

GDP model for Chinese energy modeling based on empirical production function

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Abstract: In many energy models, GDP is an exogenous variable, so that variables within energy model are not able to change the value of GDP. Based on empirical production function, a GDP model has been established in this paper using capital stock, urbanization rate and population size as independent variables. It has been found that urbanization rate is a kind of integrated indicator of labor quantity and the education level of labors in China. And it also takes away the labor surplus in rural area in China. The forecasting results show that the model is robust. The results have the same tendency as the results from famous CGE model and the results from responsible Chinese authorities, and the numbers of GDP growth rates are also similar in 50 years. It has been concluded that the model is a good candidate for energy model as an endogenous variable.

Keywords: China, GDP model, Empirical production function, Energy model

1. Introduction

In energy modeling, GDP is often an exogenous variable, GDP growth rate or GDP values are often from other researches [11], [8], [6]. So that variables within energy model are not able to change the value of GDP, although GDP might be a variable of other variables inside the model. This might cause inconsistent within the energy model sometime when scenarios of GDP and other variables are not properly chosen.

A GDP model has been established in this paper based on empirical production function that uses the variables commonly in energy models to change GDP from exogenous variable to endogenous variable in energy models.

Cobb-Douglas production function follows:

$$Q = AL^\alpha K^{1-\alpha} \quad (1)$$

where Q is production; L is labor; K is capital stock; and α is elasticity coefficient of labor.

Some researchers have studied to establish GDP models based on Cobb-Douglas production function or its changed format. Cai (1999) derived a difference model based on production function and further established a regression relationship to calculate GDP from labor, capital stock and education level of labors, but the regression coefficient is only 0.608.

Chow et al (2002) used Cobb-Douglas production function established GDP models for China mainland

and Taiwan. Labor was weighted by the education level. Their results were good. However they did not take labor surplus in rural area in China into consideration.

This paper mainly uses World Development Indicators published by World Bank to establish a GDP model based on empirical production function. The results show that the model is robust and reliable.

2. GDP model

Empirical production function can be in different format. One format is:

$$Q = AX_1^{\alpha_1} X_2^{\alpha_2} X_3^{\alpha_3} K \quad (2)$$

where A is constant; X_1 , X_2 , and X_3 are variables

Capital stock K , urbanization rate UR and population size P have been chosen as variables, so that the model follows:

$$GDP = AK^{\alpha_1} UR^{\alpha_2} P^{\alpha_3} \quad (3)$$

or

$$GDP = AK^{\alpha_1} UR^{\alpha_2} \quad (4)$$

2.1 GDP and capital stock

GDP data is from World Development Indicators.

Capital stock is a variable in Cobb-Douglas production function, it is not necessary to discuss the reason to include this variable. Capital stock data used in this model is from Chow et al (2002).

2.2 Urbanization rate

From statistics point of view, McCoskey Suzanne and Kao Chihwa (1999) proved that urbanization rate is a shift variable in this sort of GDP model:

$$Y_{it} = A_{it}(U_{it})^{\lambda}(K_{it}^{\beta_1}N_{it}^{1-\beta_1}) \quad (5)$$

where Y_{it} is GDP in i -th country in time t ; U is urbanization rate, K is capital stock and N is labor.

Urbanization rate is even more significant in China than in most of countries in the world. People's changing residence place within China has been tightly controlled by the government via HuKou system that is a registration system of citizenship in China. The main way for people to move from rural area to cities was after studying in universities or professional schools. Recent years, this has been relatively easier for Chinese, but still only some educated rural people who can find a job in cities.

According to World Bank, labor in agriculture in China is 47.4% of total in 1997 and produce 19.08% of GDP. This is because of the low productivity in rural area in China and also because of the surplus of labor in rural area. The urbanization rate at least partly takes away this labor surplus.

2.3 Population size

Population size here represents labors, but population size is a very common variable in energy model. From World Bank data from 1960 to 1999, the following regression relationship is found:

$$\text{Lab} = 0.7107 \times P - 1E + 08 \quad (6)$$

$$R^2 = 0.991$$

where Lab is labor; P is population size; and R is regression coefficient.

Obviously the relationship between labor and population size is linear. This relationship may shift because of the aging problem emerging in China. However it will still hold in long time within acceptable accuracy.

2.4 GDP model for China

From the data described above, a regression model of GDP for China has been found:

$$\text{LnGDP} = -9.41 + 0.617\text{Ln}K + 0.939\text{LnUR} + 0.759\text{Ln}P \quad (7)$$

$$R^2 = 0.992$$

It can be seen that the regression coefficient is very high.

It has been further found that the regression coefficient is still very high if the variable population size is taken away. This indicates the strong

relationship between urbanization rate and labor. After eliminating population variable, the regression model reads:

$$\text{LnGDP} = -0.22 + 0.902\text{Ln}K + 0.521\text{LnUR} \quad (8)$$

$$R^2 = 0.99$$

3. GDP forecast

In this section, GDP until 2050 in China has been forecasted using model developed in this paper.

3.1 Population size

Future population size comes from the forecasting results of Population Planning and Control Commission of China. TFR (Total Fertility Rate) is 1.8. Part of data is listed in table 2.

3.2 Capital stock

Future capital stock relates to current capital stock and future investment. Calculation method is from Chow (2002).

$$K(t) = (1 - d)K(t-1) + I(t) \quad (9)$$

where d is dispersion rate, 0.045 is assumed in calculation. $I(t)$ is the gross national investment amount in t year.

From 1975 to 1999 historic data, the investment ratio to GDP is listed as Table 1.

Table 1. Statistic results of investment ratio to GDP in China

Average	Medium	Max	Min	StDev
34.789	35.539	43.3	27.4	4.219

Three scenarios of investment ratio have been set up based on the analysis above. The high scenario assumes that 36% will remain until 2050; the ratio in Japan will be reached in 2050 in China is assumed as the middle scenario; the low scenario assumes that in 2050 the ratio in America will be reached. Part of those data is also listed in Table 2.

3.3 Urbanization ratio

From World Bank, urbanization ratio in China in 1999 was 31.62%. Historic data of urbanization ratio is also analyzed. The growth rates of urbanization from 1966 to 1974 are zero or negative, so that they have been ignored. The statistic data of urbanization ratio is listed in Table 3. The medium of growth rate is 0.46%, this rate has been assumed as low scenario of future urbanization rate. Since 1980, China has picked up the urbanization pace, the medium of growth rate is 0.68%, this rate has been assumed as middle scenario. According to World Bank, urbanization rate in Japan in

1999 was 78.66%, 76.98% in America. These data have been used as reference for high scenario of urbanization in the future. 60% has been assumed to be

the urbanization rate in 2020 in China, and in 2050 the urbanization rate will reach 78%. Some of those data are listed in Table 3.

Table 2. Data of independent variables

Year	Population	Investment Ratio(H)	Investment Ratio (M)	Investment Ratio(L)	UR(H)	UR(M)	UR(L)
2000	12.7	36	36.00	36.0	33.0	33.0	33.0
2010	13.6	36	34.31	32.7	46.5	39.8	37.6
2020	14.3	36	32.23	29.4	60.0	46.6	42.2
2030	14.6	36	30.15	26.1	66.0	53.4	46.8
2040	14.6	36	28.08	22.8	72.0	60.2	51.4
2050	14.1	36	26.00	19.5	78.0	67.0	56.0

Some Chinese scholars have also studied the urbanization rate in the future. Chinese Science Academy Wu LiangYong (2003) believed that urbanization rate in China would be 45% and 65% in 2010 and in the middle of this century. Chinese Science Academy (2003) Niu WenYuan believed that it would be 75% in the middle of this century, 1% growth would be the average pace in the future.

3.4 Results of GDP

High, middle and low scenarios of GDP have been calculated from the high, middle and low scenarios of national investment and urbanization rate. Those results have been listed in Table 4 and Table 5. Table 6 lists the results from China Macro Economic Network and the results from the Computational General Equilibrium (CGE) models (Li et al, 2003).

From those results, we can see that:

- 1) These GDP models are robust, the results for future 50 years are reasonable.
- 2) From the GDP growth rate tendency, bigger rate first and gradually slow down in the future. This tendency matches the results from CGE model and the results from Chinese responsible authorities.
- 3) The numbers of future growth rates are very similar to the numbers from other scholars, especially model (8).
- 4) The results from (7) are smaller than the results from model (8), especially in latter stage. The reason is that the population size becomes smaller that means less labors in the model. As a matter of fact, the population size is so big in China, the case of labor shortage is hardly possible if urbanization pace and education would not slow down. So that model (8)

may be a better one comparing with model (7).

Table 3. statistic data of urbanization growth rate in China. unit: %/a

Period	Average	Medium	Max	Min	StD
1961~1965	0.5455	0.4600	0.8800	0.3200	0.1903
1975~1999	0.6326	0.6800	0.8800	0.4600	0.1763

Table 4. GDP forecast results

Scenario	Results/ \$			GDP Growth rate/ %		
	High	middle	low	high	Middle	Low
2010	2.52E+12	2.17E+12	2.01E+12	8.97	7.6	6.91
2020	6.04E+12	4.06E+12	3.33E+12	8.19	6.47	5.20
2030	1.34E+13	7.19E+12	5.05E+12	8.26	5.88	4.24
2040	2.83E+13	1.20E+13	6.99E+12	7.78	5.25	3.31
2050	5.72E+13	1.88E+13	8.85E+12	7.30	4.60	2.40

Note: GDP model is: $GDP=e-0.22K0.902UR0.521$

Table 5. GDP Forecast Results

Scenario	Result /\$			GDP growth rate / %		
	High	middle	low	high	Middle	Low
2010	2.21E+12	1.79E+12	1.64E+12	7.78	5.91	5.15
2020	4.55E+12	2.94E+12	2.43E+12	7.48	5.06	3.99
2030	7.43E+12	4.41E+12	3.28E+12	5.03	4.14	3.03
2040	1.11E+13	6.10E+12	4.07E+12	3.95	3.31	2.19
2050	1.47E+13	7.74E+12	4.62E+12	2.97	2.41	1.28

Note: GDP model is: $GDP=e-9.41K0.617UR0.939P0.759$

Table 6. GDP Growth rate from other scholars in unit: %

scenario	Macro EN	Li et al	Li et al
		middle	Low
2000~2010	8.1	7.9	6.6
2010~2020	6.4	6.6	4.7
2020~2030	5.4		
2030~2040	4.9		
2030~2050	4.3		

4. Conclusions

Some researchers have tried to establish national GDP models based on production function. Chow et al (2000) built models for China mainland and Taiwan based on Cobb-Douglas production function. McCoskey Suzanne and Kao Chihwa proved that urbanization rate could be a shift variable in production function.

This paper uses empirical production function, employs national capital stocks, urbanization rate and population size as variables to establish GDP model for China. Urbanization rate in this model in fact is a variable of quantity of labors and education level of labors, and it at least partly takes away the labor surplus in rural area.

The results from those GDP models show that they are very close to the results from famous CGE model and the results from Chinese responsible authorities, not only the tendency of GDP growth rate, but also the growth rate numbers.

The forecast results of model (7) may be a bit too small, especially in the latter stage. The reason is less labors during that period. This case in fact is not going to happen in China because of the big population size, so that model (8) may be better than model (7).

The GDP model based empirical production function developed in this paper has been successfully applied in China. This is a good reference to develop similar models for other developing countries.

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