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Research of Energy Substitution Strategy of China

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Abstract

For a long time, China's energy endowment structure determines the production structure and consumption structure of energy are coal-based. This situation is difficult to change for quite a long time. With the rapid economic growth, industrialization and urbanization, the demand for energy, especially for oil, natural gas will continue to increase. But the oil and gas supply can not meet the needs of rapid growth. The most direct way is to import, and imports will be charged by the international energy situation, and will affect energy and economic security. In view of our country abundant coal resources, we can consider to use coal substituting oil and natural gas to reduce dependence on foreign energy, to strengthen energy and economic security. Therefore, using translog production function, the text forecasts substitution elasticity and the marginal substitution rate between the capital, coal, oil and natural gas, and puts forward substitution program.

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Keywords: energy substitution; trans-log production function; strategy

1. Introduction

As China's energy demand continues to substantially increase, the output growth is limited, oil and gas gap between production and consumption is gradually increasing, if we donot develop alternative energy sources, entirely dependent on imports, foreign dependence will be very large. To be emphasized is that the oil industry involves in extensive long industrial chain, oil prices is conducted further by industrial chain penetrateing into all aspects of production, the negative impact of macroeconomic is fully apparent. If this situation is not improved, energy self-support system of sustainable economic development will become very vulnerable.

The next 50 years, coal will remain China's primary energy sources, the technology of coal clean and efficient use must be addressed, because the exploration and utilization of new oil and gas fields and gas water compounds require to focus on the theory and application technology; the use of nuclear energy is bound to be the most important energy sources after fossil fuels, the use of fusion energy will be 50 years after, and the use of fission energy needs to develop a new generation of nuclear technology which is safe, efficient, and can handle waste nuclear; As to solar energy and other renewable energy, although the

share is not high, but it is urgent to develop low-cost, convenient new technologies to meet the needs of different regions. Therefore, the gradual depletion of global oil and gas resources, rising international oil prices, China's rich coal, less oil endowment structure, energy independence support system and national security and so on determine it is an inevitable choice for coal to substitute oil (gas), coal will remain the pillar industry to guarantee energy supply security. Therefore, this paper predict the substitution elasticity and the marginal substitution rate between the capital, coal, oil, natural gas using the tranlog production function, and puts forward the substitution projects.

2.Forecast of Energy substitution

2.1.Selection of Variables and Method Description

The variables include in the translog production function ^[1-6]: dependent variable is gross domestic product (GDP), the independent variables are coal (C), oil (O), gas (G) and capital (K). GDP data are from "China Statistical Yearbook ", in order to ensure comparability, the price is adjusted to 1978 constant price, the unit is Billion yuan. Coal, oil, natural gas consumption comes from the "China Energy Statistical Yearbook ", the unit is tons of standard coal; capital variable values is obtained using the perpetual inventory method ^[7], the unit is Billion yuan; considering technical progress over time, it introduces a time trend variable t. Selecting the 1978-2005 period is the sample data.

Because of the more cross terms and serious multicollinearity between the variables in the translog production function, we use the ridge regression method of STATISTICA6.0 package ^[8] to estimate the parameters (ridge parameter R=0.88 determined by the ridge parameter trajectories), and then calculate the elasticity of substitution and the marginal rate of substitution between input factors each year based on parameter estimates results. This article focuses on the forecast of substitution elasticity, the marginal substitution rate and the substitution projects, some formulas and data are no longer listed in details.

2.2.Forecast

This article first makes use of author's forecast results on total energy demand, total energy production, coal oil and gas production and consumption from 2010 to 2050 (prediction process is abbreviated), forecast results is in Table 1.

Table 1 shows that the gap between supply and demand of energy is increased with the increase of energy consumption from 44.99 million tons of standard coal in 2010 to 759.58 million tons of standard coal in 2050, accounting for 14% of energy consumption. Coal is China's advantage resource, coal supply and demand keeps balance and has a slight surplus. Oil and natural gas have varying degrees of supply gap, especially oil supply shortage is most prominent, if oil, gas gap all depend on imports, then the oil foreign dependence will get From 40% in 2010 to 77.4% in 2050. (foreign dependence is imported oil, natural gas account for oil, natural gas consumption of one country or region) natural gas foreign dependence will get 73% in 2050. This will directly threat to our energy security. China's oil and natural gas supply and demand gap is mainly due to resources, the current mining technology and other reasons, so making use of international resources is an indisputable fact.

Table 1 Forecast Results of Energy Production and Consumption

		2010	2020	2030	2040	2050
Energy	Consum-ption	2101.01	2997.77	3864.98	4799.09	5551.16
	Production	2056.01	2735.48	3429.49	4147.31	4791.58
	gap	44.99	262.29	435.48	651.78	759.58
Coal	Consumption	1978.75	2746.79	3428.26	4122.17	4525.78
	Production	2122.90	2814.26	3629.59	4581.35	5409.04
	Surplus	144.15	67.47	201.33	459.18	883.26

Oil	Consumption	293.14	401.01	536.35	670.65	840.21
	Production	177.82	183.61	187.45	188.95	189.78
	gap	115.31	217.39	348.91	481.69	650.41
Gas	Consumption	538.61	956.31	1758.11	2696.14	4105.93
	Production	540.91	955.25	1213.23	1154.21	1097.71
	gap	-	1.05	544.87	1541.94	3008.23

Note: Total Energy: million tons of standard coal; Coal: million tons; Oil: million tons; natural gas: billion cubic meters

There are three ways to solve the energy supply and demand gap: one is to reduce energy demand, second is through imports to meet domestic energy needs, third is through the substitution. From a strategic point of view, we should not be entirely dependent on imports, oil imports should be taken to alternative strategies. It is conducive to develop a series of major domestic industries and related industries, safe and reliable of oil supply. This is the best way to solve the shortage of oil supply in China. The main alternative to oil imports strategy include: first, substitution between energy and other factors of production; Second, substitution between the energy of all varieties. Energy substitution is one of the best ways to solve the energy supply and demand gap.

Secondly, this paper applies the parameters of ridge regression and the author's prediction results about the GDP and coal, oil, natural gas consumption, and obtains the capital stock each year, and then calculates substitution elasticity and the marginal rate of substitution between capital, coal, natural gas, analyses varieties of energy production and consumption gap. The predicted results of substitution elasticity and the marginal substitution rate between various inputs are shown in Table 2 and Table 3.

Table 2 shows, the elasticity of substitution between capital and coal is greater than the capital for oil and natural gas, which shows capital replacing coal is easier than oil and natural gas with the same amount of capital. Elasticity of substitution of coal instead of oil is greater than the natural gas, indicating the same amount of coal replaces instead of oil is easier than the natural gas.

Table 2 The Predicted Results of Substitution Elasticity Between Various Inputs

Year	Capital and Coal	Capital and Oil	Capital and Gas	Coal and Oil	Coal and Gas
2010	0.9816	0.8617	0.9623	1.0779	1.0491
2020	0.9824	0.8834	0.9676	1.0772	1.0480
2030	0.9833	0.9027	0.9723	1.0770	1.0472
2040	0.9841	0.9176	0.9758	1.0768	1.0466
2050	0.9847	0.9288	0.9787	1.0770	1.0460

Table 3 The Predicted Results of the Marginal Substitution Rate Between Various Inputs

Year	Capital and Coal	Capital and Oil	Capital and Gas	Coal and Oil	Coal and Gas
2010	0.4755	1.0557	6.9310	2.2203	14.576
2020	0.1620	0.3668	1.8644	2.2646	11.509
2030	0.0442	0.0938	0.3485	2.1235	7.8832
2040	0.0112	0.0230	0.0699	2.0503	6.2222
2050	0.0032	0.0058	0.0146	1.8058	4.5179

Table 3 shows, the marginal rate of substitution between the capital, coal, oil and natural gas has a more evident decreasing trend. Similarly, the marginal rate of substitution between coal, oil and natural gas has gradually declining trend dropping great.

3. Energy substitution Program

According to the forecast of energy production and consumption gap data, there is a surplus of coal, and oil and gas gap is gradually increasing. In order to eliminate the gap, we can use coal to replace oil and natural gas, play our advantages in resources, reduce external dependence and increase energy security. Using the predicted results of coal, oil, and natural gas of marginal rate of substitution, the substitution projects are in Table 4 and Table 5.

Table 4 shows that, if all the coal surplus replace oil gap, China's oil imports are also increasing year by year, from 118.371 million tons of standard coal in 2010 to 578.908 million tons of standard coal in 2050, oil import dependence is from 28.3% in 2010 to 48.3% in 2050, but compared with no substitution, there is a 29% reduction, this is not a small figure, coal replacing oil significantly increase our energy security, but we should also use the oil as soon as possible to improve efficiency and reduce per unit of product fuel consumption, thereby reducing oil consumption and reduce dependence on foreign oil, and fundamentally to ensure the country's energy security.

Table 4 Substitute Coal for Oil of Standard Coal

Unit: Million Tons

Year	Coal Surplus	OilGap	Coal Substitution	Oil Import	Oil Consumption	Oil Foreign Dependence
2010	102.96	164.74	46.37	118.37	418.78	28.3
2020	48.19	310.56	21.27	289.28	572.87	50.5
2030	143.80	498.44	67.71	430.72	766.23	56.2
2040	327.99	668.15	159.96	508.18	958.09	53.0
2050	630.91	929.18	349.37	579.80	1200.31	48.3

Table 5 Substitute Coal for Gas of Standard Coal

Unit: Million Tons

year	Coal Surplus	Gas Gap	Coal Substitution	Gas Import	Gas Consumption	Gas Foreign dependence
2030	143.80	72.46	18.24	54.22	233.82	23.2
2040	327.99	205.07	52.71	152.36	358.58	42.4
2050	63.09	400.09	139.64	260.44	546.08	47.7

Table 5 shows that, if all the surplus of coal replaces natural gas production and consumption gap, imports of natural gas is increasing year by year, from 54.22 million tons of standard coal in 2030 to 260.44 million tons of standard coal in 2050. Although the gas imports dependence is from 23.2% in 2030 to 47.7% in 2050, compared with no substitution, there is a 25% reduction. This has important significance to ensure our energy security. Meanwhile, the priority should be the use of natural gas as soon as possible to improve efficiency and reduce consumption of natural gas, and ultimately ensure the country's energy security and economic security.

Although China is rich in coal resources, in addition to coal to meet their own needs, but also a slight surplus. However, if you do not improve energy efficiency, improve the industrial structure, and the rapidly growing energy demand, particularly oil, natural gas demand, it will inevitably lead to excessive dependence on imports, China's economic development is subject to external situation, which we do not like to see in the picture. Therefore, it is imperative that in the basis of domestic resources, to meet steady economic growth, we must first improve energy efficiency, promote conservation, reduce energy consumption, thus relying on the international market, and appropriately increase imports to meet energy needs.

The above discussion is only a theoretical discussion, coal substituting oil, natural gas also relies on coal liquefaction and gasification of the progress of technology, the strong investment in clean coal technology, so as to realize the true substitution between coal, oil and gas.

4. Conclusions and recommendations

1. Using the author's forecast data on the GDP, coal, oil, natural gas, the paper forecasts the marginal rate of substitution between the capital, coal, oil, natural gas. The predicted results show that: the marginal rate of substitution between the capital, coal, oil and natural gas was a gradual decline trend, the trend is obvious. Similarly, the marginal rate of substitution between coal, oil and natural gas has a downward trend dropping largely.

2. If the coal surplus all replace oil gap, China's oil imports are also increasing year by year, from 118.371 million tons of standard coal in 2010 to 578.908 million tons of standard coal in 2050. Although oil import dependence is from 28.3% in 2010 to 48.3% in 2050, compared with no substitution there has a 29% reduction of external dependence. Natural gas has the same result. Using coal to replace oil, natural gas can greatly enhance our energy security.

3. We should strive to improve oil and gas utilization efficiency, and reduce unit product energy consumption, thereby, reduce the oil, natural gas consumption, external dependence to ensure national energy security and economic security.

4. Relying on the advantages of China's coal resources, we should increase investment in clean coal technology, and improve coal liquefaction and gasification technical level, so that we can reduce energy demand dependence on foreign markets, and enhance energy and economic Security.

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References

- [1] Caloghiro, Yannis, Mourelatos, Alexi, Thompson, Henry. Industrial energy substitution during the 1980s in the Greek economy[J]. *Energy Economics* 19, 1997, pp.476-491.
- [2] Kemler, Claudia. Estimated substitution elasticities of a nested CES production function approach for Germany[J]. *Energy Economics*, 20, 1998, pp.249-264.
- [3] Mahmud, Syed. The energy demand in the manufacturing sector of Pakistan: some further results[J]. *Energy Economics*, 22, 2000, pp.641-648.
- [4] Chang, Kuo-Ping. Capital-energy substitution and the multi-level CES production function[J]. *Energy Economics*, 16, 1994, pp.22-26.
- [5] Zhaoning ZHeng; Deshun Liu. China's Trans-log Production Function Using Capital, Energy and Labor as Input [J]. *Systems Engineering-theory & Practice*, (5), 2004, pp.51-54.
- [6] Zhaoning ZHeng; Deshun Liu. Uncertainty of Capital-energy Substitution in China[J]. *Operations Research and Management Science*, 13(2), 2004, pp.74-78.
- [7] Zhiguo Li. A Model of Capital Stock Adjustment in China in the Transitional Period: A Positive Study [J]. *Nankai Economic Studies*, (6), 2002, pp.35-36.
- [8] Hong nan, Hou jun, Zhihui Li. STATISTICA for Windows [M]. Tsinghua University Press, Beijing, 2002, pp.205-209.