086
	Heilongjiang	−0.492	0.036	−0.008	−0.089
	Hebei	1.941	0.048	0.017	−0.041
	Hubei	−5.489	0.011	−0.049	−0.145
	Chongqing	0.718	0.083	0.016	−0.066
	Sichuan	−7.767	0.018	−0.048	−0.124
	Inner Mongolia	−2.393	−0.022	−0.055	−0.124
	Shandong	1.674	0.036	0.009	−0.050
	Other provinces	14.365	0.059	0.014	−0.069
Total change in rural households		−14.952	0.037	−0.006	−0.086
Urban households		−101.085	0.007	−0.014	−0.057

Note: Sources: Derived from simulation.

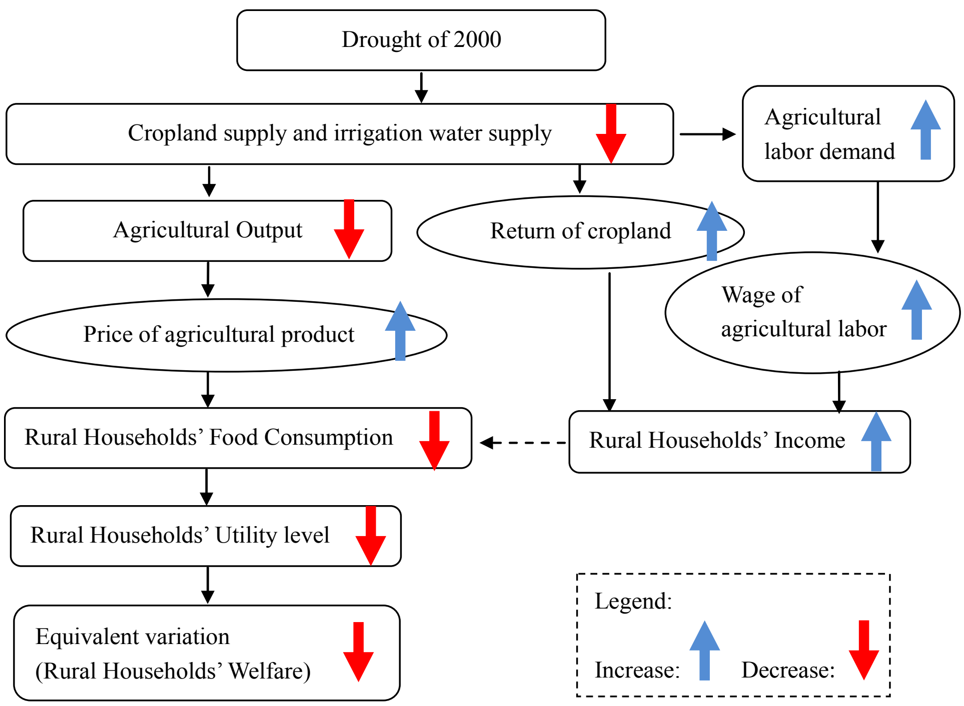


Figure 7. Flow chart of the impact of drought 2000 on rural households.

5. Conclusions and Policy Recommendation

The basic purpose of a CGE analysis is to provide several possible solutions for policy recommendation regarding a series of assumptions. The main originalities of this study focused on two aspects to construct the SCGE-16P: (1) Extending the given SAM by introducing irrigation water and its irrigation subsidy and then segmenting them into 16 provincial levels; (2) Introducing the water parallel pricing system into the CGE model, where the price distortion between irrigation water and pipe water was defined, and the supply of irrigation water and that of pipe water were managed by the government and the pipe water production sector, respectively. In the simulation of the 2000 drought, the macroeconomic results indicated that the effects on nominal and real GDP were negative but insignificant. However, the decline in the output of some crops was significant and varied. All crop outputs and exports decreased, particularly for sorghum, wheat and oil seed, which are mainly cultivated in the northern areas, and then their imports increased. Furthermore, most farming production sectors employed more capital and labor to sustain output because of the decline in the supplies of cropland and irrigation water. As a result, agricultural labor was redistributed from non-farming agricultural production sectors into farming. Households suffered significant losses in welfare, total consumption and food consumption. Rural households from both northern and southern areas experienced the most significant declines in welfare, including in Henan, Sichuan, Hubei, Guangdong, Inner Mongolia, Yunnan and Jilin. Furthermore, the close relationship between food consumption and welfare was exemplified for both urban and rural areas.

The purpose of the water pricing reform is to allocate water resources to different sectors with more efficiency, especially between agricultural sectors and industrial sectors. To promote this reform, both irrigation water and pipe water should be formulated with volumetric pricing according to the marginal cost level. To protect the losses of both northern and southern households from drought, their basic level of food consumption should be guaranteed by additional supports, such as providing new subsidy and promoting employment to make up their losses in income and consumption. Moreover, it is necessary to shift additional agricultural labor to the non-farming agricultural sectors to prevent losses in output. In the northern area, more water-efficient irrigation technologies should be introduced into the production of water-intensive crops. The production of less water-intensive crops should be extended to this area. Other policy supports should consider limiting urban expansion on high-quality land, promoting capital investments into basic agricultural inputs (fertilizer and machinery), extension services and agri-business development [55]. Furthermore, water-saving technology should be improved in the urban-industrial sectors; thus, more water could be redistributed to agricultural sectors.

It would be interesting to make a comparison between the real impacts of drought and the simulation results. However, the 2000 drought was a short-term event, which only continued few months varied across different regions, and the detailed seasonal data describing the real impacts are not available in official database but only annual data recorded at the end of 2000 [15,53,54]. The only available data in official database about this drought are the drought-affected areas, which were already considered in the simulation design. Moreover, the relatively work of the drought 2000 are also rare found in previous studies. On the other hand, the SCGE-16P model constructed in this study was expended from the standard CGE model, where many assumptions setting are too strict to reflect the reality. So the simulation results derived from this model just provided the "perfect market reaction", which might have some discrepancies between model responses and actual responses because of two reasons: Firstly, the simulation of 2000 drought in design only considered those drought-affected areas with more 30% decline in yield as interpreted in the yearbook, but those areas with less 30% decline were ignored, which were much larger than the areas in our design; Secondly, as well known, China's market-oriented reform is still underway, and so there are many barriers impeding the market force at the institutional level and at the regional level. Consequently, it is possible that the observed output impacts would be more significant than the results generated from model simulation. In other words, the simulation just provided a theoretical response to the drought under the strict market condition rather than an actual response. This theoretical response would play an important role for government to improve the market-oriented reform and water management system, especially in the period of a serious drought.

Besides, several parameters (σ_E,σ_M, σ_F and σ_{LB}) used in this study were set according to previous studies. Some other parameters (σ_{RLW}, σ_{VAW} and σ_{WARP}), due to data limitation, were based on assumption instead of estimation, which might not be precise enough to describe the detailed condition of economic system. More accurate values of these parameters need to be estimated for future study by using econometric approach to improve the quality of model simulation.

Acknowledgments

The authors appreciate Yuko Akune for her extensive support, and especially for the prototype model utilized to build our model. The authors also appreciate the cooperation of Jianping Ge for permitting us to employ his multi-regional social accounting matrix. The authors would like to give our sincere thanks to three reviewers for their very helpful comments and suggestions to improve this paper, and to editors for their generous supports on this paper. This work was financially supported by the National Natural Science Foundation of China (Grant No. 41271547), Energy Supply Security of China and Its Natural Resources-Environmental Impacts under Climate Change; and by the Key Laboratory of Carrying Capacity Assessment for Resource and Environment, Ministry of Land and Resources (Grant No. CCA2015.11).

Author Contributions

Shuai Zhong, Mitsuru Okiyama and Suminori Tokunaga conceived and designed the initial work of study and simulation; Lei Shen, Jinghua Sha, Litao Liu and Jingjing Yan provided many very helpful suggestions to improve its analysis, discussed the results and commented on the manuscript; Shuai Zhong collected the data, constructed the model and wrote the paper.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix: SCGE Model with Irrigation Water from 16 Provinces (SCGE-16P)

A1. Model Equations

A1.1. Production Block

A1.1.1. Provinces' Agricultural Labor in Cobb-Douglas Function

$$LFR_{agc,prov} = \beta LFR_{agc,prov} \times PLF_{agc} \times LF_{agc} / PLFR_{prov} \qquad \text{(A1)}$$

A1.1.2. Composite Agricultural Labor in Cobb-Douglas Function

$$LF_{agc} = bFLFR_{agc} \times \left(\prod_{prov} LFR_{agc,prov}{}^{\beta LFR_{agc,prov}} \right) \quad \text{(A2)}$$

A1.1.3. Non-agricultural Labor in CES Function

$$LE_{agc} = \left(\frac{L_{agc}}{aL_{agc}} \right) \times \left(\frac{\gamma L_{agc}}{PLE} \right)^{\sigma L_{agc}} \times \left(\begin{array}{l} \gamma L_{agc}{}^{\sigma L_{agc}} \times PLE^{(1-\sigma L_{agc})} \\ +(1-\gamma L_{agc})^{\sigma L_{agc}} \times PLF_{agc}{}^{(1-\sigma L_{agc})} \end{array} \right)^{\frac{\sigma L_{agc}}{(1-\sigma L_{agc})}} \quad \text{(A3)}$$

A1.1.4. Composite Agricultural Labor in CES Function

$$LF_{agc} = \left(\frac{L_{agc}}{aL_{agc}} \right) \times \left(\frac{1-\gamma L_{agc}}{PLF_{agc}} \right)^{\sigma L_{agc}} \times \left(\begin{array}{l} \gamma L_{agc}{}^{\sigma L_{agc}} \times PLE^{(1-\sigma L_{agc})} \\ +(1-\gamma L_{agc})^{\sigma L_{agc}} \times PLF_{agc}{}^{(1-\sigma L_{agc})} \end{array} \right)^{\frac{\sigma L_{agc}}{(1-\sigma L_{agc})}} \quad \text{(A4)}$$

A1.1.5. Zero-profit Condition in CES Function for the Labor

$$PL_{agc} \times L_{agc} = PLF_{agc} \times LF_{agc} + PLE \times LE_{agc} \quad \text{(A5)}$$

A1.1.6. Irrigation Water Demand of "Other Provinces" for Farming Production Sectors

$$\begin{aligned} WAR_{cro,\text{"}OTH\text{"}} &= \left(\frac{WARPOTH_{cro}}{aWARP_{cro}} \right) \times \left(\frac{\gamma WARP_{cro}}{PWR_{\text{"}OTH\text{"}}} \right)^{\sigma WARP_{cro}} \\ &\times \left(\begin{array}{l} \gamma WARP_{cro}{}^{\sigma WARP_{cro}} \times PWR_{\text{"}OTH\text{"}}{}^{(1-\sigma WARP_{cro})} \\ +(1-\gamma WARP_{cro})^{\sigma WARP_{cro}} \times P_{\text{"}WAP\text{"}}{}^{(1-\sigma WARP_{cro})} \end{array} \right)^{\frac{\sigma WARP_{cro}}{(1-\sigma WARP_{cro})}} \end{aligned} \quad \text{(A6)}$$

A1.1.7. Pipe Water Demand of "Other Provinces" for Farming Production Sectors

$$\begin{aligned} WAP_{cro} &= \left(\frac{WARPOTH_{cro}}{aWARP_{cro}} \right) \times \left(\frac{1-\gamma WARP_{cro}}{P_{\text{"}WAP\text{"}}} \right)^{\sigma WARP_{cro}} \\ &\times \left(\begin{array}{l} \gamma WARP_{cro}{}^{\sigma WARP_{cro}} \times PWR_{\text{"}OTH\text{"}}{}^{(1-\sigma WARP_{cro})} \\ +(1-\gamma WARP_{cro})^{\sigma WARP_{cro}} \times P_{\text{"}WAP\text{"}}{}^{(1-\sigma WARP_{cro})} \end{array} \right)^{\frac{\sigma WARP_{cro}}{(1-\sigma WARP_{cro})}} \end{aligned} \quad \text{(A7)}$$

A1.1.8. Zero-profit Condition in CES Function for the Composite Water Demand of "Other Provinces" for Farming Production Sectors

$$WARPOTH_{cro} \times PWRPOTH_{cro} = PWR_{\text{"}OTH\text{"}} \times WAR_{cro,\text{"}OTH\text{"}} + P_{\text{"}WAP\text{"}} \times WAP_{cro} \quad \text{(A8)}$$

A1.1.9. Composite Water Demand of "Other Provinces" for Farming Production Sectors

$$WARPOTH_{cro} = \left(\frac{LW_{cro,"OTH"}}{aLW_{cro,"OTH"}}\right) \times \left[\frac{\gamma LW_{cro,"OTH"}}{\left((1 + tswr_{cro,"OTH"}) \times PWRPOTH_{cro}\right)}\right]^{\sigma LW_{cro,"OTH"}} \times \left(\begin{array}{l} \gamma LW_{cro,"OTH"}{}^{\sigma LW_{cro,"OTH"}} \times \left[(1 + tswr_{cro,"OTH"}) \times PWRPOTH_{cro}\right]^{(1-\sigma LW_{cro,"OTH"})} \\ +(1 - \gamma LW_{cro,"OTH"})^{\sigma LW_{cro,"OTH"}} \times PLD_{"OTH"}{}^{(1-\sigma LW_{cro,"OTH"})} \end{array}\right)^{\frac{\sigma LW_{cro,"OTH"}}{(1-\sigma LW_{cro,"OTH"})}} \quad \text{(A9)}$$

A1.1.10. Cropland Demand of "Other Provinces" for Farming Production Sectors

$$LD_{cro,"OTH"} = \left(\frac{LW_{cro,"OTH"}}{aLW_{cro,"OTH"}}\right) \times \left(\frac{1 - \gamma LW_{cro,"OTH"}}{PLD_{"OTH"}}\right)^{\sigma LW_{cro,"OTH"}} \times \left(\begin{array}{l} \gamma LW_{cro,"OTH"}{}^{\sigma LW_{cro,"OTH"}} \times \left[(1 + tswr_{cro,"OTH"}) \times PWRPOTH_{cro}\right]^{(1-\sigma LW_{cro,"OTH"})} \\ +(1 - \gamma LW_{cro,"OTH"})^{\sigma LW_{cro,"OTH"}} \times PLD_{"OTH"}{}^{(1-\sigma LW_{cro,"OTH"})} \end{array}\right)^{\frac{\sigma LW_{cro,"OTH"}}{(1-\sigma LW_{cro,"OTH"})}} \quad \text{(A10)}$$

A1.1.11. Zero-profit Condition in CES Function for the Land-Water Bundles of "Other Province" for Farming Production Sectors

$$\begin{array}{l} LW_{cro,"OTH"} \times PLW_{cro,"OTH"} \\ = (1 + tswr_{cro,"OTH"}) \times WARPOTH_{cro} \times PWRPOTH_{cro} + PLD_{"OTH"} \times LD_{cro,"OTH"} \end{array} \quad \text{(A11)}$$

A1.1.12. Irrigation Water Demand of 16 Provinces except "Other Provinces" for Farming Production Sectors

$$WAR_{cro,prov} = \left(\frac{LWR_{cro,prov}}{aLWR_{cro,prov}}\right) \times \left[\frac{\gamma LW_{cro,prov}}{(1 + tswr_{cro,prov}) \times PWR_{prov}}\right]^{\sigma LW_{cro,prov}} \times \left(\begin{array}{l} \gamma LW_{cro,prov}{}^{\sigma LW_{cro,prov}} \times \left[(1 + tswr_{cro,prov}) \times PWR_{prov}\right]^{(1-\sigma LW_{cro,prov})} \\ +(1 - \gamma LW_{cro,prov})^{\sigma LW_{cro,prov}} \times PLD_{prov}{}^{(1-\sigma LW_{cro,prov})} \end{array}\right)^{\frac{\sigma LW_{cro,prov}}{(1-\sigma LW_{cro,prov})}} \quad \text{(A12)}$$

A1.1.13. Cropland Demand of 16 Provinces except "Other Provinces" for Farming Production Sectors

$$LD_{cro,prov} = \left(\frac{LWR_{cro,prov}}{aLW_{cro,prov}}\right) \times \left(\frac{1 - \gamma LW_{cro,prov}}{PLD_{prov}}\right)^{\sigma LW_{cro,prov}} \times \left(\begin{array}{l} \gamma LW_{cro,prov}{}^{\sigma LW_{cro,prov}} \times \left[(1 + tswr_{cro,prov}) \times PWR_{prov}\right]^{(1-\sigma LW_{cro,prov})} \\ +(1 - \gamma LW_{cro,prov})^{\sigma LW_{cro,prov}} \times PLD_{prov}{}^{(1-\sigma LW_{cro,prov})} \end{array}\right)^{\frac{\sigma LW_{cro,prov}}{(1-\sigma LW_{cro,prov})}} \quad \text{(A13)}$$

A1.1.14. Zero-profit Condition in CES Function for Land-water Bundles of 16 Provinces Except "Other Provinces" for Farming Production Sectors

$$PLWR_{cro,prov} \times LWR_{cro,prov} = (1 + tswr_{cro,prov}) \times PWR_{prov} \times WAR_{cro,prov} + PLD_{prov} \times LD_{cro,prov} \quad \text{(A14)}$$

A1.1.15. Demand of Land-water Bundle of 16 Provinces in Cobb-Douglas Function for Farming Production Sectors

$$LWR_{cro,prov} = \beta LW_{cro,prov} \times PLW_{cro} \times LW_{cro} / PLWR_{cro,prov} \quad \text{(A15)}$$

A1.1.16. Composite Land-Water Demand in Cobb-Douglas Function for Farming Production Sectors

$$LW_{cro} = bFLW_{cro} \times \left(\prod_{prov} LWR_{cro,prov}{}^{\beta LW_{cro,prov}} \right) \quad \text{(A16)}$$

A1.1.17. Capital Demand in Cobb-Douglas Function for Agricultural Production Sectors

$$K_{agc} = \beta FK_{agc} \times PVA_{agc} \times VA_{agc} / PK \quad \text{(A17)}$$

A1.1.18. Composite Labor Demand in Cobb-Douglas Function for Agricultural Production Sectors

$$L_{agc} = \beta FL_{agc} \times PVA_{agc} \times VA_{agc} / PL_{agc} \quad \text{(A18)}$$

A1.1.19. Composite Land-Water Demand in Cobb-Douglas for Farming Production Sectors

$$LW_{cro} = \beta FLW_{cro} \times PVA_{cro} \times VA_{cro} / PLW_{cro} \quad \text{(A19)}$$

A1.1.20. Value-Added Demand in Cobb-Douglas Function for Farming Production Sectors

$$VA_{cro} = bF_{cro} \times \left(K_{cro}{}^{\beta FK_{cro}} \times L_{cro}{}^{\beta FL_{cro}} \times LW_{cro}{}^{\beta FLW_{cro}} \right) \quad \text{(A20)}$$

A1.1.21. Value-Added Demand in Cobb-Douglas Function for Non-farming Production Sectors

$$VA_{ncro} = bF_{ncro} \times \left(K_{ncro}{}^{\beta FK_{ncro}} \times L_{ncro}{}^{\beta FL_{ncro}} \right) \quad \text{(A21)}$$

A1.1.22. Capital Demand in CES Function for the Production of Other Sectors

$$K_{inse} = \left(\frac{VA_{inse}}{aF_{inse}} \right) \times \left(\frac{1 - \gamma F_{inse}}{PK} \right)^{\sigma F_{inse}} \times \begin{pmatrix} \gamma F_{inse}{}^{\sigma F_{inse}} \times PL_{inse}{}^{(1 - \sigma F_{inse})} \\ +(1 - \gamma F_{inse})^{\sigma F_{inse}} \times PK^{(1 - \sigma F_{inse})} \end{pmatrix}^{\frac{\sigma F_{inse}}{(1 - \sigma F_{inse})}} \quad \text{(A22)}$$

A1.1.23. Non-agricultural Labor Demand in CES Function for the Production of Other Sectors

$$LE_{inse} = \left(\frac{VA_{inse}}{aF_{inse}} \right) \times \left(\frac{\gamma F_{inse}}{PL_{inse}} \right)^{\sigma F_{inse}} \times \begin{pmatrix} \gamma F_{inse}{}^{\sigma F_{inse}} \times PLE^{(1 - \sigma F_{inse})} \\ +(1 - \gamma F_{inse})^{\sigma F_{inse}} \times PK^{(1 - \sigma F_{inse})} \end{pmatrix}^{\frac{\sigma F_{inse}}{(1 - \sigma F_{inse})}} \quad \text{(A23)}$$

A1.1.24. Zero-profit Condition in CES Function for Value Added of Other Sectors

$$PVA_{inse} \times VA_{inse} = PK \times K_{inse} + PLE \times LE_{inse} \quad \text{(A24)}$$

A1.1.25. Value-Added Demand in CES Function for Non-farming Agricultural and Other Sectors

$$\begin{aligned} VA_{ncpinse} &= \left(\frac{VAW_{ncpinse}}{aVAW_{ncpinse}} \right) \times \left[\frac{\gamma VAW_{ncpinse}}{(1+tva_{ncpinse}) \times PVA_{ncpinse}} \right]^{\sigma VAW_{ncpinse}} \\ &\times \begin{pmatrix} \gamma VAW_{ncpinse}{}^{\sigma VAW_{ncpinse}} \times P_{"WAP"}{}^{(1-\sigma VAW_{ncpinse})} \\ +(1-\gamma VAW_{ncpinse})^{\sigma VAW_{ncpinse}} \times \left[(1+tva_{ncpinse}) \times PVA_{ncpinse} \right]^{(1-\sigma VAW_{ncpinse})} \end{pmatrix}^{\frac{\sigma VAW_{ncpinse}}{(1-\sigma VAW_{ncpinse})}} \end{aligned} \quad \text{(A25)}$$

A1.1.26. Pipe Water Demand in CES Function for Non-farming Agricultural and Other Sectors

$$\begin{aligned} WAP_{ncpinse} &= \left(\frac{VAW_{ncpinse}}{aVAW_{ncpinse}} \right) \times \left[\frac{1-\gamma VAW_{ncpinse}}{P_{"WAP"}} \right]^{\sigma VAW_{ncpinse}} \\ &\times \begin{pmatrix} \gamma VAW_{ncpinse}{}^{\sigma VAW_{ncpinse}} \times P_{"WAP"}{}^{(1-\sigma VAW_{ncpinse})} \\ +(1-\gamma VAW_{ncpinse})^{\sigma VAW_{ncpinse}} \times \left[(1+tva_{ncpinse}) \times PVA_{ncpinse} \right]^{(1-\sigma VAW_{ncpinse})} \end{pmatrix}^{\frac{\sigma VAW_{ncpinse}}{(1-\sigma VAW_{ncpinse})}} \end{aligned} \quad \text{(A26)}$$

A1.1.27. Zero-profit Condition in CES Function for the Pipe Water Demand and Value-added Demand of Non-farming Agricultural and Other Sectors

$$PVAW_{ncpinse} \times VAW_{ncpinse} = P_{"WAP"} \times WAP_{ncpinse} + (1+tva_{ncpinse}) \times PVA_{ncpinse} \times VA_{ncpinse} \quad \text{(A27)}$$

A1.1.28. Intermediate Demand Except Water in Leontief Function

$$IO_{nwa,\sec} = iio_{nwa,\sec} \times XD_{\sec} \quad \text{(A28)}$$

A1.1.29. Vale-Added Demand in Leontief Function for Farming Sectors

$$VA_{cro} = iva_{cro} \times XD_{cro} \quad \text{(A29)}$$

A1.1.30. Composite Vale-Added Demand in Leontief Function for Non-farming Agricultural and Other Sectors

$$VAW_{ncpinse} = iva_{ncpinse} \times XD_{ncpinse} \quad \text{(A30)}$$

A1.1.31. Relationship between the Producer Price, the Price of Value-Added and the Price of Intermediate Inputs for Production Sectors

$$PD_{cro} = iva_{cro} \times PVA_{cro} \times (1+tva_{cro}) + \sum_{nwa} P_{nwa} \times iio_{nwa,cro} \quad \text{(A31)}$$

A1.1.32. Relationship between the Producer Price, the Price of Value-Added and the Price of Intermediate Inputs for Non-farming Agricultural and Other Sectors

$$PD_{ncpinse} = iva_{ncpinse} \times PVAW_{ncpinse} \times (1 + tva_{ncpinse}) + \sum_{nwa} P_{nwa} \times iio_{nwa,ncpinse} \tag{A32}$$

A1.2. Trade Block

A1.2.1. Import Demand in Armington Function

$$M_{\sec} = \left(\frac{X_{\sec}}{aA_{\sec}}\right) \times \left(\frac{\gamma A_{\sec}}{PM_{\sec}}\right)^{\sigma A_{\sec}} \times \begin{pmatrix} \gamma A_{\sec}{}^{\sigma A_{\sec}} \times PM_{\sec}{}^{(1-\sigma A_{\sec})} \\ +(1-\gamma A_{\sec})^{\sigma A_{\sec}} \times PDD_{\sec}{}^{(1-\sigma A_{\sec})} \end{pmatrix}^{\frac{\sigma A_{\sec}}{(1-\sigma A_{\sec})}} \tag{A33}$$

A1.2.2. Domestic Product Demand in Armington Function

$$XDD_{\sec} = \left(\frac{X_{\sec}}{aA_{\sec}}\right) \times \left(\frac{1-\gamma A_{\sec}}{PDD_{\sec}}\right)^{\sigma A_{\sec}} \times \begin{pmatrix} \gamma A_{\sec}{}^{\sigma A_{\sec}} \times PM_{\sec}{}^{(1-\sigma A_{\sec})} \\ +(1-\gamma A_{\sec})^{\sigma A_{\sec}} \times PDD_{\sec}{}^{(1-\sigma A_{\sec})} \end{pmatrix}^{\frac{\sigma A_{\sec}}{(1-\sigma A_{\sec})}} \tag{A34}$$

A1.2.3. Zero-profit Condition in Armington Function

$$P_{\sec} \times X_{\sec} = PM_{\sec} \times M_{\sec} + PDD_{\sec} \times XDD_{\sec} \tag{A35}$$

A1.2.4. Export Demand in CET Function

$$E_{\sec} = \left(\frac{XD_{\sec}}{aT_{\sec}}\right) \times \left(\frac{1-\gamma T_{\sec}}{PE_{\sec}}\right)^{\sigma T_{\sec}} \times \begin{pmatrix} (1-\gamma T_{\sec})^{\sigma T_{\sec}} \times PE_{\sec}{}^{(1-\sigma T_{\sec})} \\ +\gamma T_{\sec}{}^{\sigma T_{\sec}} \times PDD_{\sec}{}^{(1-\sigma T_{\sec})} \end{pmatrix}^{\frac{\sigma T_{\sec}}{(1-\sigma T_{\sec})}} \tag{A36}$$

A1.2.5. Domestic Product Demand in CET Function

$$XDD_{\sec} = \left(\frac{XD_{\sec}}{aT_{\sec}}\right) \times \left(\frac{\gamma T_{\sec}}{PDD_{\sec}}\right)^{\sigma T_{\sec}} \times \begin{pmatrix} (1-\gamma T_{\sec})^{\sigma T_{\sec}} \times PE_{\sec}{}^{(1-\sigma T_{\sec})} \\ +\gamma T_{\sec}{}^{\sigma T_{\sec}} \times PDD_{\sec}{}^{(1-\sigma T_{\sec})} \end{pmatrix}^{\frac{\sigma T_{\sec}}{(1-\sigma T_{\sec})}} \tag{A37}$$

A1.2.6. Zero-profit Condition in CET Function

$$PD_{\sec} \times XD_{\sec} = PE_{\sec} \times E_{\sec} + PDD_{\sec} \times XDD_{\sec} \tag{A38}$$

A1.2.7. Import Price

$$PM_{\sec} = (1 + tm_{\sec}) \times ER \times \overline{pWmZ}_{\sec} \tag{A39}$$

A1.2.8. Export Price

$$PE_{\sec} = ER \times \overline{pWeZ}_{\sec} \tag{A40}$$

A1.3. Blocks of Households and Enterprise

A1.3.1. Household Consumption

$$P_{\sec} \times C_{\sec,hou} = \alpha H_{\sec,hou} \times \left[(1 - ty_{hou}) \times (1 - mps_{hou}) \times Y_{hou} - PCINDEX \times \sum_{insd} \overline{TRI}_{insd,hou} \right] \tag{A41}$$

A1.3.2. Initial Utility Level of Households

$$UUZ_{hou} = \prod_{\sec} CZ_{\sec,hou}{}^{\alpha H_{\sec,hou}} \tag{A42}$$

A1.3.3.Proposed Change in Utility Level of Households

$$UU_{hou} = \prod_{\sec} C_{\sec,hou}{}^{\alpha H_{\sec,hou}} \tag{A43}$$

A1.3.4. Initial Level of Equivalent Variation Level

$$EPZ_{hou} = UUZ_{hou} \Big/ \prod_{\sec} \left(\alpha H_{\sec,hou} / 1 \right)^{\alpha H_{\sec,hou}} \tag{A44}$$

A1.3.5. Proposed Change in the Level of Equivalent Variation

$$EP_{hou} = UU_{hou} \Big/ \prod_{\sec} \left(\alpha H_{\sec,hou} / 1 \right)^{\alpha H_{\sec,hou}} \tag{A45}$$

A1.3.6. Equivalent Variation to Measure the Welfare Changing of Households

$$EV_{hou} = EP_{hou} - EPZ_{hou} \tag{A46}$$

A1.3.7. Income of Households and Enterprise

$$\begin{aligned} Y_{insdng,prov} &= PK \times \overline{KS}_{insdng,prov} + PLFR_{insdng,prov} \times \overline{LSF}_{insdng,prov} + PLE \times \overline{LSE}_{insdng,prov} \\ &+ PLD_{prov} \times \overline{LDS}_{insdng,prov} + PCINDEX \times \sum_{insed} \overline{TRI}_{insd,prov} + ER \times \overline{NFD}_{insdng,prov} \end{aligned} \tag{A47}$$

A1.3.8. Savings of Household and Enterprise

$$SP_{insdng} = mps_{insdng} \times (1 - ty_{insdng}) \times Y_{insdng} \tag{A48}$$

A1.4. Saving/Investment

A1.4.1. Total Saving

$$S = \sum_{insdng} SP_{insdng} + SG + ER \times \overline{SF} \tag{A49}$$

A1.4.2.Sectoral Investment of Bank

$$P_{\sec} \times I_{\sec} = \alpha I_{\sec} \times S \tag{A50}$$

A1.5. Government Block

A1.5.1. Government Saving

$$SG = mpg \times TAXR \tag{A51}$$

A1.5.2. Interest Payments to Government

$$IG = \alpha IG \times S \tag{A52}$$

A1.5.3. Total Subsidy for Irrigation Water

$$\begin{aligned} TSDWR = & \sum_{cro,prov} tswr_{cro,prov} \times PWR_{prov} \times WAR_{cro,prov} \\ & + \sum_{cro} tswr_{cro,"OTH"} \times PWRPOTH_{cro} \times WARPOTH_{cro} \end{aligned} \tag{A53}$$

Note: the set "*prov*" in this equation (A53) only covers pre-15 provinces.

A1.5.4. Government Consumption

$$P_{\sec} \times CG_{\sec} = \alpha CG_{\sec} \times \begin{bmatrix} TAXR + TSDWR + IG + ER * \overline{RGF} + \sum_{prov} PWR_{prov} \times \overline{IRWAG}_{prov,"GOV"} \\ -\left(PCINDEX \times \sum_{insdng} \overline{TRI}_{insdng} + ER * \overline{EGF} + SG \right) \end{bmatrix} \tag{A54}$$

A1.5.5. Total Tax Revenue

$$\begin{aligned} TAXR = & \sum_{cro} tva_{cro} \times \left(PL_{cro} \times L_{cro} + PK \times K_{cro} + PLW_{cro} \times LW_{cro} \right) \\ & + \sum_{ncro} tva_{ncro} \times \left(PL_{cro} \times L_{cro} + PK \times K_{cro} \right) + \sum_{inse} tva_{inse} \times \left(PLE \times LE_{inse} + PK \times K_{inse} \right) \\ & + \sum_{\sec} tm_{\sec} \times \overline{pWmZ}_{\sec} \times ER \times M_{\sec} + \sum_{insdng} ty_{insdng} \times Y_{insdng} \end{aligned} \tag{A55}$$

A1.6. Market Condition

A1.6.1. Consumer Price Index

$$PCINDEX = \frac{\sum_{\sec} P_{\sec} \times \overline{CZ}_{\sec}}{\sum_{\sec} \overline{PZ}_{\sec} \times \overline{CZ}_{\sec}} \tag{A56}$$

A1.6.2. Non-agricultural Labor Markets

$$\sum_{\sec} LE_{\sec} = \sum_{insdng} \overline{LSE}_{insdng} \tag{A57}$$

A1.6.3. Agricultural Labor Markets of 16 Provinces

$$\sum_{agc} LFR_{agc,prov} = \sum_{insd} \overline{LSFR}_{insd,prov} \tag{A58}$$

A1.6.4. Capital Markets

$$\sum_{\sec} K_{\sec} = \sum_{insdng} \overline{KS}_{insdng} + \overline{KSRW} \tag{A59}$$

A1.6.5. Cropland Markets of 16 Provinces

$$\sum_{cro} LD_{cro,prov} = \sum_{insd} \overline{LDS}_{prov,insd} \tag{A60}$$

A1.6.6. Irrigation Markets of 16 Provinces

$$\sum_{cro} WAR_{cro,prov} = \sum_{insd} \overline{IRWAG}_{insd,prov} \tag{A61}$$

A1.6.7. Commodity Markets except Pipe Water

$$X_{nwa} = \sum_{hou} C_{nwa,hou} + I_{nwa} + CG_{nwa} + \sum_{\sec} IO_{nwa,\sec} \tag{A62}$$

A1.6.8. Commodity Markets of Pipe Water

$$X_{"WAP"} = \sum_{hou} C_{"WAP",hou} + I_{"WAP"} + CG_{"WAP"} + \sum_{\sec} WAP_{\sec} \tag{A63}$$

A1.6.9. Balance of International Payments

$$\begin{aligned} &\sum_{\sec} \overline{pWmZ}_{\sec} \times M_{\sec} + (PK/ER) \times \overline{KSRW} + (PK/ER) \times \overline{EGF} \\ &= \sum_{\sec} \overline{pWeZ}_{\sec} \times E_{\sec} + \overline{SF} + \sum_{insdng} \overline{NFD}_{insdng} + \overline{RGF} \end{aligned} \tag{A64}$$

A1.6.10. Nominal Gross Domestic Products (NGDP)

$$NGDP = \sum_{nwa,\sec} P_{nwa} \times IO_{nwa,\sec} + \sum_{\sec} P_{"WAP"} \times WAP_{\sec} + \sum_{\sec,hou} P_{\sec} \times C_{\sec,hou} + \sum_{\sec} P_{\sec} \times CG_{\sec} + \sum_{\sec} P_{\sec} \times I_{\sec} + \sum_{\sec} PE_{\sec} \times E_{\sec} - \sum_{\sec} PM_{\sec} \times M_{\sec} \quad \text{(A65)}$$

A1.6.11. Real Gross Domestic Products (RGDP)

$$RGDP = \sum_{nwa,\sec} \overline{PZ}_{nwa} \times IO_{nwa,\sec} + \sum_{\sec} \overline{PZ}_{"WAP"} \times WAP_{\sec} + \sum_{\sec,hou} \overline{PZ}_{\sec} \times C_{\sec,hou} + \sum_{\sec} \overline{PZ}_{\sec} \times CG_{\sec} + \sum_{\sec} \overline{PZ}_{\sec} \times I_{\sec} + \sum_{\sec} \overline{PEZ}_{\sec} \times E_{\sec} - \sum_{\sec} \overline{PMZ}_{\sec} \times M_{\sec} \quad \text{(A66)}$$

A2. Model Variables

A2.1. Sets

sec	Activities and commodities
prov	16 provinces
agc: $agc \subset sec$	Agricultural sectors including farming and non-farming
cro: $cro \subset sec$; $cro \subset agc$	Farming sectors
ncro: $ncro \subset sec$; $ncro \subset agc$	Non-farming agricultural sectors
ncpinse: $ncpinse \subset sec$	Non-farming agricultural, construction, industrial and service sectors
inse: $inse \subset sec$; $inse \subset ncpinse$	Construction, industrial and service sectors
nwa: $nwa \subset sec$	Non-water sectors
insd	Domestic institutions including government, enterprise and households
insdng: $insdng \subset insd$	Domestic institutions except government
hou: $hou \subset insdng$	Urban and rural households

A2.2. Variables

PK	Return to capital
PL_{sec}	Wage rate of composite labor
PLF_{agc}	Wage rate of composite agricultural labor
$PLFR_{prov}$	Wage rate of provincial agricultural labor
PLE	Wage rate of non-agricultural labor (fixed as the numeraire)
PLD_{prov}	Return to cropland of 16 provinces
PWR_{prov}	Irrigation water price of 16 provinces
$PWRPOTH_{cro}$	Price of composite water of "Other provinces"
$PLWR_{cro,prov}$	Price of provincial land-water bundle of 16 provinces
PLW_{cro}	Price of land-water bundle
PVA_{sec}	Price level of value-added

$PVAW_{ncpinse}$	Price level of composite demand of water and value-added
P_{sec}	Price level of domestic sales of composite commodities
PD_{sec}	Price level of domestic output of firm
PDD_{sec}	Price of domestic output delivered to home market
PM_{sec}	Import price with tariffs in local currency
PE_{sec}	Price of exports in local currency
$PCINDEX$	Consumer price index (commodities)
ER	Exchange rate (RMB against U.S. dollar)
X_{sec}	Domestic sales of composite commodity
XD_{sec}	Gross domestic production (output) level firm
XDD_{sec}	Domestic production delivered to home markets
E_{sec}	Export demand
M_{sec}	Import demand
K_{sec}	Capital demand
L_{sec}	Composite labor demand
LF_{agc}	Composite agricultural labor demand
LE_{sec}	Non-agricultural labor demand
$LFR_{prov,agc}$	Agricultural labor demand at provincial level
WAP_{sec}	Pipe water demand
$LD_{cro,prov}$	Cropland demand of farming sectors of 16 provinces
$WAR_{cro,prov}$	Irrigation demand of farming sectors of 16 provinces
$WARPOTH_{cro}$	Composite water demand of "Other provinces" for farming sector
$LWR_{cro,prov}$	Demand of provincial land-water bundle of 16 provinces
LW_{sec}	Demand of land-water bundle
VA_{sec}	Value-added demand
$VAW_{ncpinse}$	Composite demand of pipe water and value-added
$IO_{nwa,sec}$	Intermediate input demand
$C_{sec,hou}$	Consumer households' demand for commodities and leisure
CG_{sec}	Government commodity demand
UU_{hou}	Proposed change in utility level of households
EP_{hou}	Proposed change in the level of equivalent variation
EV_{hou}	Equivalent variation to measure the welfare changing of households
I_{sec}	Investment demand
IG_{sec}	Interests payment to government
$TAXR$	Total tax revenue of government
$TSDWR$	Total subsidies on irrigation water
SP_{insdng}	Households and enterprise savings
Y_{insdng}	Income level of households and enterprise
$NGDP$	Nominal gross domestic products of macro economy
$RGDP$	Real gross domestic products of macro economy
$IRWAG_{insd,prov}$	Supply of provincial irrigation water of 16 provinces (exogenous)
$LDS_{insd,prov}$	Domestic cropland endowment of 16 provinces (exogenous)

$TRI_{insd,insd}$	Transfers between institutions (exogenous)
SF	Foreign savings (exogenous)
LSE_{insd}	Total non-agricultural labor supply (exogenous)
$LSFR_{insd,prov}$	Total agricultural labor supply of 16 provinces (exogenous)
KS_{insdng}	Total capital supply (exogenous)
$pWeZ_{sec}$	Initial world price level of exports (exogenous)
$pWmZ_{sec}$	Initial world price level of exports (exogenous)
NFD_{insdng}	Net revenue of factor from foreign market (exogenous)
$KSRW$	Foreign capital demand in local current (exogenous)
RGF	Foreign revenue of government (exogenous)
EGF	Foreign expenditure of government (exogenous)
$CZ_{sec,hou}$	Initial households' consumer demand for commodities and leisure (exogenous)
$UUZ_{sec,hou}$	Initial utility level of households (exogenous)
EPZ_{hou}	Initial level of equivalent variation (exogenous)
PZ_{sec}	Initial price level of domestic sales of composite commodities (exogenous)
PMZ_{sec}	Initial import price with tariffs in local currency (exogenous)
PEZ_{sec}	Initial Price of exports in local currency (exogenous)

A2.3. Parameters

$\sigma LW_{cro,prov}$	Elasticity of substitution between cropland and irrigation water of 16 provinces
$\alpha LW_{cro,prov}$	Efficiency parameter for land-water bundle of 16 provinces
$\gamma LW_{cro,prov}$	CES distribution parameter for land-water bundle of 16 provinces
σL_{sec}	Elasticity of substitution between agricultural and non-agricultural labor
σA_{sec}	Substitution elasticity of Armington function
σT_{sec}	Substitution elasticity of CET function
γL_{sec}	CES distribution parameter for composite labor
γA_{sec}	CES distribution parameter for Armington function
γT_{sec}	CES distribution parameter for CET function
$\beta LW_{cro,prov}$	Cobb-Douglas power of provincial water-land bundle of 16 provinces
$\beta LFR_{agc,prov}$	Cobb-Douglas power of provincial agricultural labor of 16 provinces
βFL_{sec}	Cobb-Douglas power of composite labor in value-added bundle
βFK_{sec}	Cobb-Douglas power of capital in value-added bundle
βFLW_{cro}	Cobb-Douglas power of composite land-water in value-added bundle
$bFLWR_{sec}$	Scale parameter for composite provincial water-land bundle
$bFLFR_{sec}$	Efficiency parameter for provincial agricultural labor
$\sigma WARP_{cro}$	Elasticity of substitution between the pipe water and irrigation water of "Other provinces"
$\gamma WARP_{cro}$	CES distribution parameter for the pipe water and irrigation water of "Other provinces"
$\alpha WARP_{cro}$	Efficiency parameter for the pipe water and irrigation water of "Other provinces"

$\sigma VAW_{ncpinse}$	Elasticity of substitution between the pipe water and value-added
$\gamma VAW_{ncpinse}$	CES distribution parameter for the pipe water and value-added
$\alpha VAW_{ncpinse}$	Efficiency parameter for the pipe water and value-added
αL_{sec}	Efficiency parameter for composite labor
bF_{sec}	Efficiency parameter for value-added bundle
σF_{inse}	Elasticity of substitution between capital and non-agricultural labor
γF_{inse}	CES distribution parameter for the capital and non-agricultural labor
αF_{inse}	Efficiency parameter for the capital and non-agricultural labor
αA_{sec}	Efficiency parameter of Armington function of commodity
αT_{sec}	Efficiency parameter of CET function of commodity
iva_{sec}	Technical coefficients of Leontief function for value-added
$iio_{nwa,sec}$	Technical coefficients of Leontief function
$\alpha H_{sec,hou}$	Power in nested-ELES household utility function
mps_{insdng}	Domestic institutions' marginal propensity to save
mpg	Government's marginal propensity to save
ty_{insdng}	Tax rate on domestic institution's income including households and enterprise
tm_{sec}	Tariff rate for each import
$tswr_{cro,prov}$	Subsidy rates for irrigation waterof 16 provinces
αI_{sec}	Cobb-Douglas power in the bank's utility function
tva_{sec}	Net production tax on value-added
αCG_{sec}	Cobb-Douglas power of the government utility function (commodities)
αIG	Cobb-Douglas power of the interests payment of government

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