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Impact of Natural Hazards on Agricultural Economy and Food Production in China: Based on a General Equilibrium Analysis

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Abstract

Based on a standard general equilibrium model for China's macro economy with multi-regional sectors, including water, croplands, agricultural labor and rural households, this study estimated the impact on the agricultural economy and food production from natural hazards in 2007 and considered two simulations: i) the drought-exempt case, which supposed that a drought did not occur; ii) the flood-exempt case, which supposed that a flood did not occur. The discussion focuses on the results obtained from the drought-exempt case, which was similar to but more significant than the flood-exempt case, because the drought in 2007 was the most widespread in recent years and was also more serious than the flood. In both cases, real GDP obtained insignificant positive effects contributed by the rise of agricultural output, but the effects on nominal GDP was negative. All agricultural productions increased their outputs and exports, especially for sorghum, oil seed and corn. Another finding was that more capital and less labor were related to most crop productions. All food productions also increased their outputs and exports, thus their energy inputs increased, especially for sugar, meats and vegetables. Households benefited from lower prices for all agricultural and food products from more domestic outputs and fewer imports. However, more food consumption and higher welfare occurred in urban households rather than in rural households. This was due to the declines in the returns of cropland and in the wages of agricultural labor. The worst rural households were located in Shandong, Henan, Hebei, Yunnan, Anhui, and Heilongjiang.

Keywords: natural hazards, agricultural economy, food production, CGE model, multi-regional sectors

1. Introduction

In the past several decades, regional and paroxysmal meteorological disasters have dominated in many parts of China, causing great economic losses and affecting local sustainable development (Chen & Yang, 2013). China's recent relentless droughts and floods have threatened millions of lives and agricultural production. Such impacts include the loss of US $ 6 billion and the lack of water for 23 million people during the drought in the southwest in early 2010 and losses of US $ 40 billion and 2, 000 deaths due to flooding in 2011 (Li, 2012). With respect to agriculture, unforeseen crop failures caused by natural hazards may also be instrumental in the reported losses. This paper uses a computable general equilibrium model with an energy module (CGE-Energy model) to quantify the effect of regional natural hazards (droughts and floods) on the agricultural economy and food production as well as their effects on regional rural households.

2. Background Literature Review and Hypothesis

2.1 Regions Affected by Natural Hazards

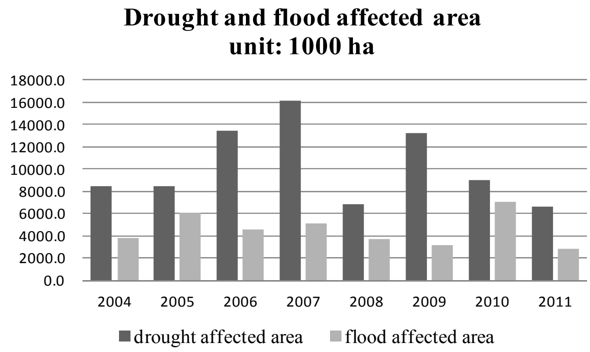

Figure 1. Changes in drought and flood affected areas from 2004 to 2011

Note: "Area" indicates cultivated area; "affected" means the cultivated area where yields are reduced by more than 30% (Center for International Earth Science Information Network & Socioeconomic Data and Applications Center [CIESIN & SEDAC], 1997-2009). Data source: China Rural Statistics Yearbook 2012 (National Bureau of Statistics [NBSC], 2012).

In China, droughts have been widespread and have caused serious losses in throughout history while floods, on the other hand, are the most frequent natural disaster. According to Figure 1, droughts have affected larger areas than floods over these years. The most widespread drought occurred in 2007, where the nationally cultivated area affected by the drought was 16169.9 ha, an area that accounts for 10.54% of the total land area. The flood-affected area was 5104.7 ha in this same year, which was the third worst loss for 2007.

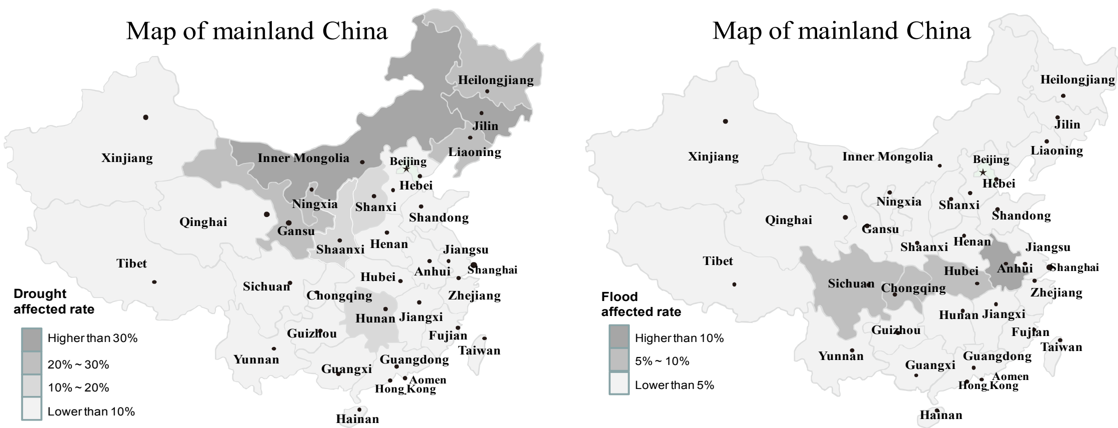

Figure 2. Regional drought and flood affected areas in 2007

Note: For each region, affected rate = affected area / cultivated area. Data source: China Rural Statistics Yearbook 2012 (NBSC, 2012).

The distribution of the occurrence of natural disasters and their impact is a reflection of the regional disparities in physical geography as well as the social and economic development of China (Liu, Yang & Li, 2012). With respect to the impact of natural disasters on regional development, the frequency of the disasters or the absolute loss in agriculture becomes the main consideration. Simelton (2011) contends that between 1955 and 2008, the southern parts of China experienced less severe drought impacts compared to the northern provinces, and the same or more intense flood impacts compared to the northern and southwestern provinces. The details of the regional areas affected by drought and flood of 2007 are displayed in Figure 2. As evidenced in this figure, the areas where the effects of the drought exceed 30% include Inner Mongolia and Jilin, and those where the effects are between 20% and 30% includes Liaoning, Heilongjiang, Gansu and Ningxia; Those areas hit hardest by the flood, that is, where the affected area exceeds 10% is Anhui, while the second most negatively impacted by the floods include the regions of Hubei, Chongqing and Sichuan.

2.2 Food Consumption and Energy Requirement

The size of China and its number of inhabitants --- one-fifth of the world's population --- along with the fact China has less than 7% of the world's cultivated land must be considered in this study (Zhao et al., 2008). Subsequent scientific analyses have noted that, while China produces approximately one-fifth of the grain produced globally, it trades very little in the three main staple crops --- rice, wheat and maize. Hence, China is largely self-sufficient (Dawe, 2009). This basic characteristic reveals the fact that the loss of cropland due to droughts and floods will have a profound influence on food security in China for decades, if not centuries (Yang & Li, 2000). Accordingly, while the significance attached to the national strategy for cropland protection, especially with respect to natural hazards, should be further enhanced and iterated on a regular basis, the systematic analysis of the macro economy, including the diversity in multi-regional households, is rarely found in the literature.

On the other hand, Harvey and Pilgrim (2011) argue that during a recent debate, a primacy of claim over land use for the production of food was staked, though the demand for energy and materials, in particular the development of alternatives to counter the depletion of petro-chemical resources, was not addressed in this debate, a failure that could inevitably result in major economic and social disruption on a global scale. In addition, Lucas, Jones and Hines (2006) posit that industrialized farming systems require 50 (sometimes up to 100) times the energy input of traditional agricultural systems, and it is estimated that 95% of all food products require the use of oil. Therefore, enhanced and sustainable social welfare will depend on developing new forms of agricultural production of both energy and food, highlighting the significance of 'the sustainable intensification of global agriculture (Godfray et al., 2010).

2.3 Hypotheses

We aim to simulate the short-term effects of the China droughts and floods of 2007. Based on the estimation from existing data regarding the affected areas at the regional level, we consider two cases, respectively: simulation 1, suppose the droughts did not occur (S1: Drought-exempt case); simulation 2, suppose the floods did not occur (S2: Flood-exempt case). We contend that a more significant impact will be observed in the Drought-exempt case than in the Flood-exempt case as a basic hypothesis. The detailed hypotheses that guide our research in this study include:

Hypothesis 1 (H1): In both cases, as all of the outputs of agricultural products will increase, their exports will also increase and their imports will decrease. The growth of agricultural production will contribute to the increase in real GDP, although the nominal GDP will decrease due to the lower consumer price index.

Hypothesis 2 (H2): In both cases, as all food products will increase, their exports will also increase and imports will decrease. Furthermore, the energy input in the food industries will increase.

Hypothesis 3 (H3): Because the price of food will decrease, urban households will benefit from the higher level of food consumption and welfare, while rural households will not benefit because their incomes will be significantly decreased due to the lower returns on cropland.

3. Methodology and Database

3.1 Previous CGE Models of Agriculture

By relying on Social Accounting Matrix (SAM), computable general equilibrium (CGE) models aggregate industries and products at a high level (Palatnik & Roson, 2012). We constructed a standard CGE model for China's agricultural economy (Zhong, Okiyama, & Tokunaga, 2013), based on Akune, Okiyama and Tokunaga (2011), Hosoe, Gasawa and Hashimoto (2010) and Tokunaga, Resosudarmo, Wuryanto and Dung (2003). In this paper, we extend this standard CGE model by adding multi-regional water demand and supply as well as a module for the substitution effect on more energy-efficient capital in food and energy production, namely, the CGE-Energy model, which is based on the EcoMod Modeling School (2013) program. This model also refers to Okiyama and Tokunaga (2010), Ge and Tokunaga (2011) and Ge, Lei and Tokunaga (2014) as well as previous CGE models with energy and water including GTAP-E (Burniaux & Truong, 2002) and GTAP-W (Calzadilla, Rehdanz & Tol, 2011). The detailed mathematical functions of CGE-Energy model are shown in Appendix 1.

3.2 Modeling Framework

The standard CGE model has often criticized as being insufficiently validated (Beckman, Hertel, & Tyner, 2011). Thus, the CGE-Energy model applied herein modifies the production structure of the standard CGE model to more closely represent the ability of firms to substitute among alternative fuels as well as among labor, capital and energy for food and energy production by removing energy from intermediate input nest and incorporating into the value-added nest, thus resulting in the GTAP-E model. The advantage of CGE model with energy is that this formulation allows for: i) the substitution among the relevant fuels; ii) the substitution between energy and capital in the energy-capital composite nest; and iii) substitution between the energy-capital composite nest and other factors (Nijkamp, Wang, & Kremers, 2005). We refer to the GTAP-W model by combining multi-regional water inputs of different crop productions with their multi-regional croplands, where these water inputs are also removed from intermediate input.

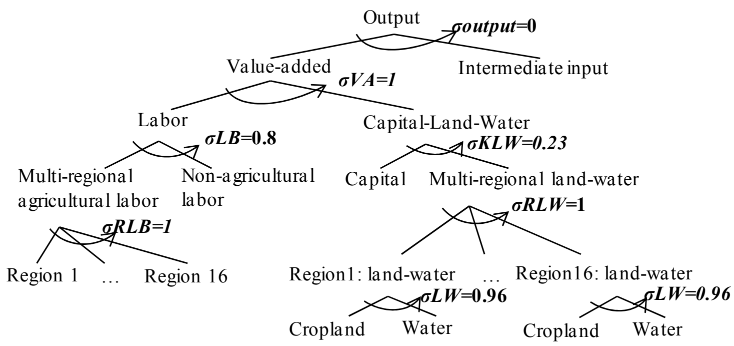

Figure 3. Nesting CES production structure of crop agricultural sectors

Note: $\sigma_{LB} = 0.8$ and σ_{RLB}=1 are given from Ge and Tokunaga (2011); $\sigma_{KLW} = 0.23$ and $\sigma_{LW} = 0.96$ is from the GTAP-W model defined by Calzadilla et al (2011); $\sigma_{output} = 0$ and $\sigma_{RLW} = 1$ are related to Leontief and Cobb-Douglas assumptions respectively. Crop sectors include paddy, wheat, corn, vegetable, fruit, oil seed, sugarcane, potato, sorghum and other crops.

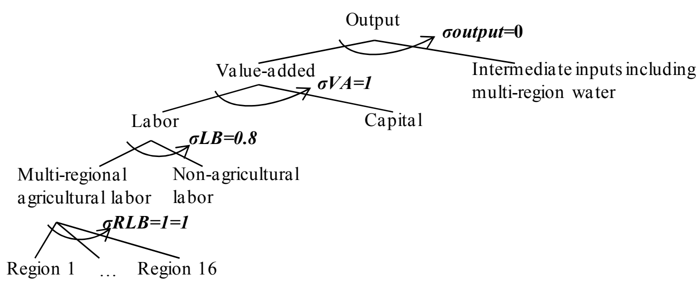

Figure 4. Nesting CES production structure of non-crop agricultural and construction sectors

Note: non-crop agricultural sectors include livestock, forestry, fishery and service for agriculture.

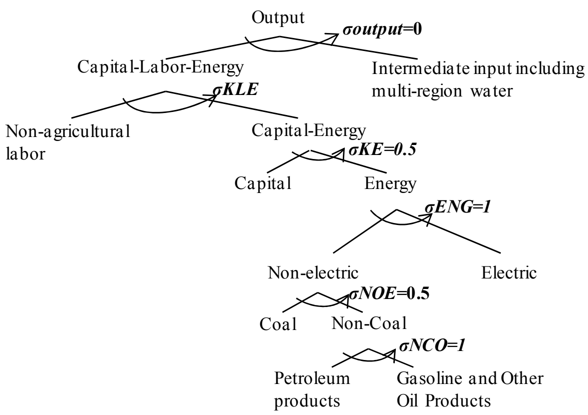

Figure 5. Nesting CES production structure of food and energy sectors

Note: the values of σ_{KLE}, σ_{KE}, σ_{ENG}, σ_{NOE}, and σ_{NCO} refer to Burniaux and Truong (2002). Food sectors include meat, vegetable oil, milk, grain, sugar, other food and alcohol, drink and tobacco.

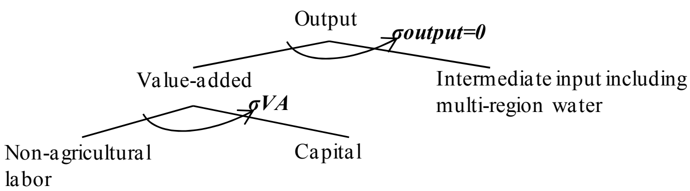

Figure 6. Nesting CES production structure of water and other sectors

Note: water sectors include 16 regional water productions, other mining, other manufactures, trade, transportation, insurance and finance, communication and computer and other service.

To minimize production costs, it is assumed that each sector produces one kind of good and that all sectors make production decisions in accordance with the principle of constant returns to scale. This model uses the nesting constant elasticity of substitution (CES) production function type. The nesting structures of the CES production function of different production sectors differ due to their differences of required input factors. We divide production sectors into three categories: i) the agriculture and construction sectors, which employ multi-regional inputs including croplands, waters, and agricultural labors combined with macro non-agricultural labor and capital; ii) the food and energy sectors, which require multi-energy inputs; and iii) the multi-regional waters as well as other sectors considered as normal in the standard CGE model. The nesting CES production structure of the above production sectors are shown in Figures 3-6. The values of substitution elasticity (σ) are derived from previous studies.

3.3 Database and Assumptions of Model

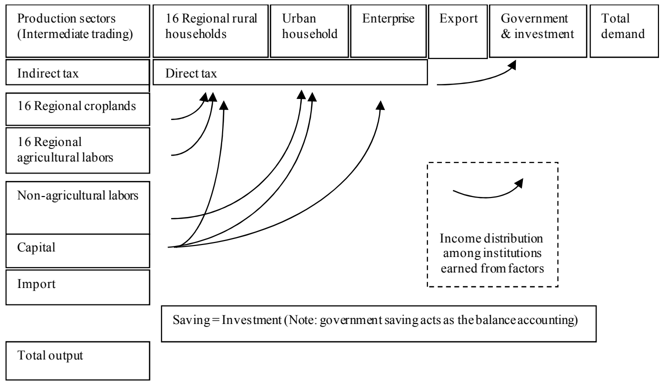

Figure 7. The CGE-Energy flows database

The Social Accounting Matrix (SAM) applied in this CGE model is basically contributed by Ge and Tokunaga (2011) and Ge et al. (2014) (the simplified structure of SAM is displayed in Figure 7), and the detailed construction of SAM can be found in those studies. In short, the disaggregated information on regional inputs for sectoral cropland and agricultural labor is calculated by the data on area planting data from the China Agricultural Yearbook 2008 (NBSC, 2008a) and National Data Compilation of Revenue and Cost of Agricultural Products 2008 (NDRCC, 2008). The income distributions among government and enterprise as well as urban and rural households are derived from China Statistic Yearbook 2008 (NBSC, 2008b). Indeed, the SAM given from Ge and Tokunaga (2011) has only the aggregated account defined as the electrical, gas and water account without a signal water account. However, there is no data in detail regarding regional water inputs distributed by different agricultural and food productions. To separate this account, we use a constant share to derive the water account and the new aggregated account of electric power and gas. Furthermore, the regional water sectors - the production and distribution of water defined in office database, are derived from the China Regional Input-Output Table (NBSC, 2011). Since there are only two sectors --- agricultural sector and food sector defined in this regional input-output table, we assume the constant shares of regional water inputs are used to separate the sectoral water inputs in agricultural and food productions. These regional water sectors represent the water demand and supply at the regional level. Cropland, agricultural labor and rural household are also divided into 16 regions including Guangdong, Jiangxi, Hainan, Yunnan, Guangxi, Henan, Jilin, Anhui, Heilongjiang, Hebei, Hubei, Chongqing, Sichuan, Inner Mongolia, Shandong, and other regions, which are the same as those in the water sector. For the sake of brevity, the detailed SAM can be obtained from the authors upon request.

As a single country, open economy, the CGE model assumes a small country context in which the world prices of imports and exports are exogenously fixed. The CGE-Energy model follows the Armington (1969) assumption as do most CGE models. The domestic production of each commodity is allocated between domestic and export markets through a constant elasticity of transformation (CET) function, and the domestic consumption of each commodity is presented by an Armington composite commodity combined with domestic products and importing products according to the CES function. Those values of elasticity in the above functions are also derived from previous studies by Zhai and Hertel (2005) and Willenbockel (2006). The impart tariff of each sector is estimated by Ge and Tokunaga (2011). Together with the estimated values of the substitution elasticities obtained from the literature, the equilibrium is calibrated based on the underlying dataset.

On the consumption side, the consumption behaviors of multi-regional rural households (16 provinces, the same as those for water, agricultural labor and land) and one urban household are defined by the Stone-Gary utility function with diversity in the income elasticities of commodities (see Appendix 2). One of the important parameters for calibration when using the Stone-Gary utility function is the Frisch parameter, which describes the relation between the price elasticity and the income elasticity for each commodity. The value of the Frisch parameter is equal to -3.5 for all households according to Zhao and Wang (2008). There are two monetary measures for the changes in welfare compared with the benchmark equilibrium and the proposed change. The first measure is the equivalent variation (EV), which measures the income change at current prices that would be equivalent to the proposed change in terms of its impact on utility. The second monetary measure is the compensating variation (CV), which measures the income change that would be necessary to compensate the consumer for the price change that is induced by the proposed change (EcoMod Modeling School, 2013). As in a typical CGE analysis, we only discuss the change in EV such that: if EV is positive, the simulation increases welfare, and if it is negative, the simulation decreases welfare. In addition, government consumption and investment are assumed to be Cobb-Douglas with respect to all commodities.

As the CGE-Energy model is a static equilibrium model, we interpret the benchmark equilibrium as a representation of the national economy over a period of time. The domestic prices of imports and exports are in Chinese Yuan (RMB). For simplicity, in the base year, all prices are assumed to equal one. The wage of non-agricultural labor is exogenously fixed as the numeraire price index. Other fixed valuables include the sectoral stock changes as the balancing account; the total amount of agricultural labor supply in different regions and the non-agricultural labor supply; the capital endowments from enterprise as well as urban and multi-regional rural households; and transfers from the rest of world, enterprise and government to households at the regional level; and the balance of total export and total import (namely, foreign saving).

4. Simulation Results and Discussion

4.1 Simulation Design

Table 1. Modified values of cultivated land input in social accounting matrix

Unit: 10000 yuan	PDR	WHT	COR	VEG	FRU	OSD	SUR	POT	SOR	OCR	Modified rate
Guangdong	33290	8	1392	20112	1149	2444	2297	2378	3	100665	-0.01836
Jiangxi	24910	90	161	8173	1755	4183	145	995	21	3898	-0.03144
Hainan	1468	0	183	2790	688	256	194	594	0	5306	-0.02784
Yunnan	9775	2921	9502	9002	562	2057	3994	4154	34	1053	-0.03033
Guangxi	29993	31	5121	19920	1660	1197	14247	1541	33	9882	-0.02251
Henan	6003	54122	27750	31144	8389	18215	41	2099	44	5268	-0.01737
Jilin	6024	40	49481	4343	1426	1722	0	671	808	2865	-0.11669
Anhui	12035	11237	3341	13255	4410	5769	73	1212	14	787	-0.03299
Heilongjiang	21117	2410	44941	4383	2558	1303	0	1511	568	1847	-0.0795
Hebei	827	26120	29120	18547	2633	3842	0	1889	315	3963	-0.03817
Hubei	11666	5441	2433	5783	2381	7924	48	1602	38	817	-0.04202
Chongqing	6387	537	1552	4097	528	634	38	4992	115	2338	-0.03796
Sichuan	20052	5803	5504	45743	1282	6280	79	8149	470	4577	-0.03282
Inner Mongolia	729	5258	26063	4493	1107	3824	0	4253	1304	7233	-0.10408
Shandong	1313	22483	17591	41347	6720	6353	0	1747	93	12691	-0.01161
Other regions	94563	51237	75458	111868	19403	23881	682	21267	2450	931	-0.04051

PDR - paddy; WHT - wheat; COR - corn; VEG - vegetable; FRU - fruit; OSD - oil seed; SUR - sugarcane; POT - potato; SOR - sorghum; OCR - other crops.

The changes caused by natural disasters in our simulation focus on the variations of the cultivated areas at the regional level. Because the cropland in the SAM, as estimated by Ge and Tokunaga (2011), is the initial cultivated level without any information about drought and flood, the first step for this study is to modify those values by reducing the parts affected by the droughts and floods in 2007. These modified values for all crops are displayed in Table 1. We define modified rate using the following method: affected farming area = cultivated area of farming – drought affected area * 0.3 – flood affected area *0.3; affected rate = (affected farming area – initial farming area) / initial farming area. The affected area is defined by the National Bureau of Statistics as a cultivated area with more than 30% harvest loss (CIESIN & SEDAC, 1997-2009).

In a second step, the above modified values of cultivated land are input into SAM as a baseline to estimate the parameters (see Table 2) for two simulations: S1 supposes drought did not occur, namely, Drought-exempt case; and S2 supposes flood did not occur, namely, Flood-exempt case. We then test the three hypotheses. For example, with respect to the Guangdong region, if the drought did not occur, the modified value of its total cultivated area should increase by 1.36%. If the flood did not occur, this value should increase by 0.830%.

Table 2. Values of regional cultivated land and the estimation of parameters for two simulations

16 Regions	The amount of regional cultivated land in 2007 Unit: 10 thousand yuan		Simulation parameters Unit: %	
	(1) Initial values of regional land	(2) Modified values of regional land	(3) Drought-exempt Case, S1	(4) Flood-exempt Case, S2
Guangdong	166800	163738	1.360	0.830
Jiangxi	45771	44332	3.306	0.561
Hainan	11808	11479	0.000	3.328
Yunnan	44401	43054	2.203	1.478
Guangxi	85552	83626	1.957	0.693
Henan	155782	153076	0.682	1.203
Jilin	76281	67380	19.408	0.173
Anhui	53911	52132	0.023	3.779
Heilongjiang	87602	80638	11.185	0.071
Hebei	90719	87256	3.341	3.036
Hubei	39807	38134	1.730	3.401
Chongqing	22056	21219	1.857	2.895
Sichuan	101262	97939	2.045	1.916
Inner Mongolia	60569	54265	18.696	0.315
Shandong	111635	110339	0.825	0.393
Others	418703	401739	4.100	0.997

Note: Column (1) presents the initial value of regional total amount of cultivated lands from Ge and Tokunaga (2011); Column (2) lists the modified values of them equal to the summation of regional input croplands shown in Table 2; Columns (3) and (4) are estimated parameters according to the database regarding 16 regional totally cultivated areas and the areas affected by drought and flood. All data are derived from China Rural Statistics Yearbook 2012 (NBSC, 2012).

4.2 Results and Hypothesis Testing

4.2.1 Impacts on Macro Economy and Agricultural Production

Table 3. Change in macro economy

Unit: %	S1: Drought-exempt case	S2: Flood-exempt case
Nominal GDP	-0.0124	-0.0035
Real GDP	0.0005	0.0001
Consumer price index	-0.0193	-0.0056
Capital return	-0.0027	-0.0008
Exchange rate	-0.0072	-0.0020
Total consumption of household	-0.0158	-0.0045
Total investment	-0.0017	-0.0005
Total Export	-0.0014	-0.0005
Total import	-0.0023	-0.0008
Total output of crops	0.0228	0.0068

Table 3 presents the results generated by the macroeconomic effects of the two cases. S1 obtains more significant changes in all results than S2, regardless of sector, thus suggesting that in 2007, the drought had more serious implications than did the flood in China. However, in reality, the change in the macro economy exhibited no significance in either of two cases. S1 increases real GDP by 0.0005%, which is mainly contributed by the increase of 0.0228% in the output of crops. The nominal GDP, on the other hand, decreases basically due to the 0.0193% reduction in the consumer price index. Furthermore, all of the other indices including capital return, exchange rate, total consumption, total investment, total export and total import suffer negative effects. As the changes in results of S2 are similar to S1, they are not more remarkable than S1. Therefore, if the droughts or the floods did not occur, the macro economy would not be expected to increase significantly, even thought there would be an increase in crop production.

Table 4. Changes in agricultural products

	S1: Drought-exempt case				S2: Flood-exempt case			
	Output	Price	Export	Import	Output	Price	Export	Import
Paddy	0.011	-0.107	0.369	-0.503	0.004	-0.032	0.112	-0.153
wheat	0.028	-0.114	0.393	-0.473	0.012	-0.047	0.167	-0.200
Corn	0.078	-0.312	1.121	-0.384	0.013	-0.048	0.170	-0.057
Vegetable	0.015	-0.100	0.341	-0.226	0.005	-0.034	0.119	-0.079
Fruit	0.018	-0.048	0.162	-0.099	0.006	-0.016	0.054	-0.033
Oil seed	0.251	-0.040	0.628	-0.059	0.092	-0.014	0.230	-0.023
Sugarcane	0.021	-0.076		-0.152	0.007	-0.027		-0.054
Potato	0.036	-0.167	0.610	-0.387	0.011	-0.051	0.188	-0.120
Sorghum	1.289	-0.837	3.652	-2.023	0.162	-0.108	0.458	-0.259
Other crops	0.011	-0.052	0.172	-0.103	0.003	-0.015	0.050	-0.030
Livestock	0.010	-0.062	0.210	-0.073	0.003	-0.016	0.053	-0.018
Forestry	0.024	-0.035	0.159	-0.070	0.007	-0.010	0.045	-0.020
Fishery	0.011	-0.048	0.156	-0.044	0.003	-0.013	0.043	-0.012
Service for Agriculture	0.013	-0.042	0.139	-0.074	0.004	-0.011	0.038	-0.020

Note: "Price" is the price of Armington composite products aggregated from domestic and import products, and it presents the selling price the final demand including household should charge.

While all of the outputs and exports of crops are increased in S1 and S2, the results in S1 are more significant than S2. In S1, the best three crops are sorghum, oil seed and corn, which increase their outputs by 1.289%, 0.251% and 0.078%, respectively, and increase their exports by 3.652%, 0.628% and 1.121%, respectively. S1 and S2 also decrease the price and import of all crops. Therefore, the domestic demand, for example, the household, will benefit from lower prices of agricultural products as the share of domestic products will increase (see Table 4). Therefore, according to the results presented in Tables 3 and 4, H1 is supported.

S1 also demonstrates more significant results than S2 in Table 5. Column ALW in S1 and S2 represents the simulation that if the drought or the flood did not occur, the croplands would increase, and thus, the aggregated regional cropland (ALW) would also increase. We also find that sorghum, potato and corn account for more of the ALW than the other crops, and their increase with respect to ALW are 5.730%, 1.721% and 3.332%, respectively. A new finding is that most crop production requires greater capital and reduces the input of labor, including agricultural labor and non-agricultural labor. There are only two exceptions to this finding: sorghum and oil seed, which increase with respect to all of their inputs. Therefore, for these two cases, whereby more cropland is available, most crop productions employ more capital to substitute for labor and increase their outputs. Moreover, the released agricultural labor is reallocated into non-crop productions, such as livestock, forestry, fishery and service for agriculture.

Table 5. Change in employment of crop productions

Unit: %	S1: Drought-exempt case				S2: Flood-exempt case			
	ALW	CAP	LAG	LNA	ALW	CAP	LAG	LNA
Paddy	0.980	0.549	-0.125	-0.173	0.302	0.170	-0.039	-0.052
Wheat	1.152	0.697	-0.119	-0.169	0.540	0.330	-0.058	-0.072
Corn	3.332	1.876	-0.290	-0.341	0.438	0.247	-0.036	-0.050
Vegetable	0.505	0.191	-0.033	-0.082	0.203	0.080	-0.015	-0.029
Fruit	0.686	0.124	-0.042	-0.091	0.245	0.046	-0.017	-0.031
Oil seed	1.287	0.636	0.146	0.098	0.506	0.250	0.049	0.035
Sugarcane	1.136	0.527	-0.031	-0.080	0.462	0.218	-0.015	-0.029
Potato	1.721	0.695	-0.083	-0.132	0.543	0.222	-0.027	-0.041
Sorghum	5.730	3.800	0.642	0.592	0.659	0.444	0.088	0.074
Other crops	0.607	0.436	0.007	-0.042	0.216	0.156	0.002	-0.012
Livestock		-0.044	0.014	-0.034		-0.013	0.004	-0.010
Forestry		-0.030	0.028	-0.021		-0.008	0.008	-0.006
Fishery		-0.042	0.015	-0.033		-0.012	0.004	-0.009
Service for Agriculture		-0.041	0.017	-0.032		-0.012	0.005	-0.009

Note: ALW - Aggregated regional land and water; CAP - Capital; LAG - Aggregated regional agricultural labor; LNA - Non-agricultural labor.

4.2.2 Impacts on the Food Production

Table 6. Change in food products

Unit: %	S1: Drought-exempt case				S2: Flood-exempt case			
	Output	Price	Export	Import	Output	Price	Export	Import
Meat	0.018	-0.044	0.187	-0.091	0.004	-0.011	0.047	-0.023
Vegetable oils	0.017	-0.027	0.117	-0.059	0.005	-0.009	0.039	-0.020
Milk	0.013	-0.030	0.118	-0.049	0.004	-0.008	0.030	-0.013
Grain	0.012	-0.037	0.146	-0.068	0.003	-0.011	0.042	-0.020
Sugar	0.022	-0.038	0.175	-0.075	0.007	-0.013	0.059	-0.026
Other food	0.021	-0.031	0.122	-0.045	0.006	-0.009	0.035	-0.013
Alcohol, drinks and tobacco	0.002	-0.020	0.060	-0.014	0.001	-0.005	0.016	-0.004

Note: The meaning of this "Price" is the same in Table 4.

In both S1 and S2, as food productions increase their outputs and exports, the final products of food decrease in prices and imports (see Table 6). We focus on S1 where the increases in outputs of sugar, meat and vegetable are more significant than others with values of 0.022%, 0.018% and 0.017%, respectively. However, the top three increases in exports are meat, sugar and grain at 0.187%, 0.175% and 0.146%, respectively. Furthermore, meat, sugar and grain are consumed at slightly lower prices than other food products with declines in prices at 0.044%, 0.038% and 0.037%, respectively. Meat, sugar and grain are also the top three declining imports, reflecting lower import levels than other food products in that they decrease by 0.091%, 0.075% and 0.068%, respectively. Accordingly, the demand for food products is met by more domestic products and fewer imports.

Table 7. Change in energy input in food production

Unit: %		MEP	VOL	MIL	GOG	SUG	OTF	ADT
S1: Drought-exempt case	Coal	0.021	0.019	0.015	0.015	0.024	0.023	0.004
	Petroleum	0.021	0.020	0.016	0.015	0.024	0.024	0.005
	Gasoline	0.021	0.020	0.016	0.015	0.024	0.024	0.005
	Electricity and gas	0.020	0.019	0.015	0.014	0.023	0.023	0.004
S2: Flood-exempt case	Coal	0.005	0.006	0.004	0.004	0.008	0.007	0.001
	Petroleum	0.006	0.006	0.004	0.004	0.008	0.007	0.001
	Gasoline	0.006	0.006	0.004	0.004	0.008	0.007	0.001
	Electricity and gas	0.005	0.006	0.004	0.004	0.007	0.007	0.001

Note: MEP - meat; VOL - vegetable oil; MIL - milk; GOG - grain; SUG - sugar; OTF - other food; ADT - alcohol, drinks and tobacco.

The greater the food production output, the more energy input required, as indicated by the results in Table 7. Grain is not included as one of the top three food products requiring the most energy. Instead, the top three are sugar, meat and vegetable. These three food products benefit from the increases of all types of energy by approximately 0.024%, 0.021% and 0.020%, respectively in S1. S2 has similar results, though with lower values, thus supporting H2, which states that a drought-exempt case or a flood-exempt case will increase the demand of food production for energy input. Therefore, H2 is accepted.

4.2.3 Impacts on Households

Table 8. Change in food consumption, income and welfare of household

Unit for consumption and income: %; Unit for welfare: 10 million yuan	Regions	S1: Drought-exempt case Food consumption	S1: Income	S1: Welfare	S2: Flood-exempt case Food consumption	S2: Income	S2: Welfare
16 regional rural household	Guangdong	0.004	-0.041	-0.498	0.001	-0.012	-0.153
	Jiangxi	0.005	-0.043	-0.278	0.002	-0.013	-0.024
	Hainan	0.006	-0.044	-0.012	0.002	-0.014	-0.005
	Yunnan	-0.009	-0.063	-2.207	-0.002	-0.017	-0.498
	Guangxi	-0.0003	-0.052	-1.061	0.000	-0.016	-0.310
	Henan	-0.022	-0.052	-4.994	-0.007	-0.015	-1.507
	Jilin	-0.011	-0.063	-1.547	-0.001	-0.014	-0.257
	Anhui	-0.003	-0.046	-1.889	-0.001	-0.014	-0.553
	Heilongjiang	-0.010	-0.057	-1.757	-0.002	-0.015	-0.386
	Hebei	-0.014	-0.054	-3.647	-0.004	-0.015	-0.988
	Hubei	0.002	-0.044	-1.038	0.001	-0.013	-0.249
	Chongqing	-0.002	-0.053	-0.654	0.000	-0.015	-0.134
	Sichuan	0.002	-0.045	-1.043	0.001	-0.013	-0.187
	Inner Mongolia	-0.014	-0.057	-1.495	-0.003	-0.015	-0.355
	Shandong	-0.012	-0.049	-5.727	-0.004	-0.014	-1.682
	Others	-0.003	-0.045	-18.023	-0.001	-0.013	-4.723
Total change in rural household		-0.004	-0.049	-45.871	-0.001	-0.014	-12.011
Total change in urban household		0.012	-0.005	79.355	0.003	-0.001	22.355

Note: "Food" in this study refers to crops and the products from food industries and includes 5 kinds of products: meat, milk, vegetable oil, gain, sugar, and other food products.

All rural households suffer more significantly in S1 and S2, incurring greater losses in food consumption, income and welfare. Three rural household regions, however, are exceptions, demonstrating increased food consumption, including those from Guangdong, Jiangxi and Hainan. Moreover, urban households exhibit greater benefits with respect to food consumption and welfare; however, their income slightly decreases (see Table 8). Rural households in Shandong, Henan, Hebei, Yunnan, Anhui, and Heilongjiang suffer more significant losses with respect to their welfare at 57.27, 49.94, 36.47, 22.07, 18.89 and 17.57 million yuan, respectively.

Table 9. Changes in the return of land and the wage of agricultural labor

Unit: %	S1: Drought-exempt case		S2: Flood-exempt case	
	Returns of land	Wages of agricultural labor	Return of land	Wage of agricultural labor
Guangdong	-1.833	-0.058	-0.989	-0.017
Jiangxi	-4.198	-0.052	-0.894	-0.015
Hainan	-0.739	-0.061	-3.500	-0.019
Yunnan	-3.748	-0.076	-1.902	-0.020
Guangxi	-3.017	-0.058	-1.047	-0.017
Henan	-2.039	-0.063	-1.613	-0.018
Jilin	-18.407	-0.069	-0.552	-0.017
Anhui	-1.205	-0.054	-4.086	-0.016
Heilongjiang	-12.059	-0.061	-0.443	-0.017
Hebei	-4.826	-0.070	-3.362	-0.019
Hubei	-2.965	-0.056	-3.743	-0.016
Chongqing	-3.237	-0.067	-3.257	-0.019
Sichuan	-3.180	-0.053	-2.284	-0.015
Inner Mongolia	-17.803	-0.060	-0.719	-0.016
Shandong	-2.051	-0.062	-0.761	-0.018
Others	-5.409	-0.061	-1.402	-0.018

The different levels of welfare are determined by the changes in consumption, which are further controlled by income. With the fixed amount of regional lands and agricultural labor in this model, all decreases in the returns of land and in the wages of agricultural labor reduce the income of 16 regional rural households, especially for those rural households located in Jilin, Inner Mongolia and Heilongjiang, whose returns of cropland decrease by 18.407%, 17.803% and 12.509%, respectively (see Table 9). If the drought-exempt case or the flood-exempt case is presented as one kind of good harvest, these results support an old finding that a good harvest may reduce the farmer's income due to the lower returns associated with their croplands. Therefore, H3 is also accepted.

5. Conclusion

By applying the CGE-Energy model in the social accounting matrix of a macro economy with multi-regional sectors, including water demand and supply, cropland, agricultural labor and rural households, this study measured the effects of a drought-exempt case and a flood-exempt case in the worst year for droughts by testing three hypotheses. The real GDP obtains an insignificant positive effect contributed by the increase in agricultural outputs, while all other macro economy indices would be slightly worse, such as a nominal GDP, consumer price index and total consumption as well as total export and total import. The results indicate that in both cases, all agricultural productions increase their outputs and exports, but selling prices and the imports of agricultural products decrease. The most significant three crops in output were sorghum, oil seed and corn because their productions collected more cropland than others. Potato was also cultivated with more cropland, but its increase in output was not more significant than the aforementioned three crops. Another finding was that by investing more land to crop production, more capital and less labor would be required by most of the crops. Accordingly, the released labor could be redistributed into non-crop agricultural productions including livestock, forestry, fishery and service for agriculture. The increase in food production was also evident in the results with the most three significant outputs occurring in sugar, meat and vegetable oil. The energy input in their production, however, was also greater than that for food products. All exports of food products increased while their domestic prices and imports decreased. Therefore, households would benefit from the lower prices of all agricultural and food products supplied by more domestic outputs and fewer imports. Only urban households benefit from increased food consumption and higher welfare, while rural households would not benefit due to the declines in the returns on cropland and in the wages for agricultural labor. The rural households demonstrating the greatest negative change in welfare are from Shandong, Henan, Hebei, Yunnan, Anhui, and Heilongjiang. This result reveals an old finding that a good harvest may reduce a farmer's income because of a lower return on cropland. Therefore, if the government and farmers aim to protect their losses in harvest from natural hazards, they must prevent the decline in the return of cropland, an issue that should be considered during policy recommendations.

In general, because the results derived from CGE model may be significantly dependent on exogenous parameters, the sensitivity analysis should be performed to guarantee the robustness of model (Harrison, Jones, Kimbell & Wigle, 1993). In this study, we did not carry out the sensitivity analysis, since all given parameters were derived from previous studies (Ge et al., 2014; Willenbockel, 2006; Zhai & Hertel, 2005), where the sensitivity analysis on these parameters were already discussed. We admit that several parameters might be too imprecise to reflect the reality, such as the elasticity values of the CES function for the regional land and water composite and the Cobb-Douglas assumption for regional agricultural labor. But because of data limitations, we must accept these parameters. In addition, previous CGE studies suggested that further detailed analysis, based on disaggregated sectors and/or space, can reveal a more thorough and comprehensive figure of disaster impacts (Okuyama & Sahin, 2009). In this study, however, as our assumption regards only adjustments in regional total amount of cropland, the multiplier effects of droughts and floods were underestimated. In addition, according to the our interview survey on farmers, they always complain that the existing compensated supports, such as disaster subsidy and agricultural insurance, are not enough for compensating their losses in droughts and floods. However, it is obviously difficult for government to measure the actual losses on farmers' welfare. This study provides two simulations --- drought-exempt and flood-exempt to estimate the effects on the households' welfare. While future research could provide more detailed data regarding the impacts of droughts and floods, we will consider improving our simulation for policy instruments in future by introducing new simulation designs with respect to markets, risk mitigation, technical change, value chain integration and insurance and so on.

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Appendix 1. CGE-Energy Model

1. Equations

1.1 Household

1.1.1 Consumption

$$P_{sec} \cdot C_{sec,hou} = P_{sec} \cdot \mu H_{sec,hou} + \alpha HLES_{sec,hou} \cdot \left(CBUD_{hou} - \sum_{sec} P_{sec} \cdot \mu H_{sec,hou}\right) \quad (1)$$

$$SH_{hou} = mps_{hou} \cdot (Y_{hou} - ty_{hou} \cdot Y_{hou}) \quad (2)$$

1.1.2 Income of Household: Rural

$$Y_{hour} = PLAN_{lad} \cdot \overline{LANS}_{lad} + PL\_RA_{laa} \cdot \overline{LARS}_{laa} + PK \cdot \overline{KH}_{hour} + ER \cdot \overline{FH}_{hour} + PCINDEX \cdot (\overline{TRF}_{hour} + \overline{TRE}_{hour}) \quad (3)$$

1.1.3 Income of Household: Urban

$$Y_{URBH} = \overline{PLNA} \cdot \overline{LNAS}_{URBH} + PK \cdot \overline{KH}_{URBH} + ER \cdot \overline{FH}_{URBH} + PCINDEX \cdot (\overline{TRF}_{URBH} + \overline{TRE}_{URBH}) \quad (4)$$

1.1.4 Consumer Expenditure

$$CBUD_{hou} = (1 - ty_{hou}) \cdot Y_{hou} - SH_{hou} \quad (5)$$

1.1.5 Equivalent and Compensating Variation

$$PLES_{hou} = \prod_{sec} P_{sec}^{\alpha HLES_{sec,hou}} \quad (6)$$

$$PLES\_10_{hou} = PLES_{hou} / PLES_{hou}^{0} \quad (7)$$

$$SI_{hou} = CBUD_{hou} - \sum_{sec} \mu H_{sec,hou} \cdot P_{sec} \quad (8)$$

$$EV = \frac{SI_{hou}}{PLES\_10_{hou}} - SI_{hou}^{0} \quad (9)$$

$$CV = SI_{hou} - PLES\_10_{hou} \cdot SI_{hou}^{0} \quad (10)$$

1.2 Enterprise

$$YE = PK \cdot \overline{EK} \quad (11)$$

$$SE = mpe \cdot (YE - tye \cdot YE) \quad (12)$$

1.3 Firms

1.3.1 Agriculture: Crop

$$KLW_{cro} = \left(\frac{XD_{cro}}{aVA_{cro}}\right) \cdot \left(\frac{\alpha KLW \cdot PL_{cro}}{\alpha L_{cro} \cdot PKLW_{cro}}\right)^{\alpha L_{cro}} \quad (13)$$

$$L_{cro} = \left(\frac{XD_{cro}}{aVA_{cro}}\right) \cdot \left(\frac{\alpha L \cdot PKLW_{cro}}{\alpha KLW_{cro} \cdot PL_{cro}}\right)^{\alpha KLW_{cro}} \quad (14)$$

$$K_{cro} = \left(\frac{KLW_{cro}}{aKLW_{cro}}\right) \cdot \left(\frac{\gamma KLW_{cro}}{PK}\right)^{\sigma KLW_{cro}} \cdot \left(\gamma KLW_{cro}{}^{\sigma KLW_{cro}} \cdot PK^{1-\sigma KLW_{cro}} + (1 - \gamma KLW_{cro})^{\sigma KLW_{cro}} \cdot PLAWA^{1-\sigma KLW_{cro}}\right)^{\sigma KLW_{cro}/(1-\sigma KLW_{cro})} \quad (15)$$

$$LAWA_{cro} = \left(\frac{KLW_{cro}}{aKLW_{cro}}\right) \cdot \left(\frac{1-\gamma KLW_{cro}}{PLAWA}\right)^{\sigma KLW_{cro}} \cdot \left(\gamma KLW_{cro}{}^{\sigma KLW_{cro}} \cdot PK^{1-\sigma KLW_{cro}} + (1 - \gamma KLW_{cro})^{\sigma KLW_{cro}} \cdot PLAWA^{1-\sigma KLW_{cro}}\right)^{\sigma KLW_{cro}/(1-\sigma KLW_{cro})} \quad (16)$$

$$LAWAR_{was,cro} \cdot PLAWAR_{was,cro} = \alpha LW_{was,cro} \cdot PLAWA_{cro} \cdot LAWA_{cro} \quad (17)$$

$$WAT_{was,cro} = \left(\frac{LAWAR_{was,cro}}{aRLW_{was,cro}}\right) \cdot \left(\frac{\gamma LW_{was,cro}}{P_{was}}\right)^{\sigma LW_{cro}} \cdot (\gamma LW_{was,cro}{}^{\sigma LW_{cro}} \cdot P_{was}{}^{1-\sigma LW_{cro}} + (1-\gamma LW_{was,cro})^{\sigma LW_{cro}} \cdot PLAN_{lad}{}^{1-\sigma LW_{cro}})^{\frac{\sigma LW_{cro}}{1-\sigma LW_{cro}}} \quad (18)$$

$$LANR_{lad,cro} = \left(\frac{LAWAR_{was,cro}}{aRLW_{was,cro}}\right) \cdot \left(\frac{1-\gamma LW_{was,cro}}{PLAN_{lad}}\right)^{\sigma LW_{cro}} \cdot (\gamma LW_{was,cro}{}^{\sigma LW_{cro}} \cdot P_{was}{}^{1-\sigma LW_{cro}} + (1-\gamma LW_{was,cro})^{\sigma LW_{cro}} \cdot PLAN_{lad}{}^{1-\sigma LW_{cro}})^{\frac{\sigma LW_{cro}}{1-\sigma LW_{cro}}} \quad (19)$$

1.3.2 Agriculture: Non-crop

$$K_{ncro} = \left(\frac{XD_{ncro}}{aVA_{ncro}}\right) \cdot \left(\frac{\alpha K_{ncro} \cdot PL_{ncro}}{\alpha L_{ncro} \cdot PK_{ncro}}\right)^{\alpha L_{ncro}} \quad (20)$$

$$L_{ncro} = \left(\frac{XD_{ncro}}{aVA_{ncro}}\right) \cdot \left(\frac{\alpha L_{ncro} \cdot PK_{ncro}}{\alpha K_{ncro} \cdot PL_{ncro}}\right)^{\alpha K_{ncro}} \quad (21)$$

1.3.3 Agriculture: Labor

$$L\_A_{agc} = (L_{agc}/aLB_{agc}) \cdot \left(\frac{\gamma LB_{agc}}{PL\_A_{agc}}\right)^{\sigma LB_{agc}} \cdot (\gamma LB_{agc}{}^{\sigma LB_{agc}} \cdot PL\_A_{agc}{}^{1-\sigma LB_{agc}} + (1-\gamma LB_{agc})^{\sigma LB_{agc}} \cdot \overline{PLNA}^{1-\sigma LB_{agc}})^{\sigma LB_{agc}/(1-\sigma LB_{agc})} \quad (22)$$

$$LNA_{agc} = (L_{agc}/aLB_{agc}) \cdot \left(\frac{1-\gamma LB_{agc}}{\overline{PLNA}}\right)^{\sigma LB_{agc}} \cdot (\gamma LB_{agc}{}^{\sigma LB_{agc}} \cdot PL_{A_{agc}}{}^{1-\sigma LB_{agc}} + (1-\gamma LB_{agc})^{\sigma LB_{agc}} \cdot \overline{PLNA}^{1-\sigma LB_{agc}})^{\frac{\sigma LB_{agc}}{1-\sigma LB_{agc}}} \quad (23)$$

$$PL\_RA_{laa} \cdot L\_RA_{laa,agc} = \alpha LB_{laa,agc} \cdot PL\_A_{agc} \cdot L\_A_{agc} \quad (24)$$

1.3.4 Zero Profit Condition: Crop

$$(1-tp_{cro}) \cdot PD_{cro} \cdot XD_{cro} = PL_{cro} \cdot L_{cro} + PKLW_{cro} \cdot KLW_{cro} + \left(\sum_{agc} io_{agc,cro} \cdot XD_{cro} \cdot P_{agc}\right) + \left(\sum_{foe} io_{foe,cro} \cdot XD_{cro} \cdot P_{foe}\right) + \left(\sum_{ots} io_{ots,cro} \cdot XD_{cro} \cdot P_{ots}\right) \quad (25)$$

$$PKLW_{cro} \cdot KLW_{cro} = PK_{cro} \cdot K_{cro} + PLAWA_{cro} \cdot LAWA_{cro} \quad (26)$$

$$LAWA_{cro} = aLW_{cro} \cdot \prod_{was} PLAWAR_{was,cro}{}^{\alpha LW_{was,cro}} . \quad (27)$$

$$PLAWAR_{was,cro} \cdot LAWAR_{was,cro} = P_{was} \cdot WAT_{was,cro} + PLAN_{lad} \cdot LANR_{lad,cro} \quad (28)$$

1.3.5 Zero Profit Condition: Non-crop and Labor

$$(1-tp_{ncro}) \cdot PD_{ncro} \cdot XD_{ncro} = PL_{ncro} \cdot L_{ncro} + PK_{ncro} \cdot K_{ncro} + \sum_{agc} io_{agc,ncro} \cdot XD_{ncro} \cdot P_{agc} + \sum_{foe} io_{foe,ncro} \cdot XD_{ncro} \cdot P_{foe} + \sum_{ots} io_{wts,ncro} \cdot XD_{ncro} \cdot P_{wts} \quad (29)$$

$$PL_{agc} \cdot L_{agc} = PL\_A_{agc} \cdot L\_A_{agc} + \overline{PLNA} \cdot LNA_{agc} \quad (30)$$

$$L\_A_{agc} = aRLB_{agc} \cdot \prod_{laa} L\_RA_{laa,agc}{}^{\alpha LB} \quad (31)$$

1.3.6 Food and Energy

$$KLE_{foe} = aVA_{foe} \cdot XD_{foe} \quad (32)$$

$$LNA_{foe} = \left(\frac{KLE_{foe}}{aKLE_{foe}}\right) \cdot (\gamma KLE_{foe}/\overline{PLNA})^{\sigma KLE_{foe}} \cdot (\gamma KLE_{foe}{}^{\sigma KLE_{foe}} \cdot \overline{PLNA}^{1-\sigma KLE_{foe}} + (1-\gamma KLE_{foe})^{\sigma KLE_{foe}} \cdot PKE_{foe}{}^{1-\sigma KLE_{foe}})^{\sigma KLE_{foe}/(1-\sigma KLE_{foe})} \quad (33)$$

$$KE_{foe} = \left(\frac{KLE_{foe}}{aKLE_{foe}}\right) \cdot ((1-\gamma KLE_{foe})/PKE_{foe})^{\sigma KLE_{foe}} \cdot (\gamma KLE_{foe}{}^{\sigma KLE_{foe}} \cdot \overline{PLNA}^{1-\sigma KLE_{foe}} + (1-\gamma KLE_{foe})^{\sigma KLE_{foe}} \cdot PKE_{foe}{}^{1-\sigma KLE_{foe}})^{\sigma KLE_{foe}/(1-\sigma KLE_{foe})} \quad (34)$$

$$ENG_{foe} = \left(\frac{KE_{foe}}{aKE_{foe}}\right) \cdot (\gamma KE_{foe}/PENG_{foe})^{\sigma KE_{foe}} \cdot (\gamma KE_{foe}{}^{\sigma KE_{foe}} \cdot PENG^{1-\sigma KE_{foe}} + (1-\gamma KE_{foe})^{\sigma KE_{foe}} \cdot PK^{1-\sigma KE_{foe}})^{\sigma KE_{foe}/(1-\sigma KE_{foe})} \quad (35)$$

$$K_{foe} = \left(\frac{KE_{foe}}{aKE_{foe}}\right) \cdot ((1-\gamma KE_{foe})/PK)^{\sigma KE_{foe}} \cdot \left(\gamma KE_{foe}{}^{\sigma KE_{foe}} \cdot PENG^{1-\sigma KE_{foe}} + (1-\gamma KE_{foe})^{\sigma KE_{foe}} \cdot PK^{1-\sigma KE_{foe}}\right)^{\frac{\sigma KE_{foe}}{1-\sigma KE_{foe}}} \quad (36)$$

$$NOE_{foe} = (ENG_{foe}/aENG_{foe}) \cdot (\alpha NOE_{foe} \cdot P_{foe}/(\alpha ELG_{foe} \cdot PNOE_{foe}))^{\alpha ELG_{foe}} \quad (37)$$

$$ELG_{foe} = (ENG_{foe}/aENG_{foe}) \cdot (\alpha ELG_{foe} \cdot PNOE_{foe}/(\alpha NOE_{foe} \cdot P_{foe}))^{\alpha NOE_{foe}} \quad (38)$$

$$COA_{foe} = \left(\frac{NOE_{foe}}{aNOE_{foe}}\right) \cdot \left(\frac{\gamma NOE_{foe}}{P_{COA}}\right)^{\sigma NOE_{foe}} \cdot (\gamma NOE_{foe}{}^{\sigma NOE_{foe}} \cdot P_{COA}{}^{1-\sigma NOE_{foe}} + (1-\gamma NOE_{foe})^{\sigma NOE_{foe}} \cdot PNOCA_{foe}{}^{1-\sigma NOE_{foe}})^{\sigma NOE_{foe}/(1-\sigma NOE_{foe})} \quad (39)$$

$$NOCA_{foe} = \left(\frac{NOE_{foe}}{aNOE_{foe}}\right) \cdot \left(\frac{1-\gamma NOE_{foe}}{PNOCA_{foe}}\right)^{\sigma NOE_{foe}} \cdot (\gamma NOE_{foe}{}^{\sigma NOE_{foe}} \cdot P_{COA}{}^{1-\sigma NOE_{foe}} + (1-\gamma NOE_{foe})^{\sigma NOE_{foe}} \cdot PNOCA_{foe}{}^{1-\sigma NOE_{foe}})^{\sigma NOE_{foe}/(1-\sigma NOE_{foe})} \quad (40)$$

$$PET_{foe} = (NOCA_{foe}/aNOCA_{foe}) \cdot (\alpha PET_{foe} \cdot P_{GAO}/(\alpha GAO_{foe} \cdot P_{PET}))^{\alpha GAO_{foe}} \quad (41)$$

$$GAO_{foe} = (NOCA_{foe}/aNOCA_{foe}) \cdot (\alpha GAO_{foe} \cdot P_{PET}/(\alpha PET_{foe} \cdot P_{GAO}))^{\alpha PET_{foe}} \quad (42)$$

1.3.7 Zero Profit Condition: Food and Energy

$$(1-tp_{foe}) \cdot PD_{foe} \cdot XD_{foe} = PKLE_{foe} \cdot KLE_{foe} + \sum_{agc} io_{agc,foe} \cdot XD_{foe} \cdot P_{agc} + \sum_{foo} io_{foo,foe} \cdot XD_{foe} \cdot P_{foo} + \sum_{wts} io_{wts,foe} \cdot XD_{foe} \cdot P_{wts} \quad (43)$$

$$PKLE_{foe} \cdot KLE_{foe} = \overline{PLNA} \cdot LNA_{foe} + PKE_{foe} \cdot KE_{foe} \quad (44)$$

$$PKE_{foe} \cdot KE_{foe} = PK \cdot K_{foe} + PENG_{foe} \cdot ENG_{foe} \quad (45)$$

$$PENG_{foe} \cdot ENG_{foe} = PNOE_{foe} \cdot NOE_{foe} + P_{ELG} \cdot ELG_{foe} \quad (46)$$

$$PNOE_{foe} \cdot NOE_{foe} = P_{COA} \cdot COA_{foe} + PNOCA_{foe} \cdot NOCA_{foe} \quad (47)$$

$$PNOCA_{foe} \cdot NOCA_{foe} = P_{PET} \cdot PET_{foe} + P_{GAO} \cdot GAO_{foe} \quad (48)$$

1.3.8 Water and Others

$$LNA_{wts} = \left(\frac{XD_{wts}}{aVA_{wts}}\right) \cdot (\gamma VA_{wts}/\overline{PLNA})^{\sigma VA_{wts}} \cdot (\gamma VA_{wts}{}^{\sigma VA_{wts}} \cdot \overline{PLNA}^{1-\sigma VA_{wts}} + (1-\gamma VA_{wts})^{\sigma VA_{wts}} \cdot PK^{1-\sigma VA_{wts}})^{\sigma VA_{wts}/(1-\sigma VA_{wts})} \quad (49)$$

$$K_{wts} = \left(\frac{XD_{wts}}{aVA_{wts}}\right) \cdot ((1-\gamma VA_{wts})/PK)^{\sigma VA_{wts}} \cdot (\gamma VA_{wts}{}^{\sigma VA_{wts}} \cdot \overline{PLNA}^{1-\sigma VA_{wts}} + (1-\gamma VA_{wts})^{\sigma VA_{wts}} \cdot PK^{1-\sigma VA_{wts}})^{\sigma VA_{wts}/(1-\sigma VA_{wts})} \quad (50)$$

1.3.9 Zero Profit Condition: Water and Other Firms

$$(1-tp_{wts}) \cdot PD_{wts} \cdot XD_{wts} = \overline{PLNA} \cdot LNA_{wts} + PK \cdot K + \sum_{agc} io_{agc,wts} \cdot XD_{wts} \cdot P_{agc} + \sum_{foe} io_{foe,wts} \cdot XD_{wts} \cdot P_{foe} + \sum_{wts} io_{wts,wts} \cdot XD_{wts} \cdot P_{wts} \quad (51)$$

1.4 Saving and Investment

$$S = \sum_{hou} SH_{hou} + SE + SG \cdot PCINDEX + \overline{SF} \cdot ER \quad (52)$$

$$P_{sec} \cdot I_{sec} = \alpha I_{sec} \cdot (S - \sum_{nwas} P_{nwas} \cdot \overline{STC}_{nwas} - \sum_{was} P_{was} \cdot \overline{GAW}_{was}) \quad (53)$$

1.5 Government

$$P_{sec} \cdot CG_{sec} = \alpha CG_{sec} \cdot (TAXR + \overline{FG} \cdot ER - (\sum_{hou} \overline{TRF}_{hou} + \overline{SG}) \cdot PCINDEX) \quad (54)$$

$$TAXR = \sum_{hou} ty_{hou} \cdot Y_{hou} + tye \cdot YE + \sum_{sec}(PD_{sec} \cdot tp_{sec} \cdot XD_{sec} + tm_{sec} \cdot M_{sec} \cdot \overline{PWMZ}_{sec} \cdot ER) \quad (55)$$

$$SG = mpg \cdot TAXR \quad (56)$$

1.6 Foreign Sector

1.6.1 Export and the Demand of Domestic Goods (CET Function)

$$E_{sec} = \left(\frac{XD_{sec}}{aT_{sec}}\right) \cdot (\gamma T_{sec}/PE_{sec})^{\sigma T_{sec}} \cdot \left(\gamma T_{sec}{}^{\sigma T_{sec}} \cdot PE_{sec}{}^{1-\sigma T_{sec}} + (1-\gamma T_{sec})^{\sigma T_{sec}} \cdot PDD_{sec}{}^{1-\sigma T_{sec}}\right)^{\frac{\sigma T_{sec}}{1-\sigma T_{sec}}} \quad (57)$$

$$XDD_{sec} = \left(\frac{XD_{sec}}{aT_{sec}}\right) \cdot ((1-\gamma T_{sec})/PDD_{sec})^{\sigma T_{sec}} \cdot \left(\gamma T_{sec}{}^{\sigma T_{sec}} \cdot PE_{sec}{}^{1-\sigma T_{sec}} + (1-\gamma T_{sec})^{\sigma T_{sec}} \cdot PDD_{sec}{}^{1-\sigma T_{sec}}\right)^{\frac{\sigma T_{sec}}{1-\sigma T_{sec}}} \quad (58)$$

1.6.2 Zero Profit Condition: CET Function

$$PD_{sec} \cdot XD_{sec} = PE_{sec} \cdot E_{sec} + PDD_{sec} \cdot XDD_{sec} \quad (59)$$

1.6.3 Import and the Demand of Domestic Goods (Armington Function)

$$M_{sec} = \left(\frac{X_{sec}}{aA_{sec}}\right) \cdot \left(\frac{\gamma A_{sec}}{PM_{sec}}\right)^{\sigma A_{sec}} \cdot \left(\gamma A_{sec}{}^{\sigma A_{sec}} \cdot PM_{sec}{}^{1-\sigma A_{sec}} + (1-\gamma A_{sec})^{\sigma A_{sec}} \cdot PDD_{sec}{}^{1-\sigma A_{sec}}\right)^{\frac{\sigma A_{sec}}{1-\sigma A_{sec}}} \quad (60)$$

$$XDD_{sec} = \left(\frac{X_{sec}}{aA_{sec}}\right) \cdot ((1-\gamma A_{sec})/PDD_{sec})^{\sigma A_{sec}} \cdot \left(\gamma A_{sec}{}^{\sigma A_{sec}} \cdot PM_{sec}{}^{1-\sigma A_{sec}} + (1-\gamma A_{sec})^{\sigma A_{sec}} \cdot PDD_{sec}{}^{1-\sigma A_{sec}}\right)^{\frac{\sigma A_{sec}}{1-\sigma A_{sec}}} \quad (61)$$

1.6.4 Zero Profit Armington

$$P_{sec} \cdot X_{sec} = PM_{sec} \cdot M_{sec} + PDD_{sec} \cdot XDD_{sec} \quad (62)$$

1.6.5 Import and Export Prices

$$PM_{sec} = (1 + tm_{sec}) \cdot ER \cdot \overline{PWMZ}_{sec} \quad (63)$$

$$PE_{sec} = ER \cdot \overline{PWEZ}_{sec} \quad (64)$$

1.7 Market Clearing

$$\sum_{cro} LANR_{lad,cro} = \overline{LANS}_{lad} \quad (65)$$

$$\sum_{agc} L\_RA_{laa,agc} = \overline{LARS}_{laa} \quad (66)$$

$$\sum_{sec} LNA_{sec} = \overline{LNAS} \quad (67)$$

$$\sum_{sec} K = \sum_{hou} \overline{KH}_{hou} + \overline{EK} + \overline{FK} \quad (68)$$

$$\sum_{hou} C_{agc,hou} + I_{agc} + CG_{agc} + \overline{STC}_{agc} + \sum_{agcc} io_{agc,agcc} \cdot XD_{agcc} + \sum_{foe} io_{agc,foe} \cdot XD_{foe} + \sum_{wts} io_{agc,wts} \cdot XD_{wts} = X_{agc} \quad (69)$$

$$\sum_{hou} C_{foo,hou} + I_{foo} + CG_{foo} + \overline{STC}_{foo} + \sum_{agc} io_{foo,agc} \cdot XD_{agc} + \sum_{foe} io_{foo,foe} \cdot XD_{foe} + \sum_{wts} io_{foo,wts} \cdot XD_{wts} = X_{foo} \quad (70)$$

$$\sum_{hou} C_{COA,hou} + I_{COA} + CG_{COA} + \overline{STC}_{COA} + \sum_{agc} io_{COA,agc} \cdot XD_{agc} + \sum_{foe} COA_{foe} + \sum_{wts} io_{COA,wts} \cdot XD_{wts} = X_{COA} \quad (71)$$

$$\sum_{hou} C_{PET,hou} + I_{PET} + CG_{PET} + \overline{STC}_{PET} + \sum_{agc} io_{PET,agc} \cdot XD_{agc} + \sum_{foe} PET_{foe} + \sum_{wts} io_{PET,wts} \cdot XD_{wts} = X_{PET} \quad (72)$$

$$\sum_{hou} C_{GAO,hou} + I_{GAO} + CG_{GAO} + \overline{STC}_{GAO} + \sum_{agc} io_{GAO,agc} \cdot XD_{agc} + \sum_{foe} GAO_{foe} + \sum_{wts} io_{GAO,wts} \cdot XD_{wts} = X_{GAO} \quad (73)$$

$$\sum_{hou} C_{ELG,hou} + I_{ELG} + CG_{ELG} + \overline{STC}_{ELG} + \sum_{agc} io_{ELG,agc} \cdot XD_{agc} + \sum_{foe} ELG_{foe} + \sum_{wts} io_{ELG,wts} \cdot XD_{wts} = X_{ELG} \quad (74)$$

$$\sum_{hou} C_{ots,hou} + I_{ots} + CG_{ots} + \overline{STC}_{ots} + \sum_{agc} io_{ots,agc} \cdot XD_{agc} + \sum_{foe} io_{ots,foe} \cdot XD_{foe} + \sum_{wts} io_{ots,wts} \cdot XD_{wts} = X_{ots} \quad (75)$$

$$\sum_{hou} C_{was,hou} + I_{was} + CG_{was} + \overline{GAW}_{was} + \sum_{cro} WAT_{was,cro} + \sum_{ncro} io_{was,ncro} \cdot XD_{ncro} + \sum_{foe} io_{was,foe} \cdot XD_{foe} + \sum_{wts} io_{was,wts} \cdot XD_{wts} = X_{was} \quad (76)$$

$$\sum_{sec} M_{sec} \cdot \overline{PWMZ}_{sec} + \left(\frac{PK}{ER}\right) \cdot \overline{FK} = \sum_{sec} E_{sec} \cdot \overline{PWEZ}_{sec} + \sum_{hou}\left(\frac{PCINDEX}{ER}\right) \cdot \overline{FH}_{hou} + \left(\frac{PCINDEX}{ER}\right) \cdot \overline{FG} + \overline{SF} \quad (77)$$

$$PCINDEX = \frac{\sum_{sec,hou} P_{sec} \cdot C^0_{sec}}{\sum_{sec,hou} P^0_{sec} \cdot C^0_{sec}} \quad (78)$$

1.8 Real GDP and Nominal GDP

$$NGDP = PK \cdot \sum_{sec} K_{sec} + \sum_{laa} PL\_RA_{laa} \cdot L\_RA_{laa,agc} + \overline{PLNA} \cdot \sum_{sec} LNA_{sec} + \sum_{lad,cro} PLAN_{lad} \cdot LANR_{lad,cro} + \sum_{sec} tp_{sec} \cdot PD_{sec} \cdot XD_{sec} + \sum_{sec} tm_{sec} \cdot M_{sec\cdot} \cdot \overline{PWMZ}_{sec} \cdot ER \quad (79)$$

$$\mathrm{RGDP} = \mathrm{PK}^0 \cdot \sum_{sec} \mathrm{K}_{sec} + \sum_{laa} \mathrm{PL\_RA}^0_{laa} \cdot \mathrm{L\_RA}_{laa,agc} + \overline{\mathrm{PLNA}} \cdot \sum_{sec} \mathrm{LNA}_{sec} + \sum_{lad,cro} \mathrm{PLAN}^0_{lad} \cdot \mathrm{LANR}_{lad,cro} + \sum_{sec} \mathrm{tp}_{sec} \cdot \mathrm{PD}^0_{sec} \cdot \mathrm{XD}_{sec} + \sum_{sec} \mathrm{tm}_{sec} \cdot \mathrm{M}_{sec} \cdot \overline{\mathrm{PWMZ}}_{sec} \cdot \mathrm{ER}^0 \quad (80)$$

2. Notation for Sectors

sec,secc	activities and commodities
agc,agcc	agriculture and construction sectors
cro,croo	crop sectors
ncro,ncroo	non crop sectors including construction
foe,foee	food and energy sectors
foo,fooo	food sectors
en,enn	energy sectors
wst,wstt	water and other sectors
was,wass	water sectors
nwas,nwass	non-water sectors
ots,otss	other sectors
hou,houu	urban and 16 regional rural households
hour	16 regional rural households
laa	agricultural labor sectors
lad	cropland sectors
0	Initial value in benchmark equilibrium

3. Variables

PLNA	wage rate of non-agricultural labor (numeraire price index, fixed)
PK	return to capital
ER	exchange rate (LCU against FCU)
PCINDEX	consumer price index (commodities)
PLAWA_{cro}	price level of total composite land-water
$\mathrm{PLAWAR}_{was,cro}$	price level of regional composite land and water
PL_{agc}	price level of composite labor
$\mathrm{PL\_A}_{agc}$	price level of composite agricultural labor
S	total savings
SG	government savings
SE	enterprise savings
FG	government revenue from foreign (exogenous)
YE	income level of enterprise
EK	enterprise capital endowment(exogenous)
TRE_{hou}	transfer for enterprise to households (exogenous)
SF	foreign savings (exogenous)
FK	foreign capital demand in local current (exogenous)
LNAS	total non-agricultural labor supply
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 EX tariffs in local currency
PE_{sec}	price of exports in local currency
$\mathrm{PL\_RA}_{laa}$	wage rate of regional agricultural labor
PLAN_{lad}	return to regional croplands

$PNOE_{foe}$	price level of composite non-electricity input
$PENG_{foe}$	price level of composite energy
PKE_{sec}	price level of composite capital-energy
$PKLW_{cro}$	price level of composite capital-energy-land-water bundle
$PKLE_{sec}$	price level of composite capital-energy-labor bundle
$PNOCA_{foe}$	price level of composite non-coal
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
$LAWAR_{was,cro}$	demand of regional composite land and water
$LAWA_{cro}$	demand of total composite land-water
$LANR_{lad,cro}$	demand of regional croplands
$LANS_{lad}$	total supply of regional croplands
NOE_{foe}	demand for non-electricity input(composite)
ENG_{foe}	demand for composite energy input
KE_{sec}	demand for capital-energy bundle by firms
KLW_{cro}	demand for capital-land-water bundle by firms
KLE_{sec}	demand for capital-energy-labor bundle by firms
$NOCA_{foe}$	demand for composite non-coal input
L_{agc}	demand for composite labor
L_A_{agc}	demand for composite agricultural labor
$L\_RA_{laa,agc}$	demand for regional agricultural labor
LNA_{sec}	demand for non-agricultural labor
$LARS_{laa}$	supply of agricultural labor in different regions
K_{sec}	capital demand of firms
COA_{foe}	demand for coal of firms
PET_{foe}	demand for petroleum products
GAO_{foe}	demand for gasoline
ELG_{sec}	demand for electricity and gas
$WAT_{was,cro}$	demand for regional water of each crop
GAW_{was}	water gap between water demand and supply (exogenous)
$C_{sec,hou}$	consumer demand for commodities and leisure
$CBUD_{hou}$	total consumption
SH_{hou}	households' savings
KH_{hou}	initial households' capital holding (exogenous)
FH_{hou}	initial households' foreign revenues (exogenous)
Y_{hou}	initial households' income level
I_{sec}	investment demand
CG_{sec}	government commodity demand
TAXR	total tax revenue of government
TRF_{hou}	transfer from government to household (exogenous)
NGDP	nominal gross domestic products of macro economy
RGDP	real gross domestic products of macro economy
$PLES_{hou}$	aggregate price level for the "proposed change"
$PLES\_10_{hou}$	index of aggregate price level
SI_{hou}	supernumerary income for the "proposed change"

EV_{hou}	equivalent variation of policy scenario
CV_{hou}	compensating variation of policy scenario
PK^0	Initial return to capital
P^0_{sec}	initial price level of domestic sales of composite commodities
PD^0_{sec}	initial price level of domestic output of firm
C^0_{sec}	initial price level of domestic sales of composite commodities
$PL\_RA^0_{laa}$	initial wage rate of regional agricultural labor
$PLAN^0_{lad}$	Initial return to regional croplands
$PWEZ_{sec}$	initial world price of experts (exogenous)
$PWMZ_{sec}$	initial world price of imports (exogenous)
ER^0	initial exchange rate (LCU against FCU)
$PLES^0_{sec}$	initial aggregate price level for the "proposed change"
SI^0_{sec}	initial supernumerary income for the "proposed change"

4. Parameters

σLW_{cro}	elasticity of substitution between cropland and water
σNOE_{sec}	elasticity of substitution between non-electricity
σKLW_{cro}	elasticity of substitution between KE and LAWA
σKE_{sec}	elasticity of substitution between capital and energy
σLB_{agc}	elasticity of substitution between agricultural labor and non-agricultural labor
σKLE_{sec}	elasticity of substitution between capital-energy and labor
σVA_{wts}	elasticity of substitution between capital and labor
σA_{sec}	substitution elasticity of ARMINGTON function
σT_{sec}	substitution elasticity of CET function
$\gamma LW_{was,sec}$	CES distribution parameter for cropland and water bundle
γNOE_{sec}	CES distribution parameter for non-electricity bundle
γKLW_{cro}	CES distribution parameter for capital-land-water bundle
γKE_{sec}	CES distribution parameter for capital-energy bundle
γLB_{sec}	CES distribution parameter for composite labor
γKLE_{sec}	CES distribution parameter for capital-energy-labor bundle
γVA_{wts}	CES distribution parameter for value added in other sectors
γA_{sec}	CES distribution parameter for Armington function
γT_{sec}	CES distribution parameter for CET function
αNOE_{sec}	Cobb-Douglas power of NOE in non-electricity bundle
αELG_{sec}	Cobb-Douglas power of ELG in non-electricity bundle
$\alpha LW_{was,cro}$	Cobb-Douglas power of regional composite land-water bundle
$\alpha LB_{laa,agc}$	Cobb-Douglas power of regional agricultural labor
αL_{agc}	Cobb-Douglas power of composite labor in value added bundle
αK_{ncro}	Cobb-Douglas power of Capital in value added bundle
αKE_{agc}	Cobb-Douglas power of composite energy-capital bundle
αKLW_{cro}	Cobb-Douglas power of composite capital
αPET_{foe}	Cobb-Douglas power of PET in non-coal bundle
αGAO_{foe}	Cobb-Douglas power of GAO in non-coal bundle
$\alpha NOCA_{foe}$	efficiency parameter for non-coal bundle
$aNOE_{sec}$	efficiency parameter for non-electricity bundle
$aENG_{sec}$	efficiency parameter for energy bundle
aKE_{sec}	efficiency parameter for capital-energy bundle
$aKLW_{cro}$	efficiency parameter for composite capital
aLW_{cro}	efficiency parameter for composite land-water bundle

$aRLW_{was,cro}$	efficiency parameter for regional composite land-water bundle
$aRLB_{agc}$	efficiency parameter for regional agricultural labor
αLB_{agc}	efficiency parameter for composite labor
$aKLE_{sec}$	efficiency parameter for capital-energy-labor bundle
aVA_{sec}	efficiency parameter for value added
aA_{sec}	efficiency parameter of ARMINGTON function of commodity(sec)
aT_{sec}	shift parameter in the CET function of firm (sec)
$io_{sec,secc}$	technical coefficients
$\alpha HLES_{sec,hou}$	power in nested-ELES household utility function
$\mu H_{sec,hou}$	subsistence household consumption quantities(sec)
mps_{hou}	household's marginal propensity to save
mpe	enterprise's marginal propensity to save
mpg	government's marginal propensity to save
tye	tax rate on enterprise' income
ty_{hou}	tax rate on households' income
tm_{sec}	tariff rate for each sector
αI_{sec}	Cobb-Douglas power in the bank's utility function
tp_{sec}	net production tax
αCG_{sec}	Cobb-Douglas power in government utility function (commodities)

Appendix 2. Values of given parameters using in CGE-Energy model

		Abbreviations	Tariff rate (%)*	Armington elasticity**	CET Elasticity **	Income Elasticity of Commodities ***	σ_{VA} ****	σ_{KLE} ****
Agriculture	Paddy	PDR	0.081	5.1	3.6	0.23	1	
	Wheat	WHT	0.081	4.5	3.6	0.23	1	
	Corn	COR	0.081	1.3	3.6	0.23	1	
	Vegetables	VEG	0.032	2.5	3.6	0.23	1	
	Fruits	FRU	0.037	2.5	3.6	0.23	1	
	Oil seeds	OSD	0.032	2.5	3.6	0.23	1	
	Sugarcane	SUR	0.077	2.5	3.6	0.23	1	
	Potato	POT	0.02	2.5	3.6	0.23	1	
	Sorghum	SOR	0.005	2.5	3.6	0.23	1	
	other crops	OCR	0.033	2.5	3.6	0.23	1	
	Livestock	LIS	0.033	1.5	3.6	0.23	1	
	Forestry	FOS	0.028	2.5	3.6	0.23	1	
	Fishery	FIS	0.029	1.3	3.6	0.23	1	
	Service for Agricultural	SSA	0	2.5	3.6	0.23	1	
Energy	Coal	COA	0.011	3.1	4.6	1.23		0.2
	Petroleum products: Oil and Gas Exploitation	PET	0.016	7.4	4.6	1.23		0.2
	Gasoline and Other Oil Products	GAO	0.009	2.1	3.8	1.12		1.26
	Electricity and GAS	ELG	0	2.8	3.8	1.23		1.26

Appendix 2. Values of given parameters using in CGE-Energy model (continued)

		Abbreviations	Tariff rate (%)*	Armington elasticity**	CET Elasticity **	Income Elasticity of Commodities ***	σ_{VA} ****	σ_{KLE} ****
Food	Meat Processing	MEP	0.047	2.6	4.5	0.8		1.45
	Vegetable Oils Processing	VOL	0.027	3.3	4.5	0.8		1.45
	Milk Processing	MIL	0.024	2.6	4.5	0.8		1.45
	Grain and Feed Processing	GOG	0.027	2.6	4.5	0.8		1.45
	Sugar Processing	SUG	0.064	2.7	4.7	0.8		1.45
	Other Food Processing	OTF	0.035	2.2	4.5	0.8		1.45
	Alcohol, Drinks and Tobacco production	ADT	0.082	1.2	4.7	0.8		1.45
Others	Other Mining	OMN	0.003	2.8	4.6	0.8	1.45	
	Other Manufactures	OTM	0.023	2.8	4.6	1.01	1.45	
	Construction	CNS	0	1.9	3.8	1.23	1	
	Trade	TRD	0	1.9	2.8	1.29	1.45	
	Transportation	TRS	0	1.9	2.8	1.29	1.45	
	Insurance and Finance	I&F	0	1.9	2.8	1.29	1.28	
	Communication and Computer	CMC	0	1.9	2.8	1.29	1.28	
	Other Service	OTS	0	1.9	2.8	1.29	1.28	
The production and distribution of water at Multi-Regional level	Water-Guangdong	WAT-GD	0	2.8	2.8	1.23	1.28	
	Water-Jiangxi	WAT-JX	0	2.8	2.8	1.23	1.28	
	Water-Hainan	WAT-HN	0	2.8	2.8	1.23	1.28	
	Water-Yunnan	WAT-YN	0	2.8	2.8	1.23	1.28	
	Water-Guangxi	WAT-GX	0	2.8	2.8	1.23	1.28	
	Water-Henan	WAT-HEN	0	2.8	2.8	1.23	1.28	
	Water-Jilin	WAT-JL	0	2.8	2.8	1.23	1.28	
	Water-Anhui	WAT-AH	0	2.8	2.8	1.23	1.28	
	Water-Heilongjiang	WAT-HLJ	0	2.8	2.8	1.23	1.28	
	Water-Hebei	WAT-HB	0	2.8	2.8	1.23	1.28	
	Water-Hubei	WAT-HUB	0	2.8	2.8	1.23	1.28	
	Water-Chongqing	WAT-CQ	0	2.8	2.8	1.23	1.28	
	Water-Sichuan	WAT-SC	0	2.8	2.8	1.23	1.28	
	Water-Inner Mongolia	WAT-NMG	0	2.8	2.8	1.23	1.28	
	Water-Shandong	WAT-SD	0	2.8	2.8	1.23	1.28	
	Water-other regions	WAT-OTH	0	2.8	2.8	1.23	1.28	

Source: Ge and Tokunaga (2011)*; Zhai and Hertel (2005)**; Willenbockel (2006)***; Burniaux and Truong (2002)****.