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THE EFFECT OF POPULATION EXPANSION ON ENERGY CONSUMPTION IN CANTON OF CHINA: A SIMULATION FROM COMPUTABLE GENERAL EQUILIBRIUM APPROACH

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ABSTRACT
This paper uses the input-output table data in 2012 of Canton, China, using CGE model to examine the effects of different population sizes on energy production, energy consumption and actual energy use in the same external conditions. The results show that the expansion of population size significantly drives up the amount of energy consumption. But the impacts of population growth on energy production and real energy prices are non-significant

INTRODUCTION
The objective of the paper is to examine the impact of population growth on energy consumption. It is being increasingly appreciated in the literature on populationand energy consumption(Amaral and Gilberto, 2005).For instance, Poyer et al., (1997)show that residential energy demand by fuel type for Latinos, the fastest growing population group, has not been explained by economic and non-economic factors in any statistical model in public domain.

According to Morikawa (2012)'s analysis, the efficiency of energy consumption in service establishments is higher for densely populated cities. Quantitatively, after controlling for differencesamong industries, energy efficiency increases by approximately 12%whenthe density ina municipality population doubles.

Liu et al., (2015)'s empirical resultsshow that a higher population density would result in a decrease in energy consumption in China as a whole and in its eastern, central and western regions, but the extent of its effect on the environment depends on the type of pollutants.

He and Gao (2017) build a theoretic model to estimates the relationship between gas consumption, population and metropolitan economic performance with annual data from 1978 to 2013 for Guangzhou in China. Based on Granger causality test with vector error correction model, their empirical results show that there is Granger causality from population to gas consumption for long run in Guangzhou.

At the same time, He and Gao (2017)estimate the relationship among population, electricity consumption and metropolitan economic growth with annual data from 1950 to 2013 for Guangzhou in China. Based on Granger Causality Test in VECM, there is Granger causality from population to electricity consumption in short run.
Hall et al. (2017)'s findings show that electricity consumption within the study's sample aging population in Australia was influenced by both structural and demographic factors. Actually, population aging may imply smaller household sizes and more home-based energy consumption, which will change the energy mix(Bardazzi and Pazienza, 2017).

The rest of the paper is organized as follows. The computable general equilibrium model is presented in section 2. Section 3 describes the dataset and parameters. A summary of the simulation result of our analysis is presented in section 4. Finally, conclusion of our main findings is presented in section 5.

THEORETICAL FRAMEWORK WITH CGE MODEL
Based on the structure of input-output table and the economic structure of Canton in China, this paper constructs we set up a CGE model consisting of eight parts.

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1. **Overall production**

The total production function of is composed of two sections: the added value of production activity, and the

intermediate inputs of production activity. The total production function is expressed as the Cobb-Douglass form. The total production structure is as follows:

2. **Added value of Production**

The added value function of production activity has two components, the capital inputand the labor input. The production added value function is also expressed as the C-D function. In addition, the sum of capital investment is equal to the total amount of social capital, and the sum of all production activities is equal to the total amount of social labor. ***wk*** and ***wl***are respectively the prices of capital and labor. For the convenience of analysis, the shadow price of labor is fixed to 1.is the weighted value of the prices of capital and labor.
The added value of production structure is as follows:

3. **Intermediate input during production**

In this paper, fixed proportional production function is used to estimate the intermediate inputs.is the proportion of the input of commodity ***c*** in the total intermediate input for producing final goods.
The production intermediate input structure is as follows:

4. **Export Function**

The export function is divided into two parts, domestic sales part and export aboard.andare the actual prices of

the domestic sales part and export aboard part, respectively. Also, the C-D function is used to estimate the export ratio,where is the constant term of the C-D function representing technology level, and are the proportion of the domestic sales part and export aboard. Since we do not consider the impact of the tariff and foreign market price shocks, the offshore price of the export is fixed to 1.The export structure is as follows:

5. **Import Function**

The import function is divided into two parts, the total amount of domestic goods sold and the total amount of foreign merchandise sales .and are the actual prices of the domestic sales part and export part. C-D function is used to estimate the import ratio.and are the proportion of the domestic sales part and export part. is the constant term of the C-D function. is the weighted price of commodity ***c*** sold domestically. In addition, and is the sales volume and prices of domestic goods sold domestically, they're equal to and .The import structure is as follows:

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6. Consumer Utility Maximization

Assume that all labor income is owned by consumers.is the consumer's savings coefficient, is the total utility of the consumer, the utility function is a C-D function, and the constant term is 1.The consumer's optimization problem is as follows:

Max:

s.t.

7. Government Behavior

Suppose the government's income completely comes from capital tax. The government's consumption of commodity ***c*** is at a fixed rate . is the government's savings coefficient.The government financial structure is as follows:

8. Investment Function

Assumes that the total amount of social savings is composed of four parts: consumer savings, government savings, manufacturer savings, and foreign account savings. Among them, the manufacturer's capital income is transferred into the manufacturer's saving, and the trade deficitis transferred into foreign account saving. The total amount of social investment is the sum of consumption surplus of each commodity. The consumption surplus of commodity is the difference between actual consumption of goods and the sum of consumer consumption, government consumption and the total amount of intermediate input.

When the economy reaches equilibrium, total investment is equal to total savings. The difference between and S is VBIS. The value of is equal to 0.The investment structure is as follows:

The definitions of all variables in the computable general equilibrium model above are shown in table1.

Table1 Definitions of all variables in the computable general equilibrium model

Variables	Definition of variable	Variables	Definition of variable
	Constant term of active production equation for active A		Domestic sales of production activity a
	Increment coefficient of production equation for active A		Foreign sales of production activity a
	The intermediate input coefficient of the production equation for active A		Domestic price of production activity a
	Constant term of the value-added equation for active A		Foreign price of production activity a
	The capital input coefficient of the increment equation for active A		Total domestic consumption of commodity C
	The labor input coefficient of the increment equation for active A		Self-sufficiency of commodity C

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	Constant term of the export structural equation for active A		Import quantity of commodity C
	Domestic coefficient of export structural equation for active A		Domestic consumer price of commodity C
	Import coefficient of imported structural equation for commodity C		Self-sufficiency price of commodity C
	Constant term of imported structural equation for commodity C		Import price of commodity C
	Self-sufficiency coefficient of imported structural equation for commodity C		Consumer income
	Consumer's consumption factor for commodity C		Consumer consumption of C products
	Government's consumption ratio factor for commodity C		Consumer welfare
	Consumer savings factor		Government revenue
	Government savings factor		Government consumption of C products
	Output quantity of production activity a		Total investment
	Added value of production activity a		C Commodity Investment
	Intermediate inputs for production activity a		Enterprise Investment
	Price of added value of production activity a		Trade deficit
	The price of the intermediate input amount of production activity a		Total savings
	Production price of production activity a		Virtual variables for balance of investment and savings
	Production activity a capital input amount		GDP
	Production activity a labor input amount		Total labor supply
	Intermediate input amount of C commodity in production activity a		Total capital supply
	Labor use price of production activity a		Capital use price of production activity a
	Exchange rate		

DATA AND PARAMETERS

The SAM table used in this paper is adjusted by the annual output table of Guangdong Province, China in 2012.The data collected from the statistical yearbook of Guangdong (http://www.gdstats.gov.cn/zmhd/wtjd/201611/t20161108_347899.html).

In order to simplify the calculation, we combines 42 items of industry into 11 terms based on energy consumption. The results of the merger are shown in table2.

Table2 Result of Industry Merger

The merged industry	The re-merger industry
01.Agriculture and forestry husbandry and fishery product and service industry	01.Agriculture, forestry, animal husbandry and fishery products and services
02.Mining industry	02.Metal mining products 03.Non-metallic mining products
03.Textile industry	04.Textile products 05.Textile clothing shoes and hats leather duvet and its products
04.Paper printing and cultural and sports equipment manufacturing industry	06.Paper printing and cultural and educational sporting goods

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05.Chemical industry	07.Chemical products
06.Metal products manufacturing	08.Metal products 09.Metal smelting and rolling processing
07.Equipment manufacturing	10.General equipment products 11.Special equipment products 12.Transport equipment products 13.Electrical machinery and equipment 14.Communication equipment, computers and other electronic equipment 15.Instrument and meter
08.Other manufacturing industries	16.Food and tobacco products 17.Wood processing and furniture products 18.Non-metallic mineral products 19.Waste disposal 20.Metal products, machinery and equipment repair services 21.The production and supply of water 22.Other manufacturing products
09.The construction industry	23.The construction industry
10.Transportation, warehousing and postal services	24.Transportation, warehousing and postal services
11.Other tertiary industry	25.Accommodation and catering 26.Wholesale retail 27.Information transmission, software and information technology services 28.The financial sector 29.The real estate industry 30.Leasing and business services 31.Scientific research and technology services 32.Water conservancy, environment and public facilities management 33.Resident services, repairs and other services 34.Education industry 35.Health and social work 36.Culture, sports and entertainment 37.Public administration, social security and social organization
12.Energy related industries	38.Coal mining products 39.Oil and gas extraction products 40.Petroleum, coking products and nuclear fuel processing products 41.Electricity, thermal production and supply 42.Gas production and supply

In terms of parameters, due to the lack of relevant data, the parameters here are directly estimated by the SAM table, and the parameters are shown in table 3 and table 4.

Table3 Parameters of CGE Model

	01	02	03	04	05	06	07	08	09	10	11	12

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	0.611	0.354	0.260	0.199	0.230	0.198	0.212	0.246	0.216	0.388	0.572	0.275
	0.389	0.646	0.740	0.801	0.770	0.802	0.788	0.754	0.784	0.612	0.428	0.725
	1.951	1.915	1.774	1.647	1.714	1.646	1.677	1.747	1.685	1.950	1.979	1.801
	0.018	0.594	0.385	0.482	0.586	0.579	0.445	0.625	0.501	0.536	0.538	0.796
	0.982	0.406	0.615	0.518	0.414	0.421	0.555	0.375	0.499	0.464	0.462	0.204
	1.095	1.965	1.948	1.999	1.970	1.975	1.988	1.938	2.000	1.995	1.994	1.658
	1.132	1.779	2.000	1.939	1.843	1.815	1.943	1.814	1.075	1.748	1.552	1.850
	0.973	0.263	0.508	0.376	0.699	0.717	0.380	0.717	0.986	0.754	0.840	0.695
	0.027	0.737	0.492	0.624	0.301	0.283	0.620	0.283	0.014	0.246	0.160	0.305
	1.764	1.639	1.658	1.797	1.939	1.999	1.993	1.733	1.927	1.447	1.378	1.998
	0.745	0.196	0.796	0.727	0.624	0.512	0.457	0.761	0.636	0.879	0.902	0.525
	0.255	0.804	0.204	0.273	0.376	0.488	0.543	0.239	0.364	0.121	0.098	0.475
	0.131	0.000	0.040	0.019	0.072	0.063	0.117	0.103	0.006	0.023	0.382	0.043
	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.996	0.000
	0.033	0.423	0.369	0.308	0.371	0.304	0.415	0.491	0.637	0.199	0.280	0.581

Table4 Parameters of Saving Coefficient

0.155	0.155

SIMULATION RESULT

The following is the result of simulation of the change in energy production, consumption and actual consumer price changes between -20% and 20% of the population scale. The results are shown in table 5.

Table5 Simulation Result

Population size	Energy output	Energy consumption	Real energy prices
-20%	-0.40%	-44.60%	-0.90%
-15%	-0.30%	-32.80%	-0.90%
-10%	-0.20%	-21.80%	-0.20%
-5%	-0.10%	-10.90%	-0.30%
0%	0.00%	0.00%	0.00%
+5%	-1.50%	+8.90%	-4.50%
+10%	0.00%	+20.80%	+2.70%
+15%	+0.10%	+31.50%	+3.20%
+20%	+0.20%	+43.60%	+0.90%

According to the results of table 4, population size has no significant impact on energy production and real energy prices. However, the impact of energy consumption on the size of the population is significant; change in

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energy consumption is even greater than population size. When the population is 20% smaller than the original, energy consumption is reduced by 44.6%; when the population size is 20% higher than the original, energy consumption will increase by 43.6%. Obviously, energy consumption is affected by the change of population size, and the change is much closer to 2 time times than the change of population itself.
This result may be due to the fact that, as an important industrial and trading base in the world, the supply of energy consumption in Canton area is largely affected by external supply. Despite the large increase in demand and internal supply increase limited, sufficient imported energy products still guarantee the market supply and price stability if the external supply is unrestricted. Therefore, we further simulate the influence of population scale change on the energy self-sufficiency rate in Canton area. The results are shown in table 6.

Table6The Relationship Between Population Size and Energy Self-sufficiency Rate

Population size	Energy self-sufficiency Rate
80%	42.46%
85%	39.97%
90%	37.76%
95%	35.79%
100%	34.02%
105%	32.19%
110%	31.06%
115%	29.73%
120%	28.40%

According to the results of table 5, the population scale is negatively correlated with the energy self-sufficiency rate, and the energy self-sufficiency rate shrinks with the expansion of population scale. If the population size is 20% larger than the original, the energy self-sufficiency rate will reduce by 5.62 percentage; If the population size is 20% smaller than the original, the energy self-sufficiency rate will increase by 8.44 percentage. Obviously, the expansion of population increases the degree of external dependence of energy in Canton, and it also proves that external supply meets the need of energy demand growth in Canton.

CONCLUSIONS

We use the input-output table data in 2012 of Canton, China, using CGE model to examine the effects of different population sizes on energy production, energy consumption and actual energy use in the same external conditions. The results show that the expansion of population size significantly drives up the amount of energy consumption. But the impacts of population growth on energy production and real energy prices are non-significant.
The results of the simulation show that under the same external conditions, the population expansion will significantly expand energy consumption, and the expansion of energy consumption will be twice as large as that of the population.

Energy industry is not a traditional dominant industry in Canton, China. According to the 2012 Canton input-output table, energy industry output accounts for only 6.45% of the total output of Canton, capital and labor inputs accounts for only 8.65% and 2.29% of total expenditure.The increase of labor force has a limited effect on the energy industry under the condition of capital use, import and export price and other factors unchanged.
The contradiction of energy supply and demand brought by population growth is mainly digested by the external market. Imported energy products guarantee the supply of overall energy products while stabilizing overall energy prices. But with the gap between the internal energy supply and demand becomes greater, energy self-sufficiency rate also declines sharply.

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