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Calculation and Optimization for Energy Saving Effect of China's Energy Conservation and Consumption Reduction Methods Based on E-G Cointegration and Granger Causality Analysis

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The purpose of this study is to improve the energy-saving effect of various energy-saving ways. To this end, this paper studies the calculation and optimization for the energy-saving effect of China's energy conservation and consumption reduction methods. Firstly, based on E-G cointegration and Granger causal analysis, this paper analyses the relationship between China's economic growth and energy consumption. Then, the system dynamics model was used to simulate China's energy economic system, and analyse the energy saving effect of China's energy conservation and consumption reduction methods. Studies show that technological progresses have caused China's industrial unit energy consumption to fall by an average of 4.26% per year, and energy intensity also decreases in certain degree. Therefore, to achieve scientific development in China, energy conservation and consumption reduction are top priorities now, and there may be a certain surplus in energy industry capacity.

1. Introduction

Energy is closely related to the development of human society, as the basis for human survival. It's also the lifeline that guarantees the economic and political security of all countries, closely related to the overall situation and long-term survival and development. As an important aspect of the energy issue, the energy consumption structure is a key indicator for measuring the economic development of a country and region. At present, China's energy consumption structure is dominated by coal, China's per capita energy consumption is low, and energy import dependence is increasing. Besides, the world's energy consumption maintains rapid growth and has become a consensus. In order to comply with this trend, China is also actively implementing the energy conservation and consumption reduction policy. Based on this, this paper analyses the relationship between China's economic growth and energy consumption based on E-G cointegration and Granger causal analysis. Then, the system dynamics model was used to simulate China's energy economic system, and analyse the energy saving effect of China's energy conservation and consumption reduction methods.

2. Literature review

Energy is the material basis of human progress and social development, and plays an important role in supporting economic growth and improving the level of economic development. Energy issue has been a hot issue of long-term concern. Especially since the outbreak of the oil crisis in the 20th century, the research on energy consumption has received special attention. Domestic and foreign scholars mainly focus on industrial restructuring, scientific and technological progress, energy prices, the relationship between energy substitution and energy consumption, and energy economic and environmental systems. Because the energy demand of each industry is very different, the change of industrial structure will inevitably lead to the change of energy consumption. If the industry with large energy demand is large occupies a larger proportion in the national economy and increases rapidly, the energy consumption will increase accordingly.

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Therefore, scholars study the change of energy consumption from the industry level. Alberini studied the relationship between economic structural change and energy demand through input-output analysis (Alberini, 2018). Boogen and Datta used input-output technology and statistical factor analysis method to establish the input-output model and factor analysis model of energy consumption intensity, and preliminarily explain the reasons for the decline of energy consumption intensity in China in recent years (Boogen and Datta, 2017). Ding et al. decomposed the change of China's energy intensity in two terms. From the perspective of three industrial divisions, they calculated the impact shares of economic structure change and sector energy efficiency change on the decline of energy intensity. The conclusion showed that the main driving force of China's energy intensity decline in the past year was the improvement of energy utilization efficiency of various industries (Ding et al., 2017). Dupret used index and decomposition model to decompose China's energy consumption intensity. The decrease of China's energy consumption intensity was mainly the result of the improvement of energy use efficiency in various industries. Compared with the efficiency share, the structural share had much less impact on energy consumption intensity (Dupret, 2017). Farag et al. decomposed the growth of energy consumption in China into intermediate demand effect, technology effect and final demand effect. The results showed that technology effect was the key factor to reduce energy consumption (Farag et al., 2017). Taking Sweden as a sample, Howell studied the relationship between information and energy consumption efficiency based on the living sector. The conclusion was that increasing information could improve energy consumption efficiency (Howell, 2014). According to the study, there are two kinds of information to improve energy consumption efficiency. One is investment information, that is, sufficient information enables consumers to choose the most reasonable investment plan. The other is to change people's consumption habits and behavior information.

In the analysis of long-term energy demand, it is necessary to analyze the impact of technological progress and related policies and measures on energy consumption in the same period. Matsumoto and Ishiguro believed that, the technological progress was the exogenous effect on energy efficiency, and for long-term energy demand, the impact of the invention of new technologies was greater than that of the diffusion of existing technologies (Matsumoto and Ishiguro, 2017). Overall, technological progress can effectively improve energy efficiency by directly or indirectly acting on energy systems. But because technological progress promotes rapid economic growth and consumes more energy, that is, the existence of the so-called return effect, the impact of technological progress on energy efficiency becomes more complex. Mezghani et al. established a vector autoregressive model and discussed the substitution effect between competitive energy sources in China through impulse response function analysis. It was found that there was a significant substitution effect between coal and electricity, while there was no substitution effect between other forms of competitive energy sources and this conclusion was explained (Mezghani et al., 2016). Taking environmental factors into the model and aiming at maximizing social welfare, Qu and Zhou constructed an optimization model of energy gradient substitution structure. The calculation results showed that the energy consumption structure of Nanjing in the coming year would gradually change from coal-based to natural gas, nuclear energy and renewable energy-based diversified structure, presenting importance of coal, oil, natural gas, nuclear, and renewable energy sources (Qu and Zhou, 2017). Based on the complex adaptive system, Suzdaleva theoretically analyzed the mechanism of technological innovation, calculated the competitiveness of different energy sources, predicted the energy supply structure, and divided technological progress into two types: endogenous technological progress and exogenous technological progress. Suzdaleva also calculated their effects on unit energy consumption respectively and predicted the energy demand and demand structure (Suzdaleva, 2017). By analyzing the characteristics of the environment-energy-economy system, using economic theory and econometric method, a logarithmic regression model of energy demand in China considering environmental impact was established. Based on the models of emission, energy consumption and economic growth established abroad, the model was further extended to the analysis, and a logarithmic regression model was established to validate the relevant data.

In summary, the above research work mainly uses input-output technology and statistical factor analysis method to establish the input-output model and factor analysis model of energy consumption intensity to study this process in detail. Therefore, based on the above research status, the calculation and optimization of energy-saving effect of energy-saving and consumption-reducing approaches in China based on E-G co-integration and Granger causality analysis is mainly focused on. The results show that further research on energy demand will make economic growth develop better in a certain range.

3. Principles and methods

In the process of China’s economic growth, energy issue has become one of the central issues in sustainable development. For years, Chinese government has made energy conservation and consumption reduction one of the important goals for government work. Considering the limited energy-saving effect of industrial restructuring, technological progress has become the most effective way to save energy and reduce consumption. Due to the rebound effect, technological progress affects energy consumption through different channels. On the one hand, technological progress will create a large number of new tools, new processes and new products to effectively reduce energy consumption; on the other hand, technological progress will promote economic growth, leading to an increase in energy consumption. This makes it extremely complicated to explain the relationship between technological progress and energy consumption. Their relationship is shown in Figure 1.

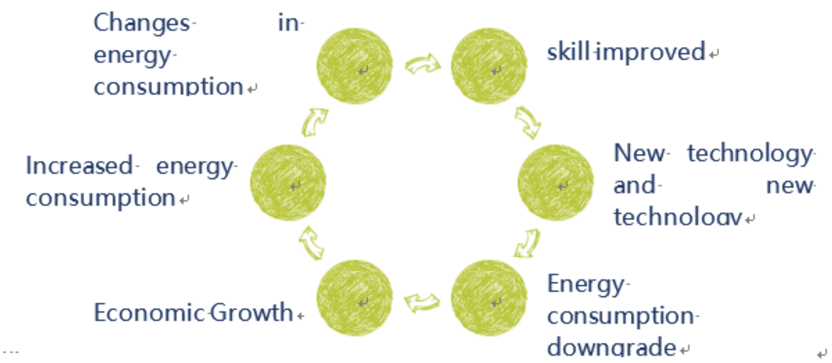

Figure 1: Relationship between technological progress and economic growth

The history of economic development in various countries shows that capital, labour, energy and technological progress are the basic elements of economic growth. Therefore, the economic growth model should consider five variables: yield (Y), capital (K), labour (L), energy (E) and technological progress (T), and capital, labour, energy and scientific and technological progress are combined to achieve the yield. The production function is used to describe this process, and its general form is as follows:

$$Y(t) = f(K(t), L(t), E(t), T(t)) \tag{1}$$

The formula above shows that the growth rate of energy intensity depends on the growth rate of unit capital output, the growth rate of unit labour output, the speed of technological progress, and the elasticity of each yield. The higher the growth rate of unit capital output and unit labour output. the faster the energy intensity grows; the greater the speed of technological progress, the faster the energy consumption intensity declines. With respect to the energy elasticity coefficient of output, the greater the energy elasticity coefficient, the the capital elasticity coefficient and the labour elasticity coefficient of output, the faster the energy intensity grows.
At present, the industry with total energy consumption is the mainstay of the Chinese economy. The industrial added value accounts for more than 40% of GDP, and industrial energy consumption accounts for more than 70% of China. Technological progress is also the most obvious in the industry. Therefore, in this paper, by taking the industry as an example, the impact of technological progress on energy conservation and consumption reduction was studied. Table 1 lists the annual average of the net value in China's industrial fixed assets, the average annual value of employees, energy consumption, and added value based on current year prices, which should be converted into corresponding indicators under constant prices.

Table 1: Annual average of the net value of China's industrial fixed assets，the average annual value of employees，energy consumption，and added value

	Annual average of net fixed assets	Average number of employees during the year	Energy consumption	Value Added
2014	60798.36	5520.66	102181	32994.8
2015	7148.8	5748.57	119627	41990.2
2016	86884.71	6098.62	143244	54805.1
2017	894060.49	6895.96	15942	72186.99

In grey system theory, buffer operators are used to solve such problems. The average weakening buffer operator has many advantages, so it has been widely used in impact system modelling and prediction. In this chapter, it’s also used to eliminate the impact of the Asian financial crisis on Chinese industry and try to restore the true trend of China’s industrial development. The data processed by the average buffer weakening operator is smoother, and the data is shown in Table 2.

Table 2: Annual average value， added value and energy consumption of the net industrial fixed assets of China

K	Y	E
76748.08	52218.39	163225.5
80163.43	57304.14	16999.22
82603.63	63398.28	175137
88907	69734.29	175137

Causality refers to the dependence between variables, i.e., the resulting variable is determined by the variable as the cause, and the change of the cause variable causes the change of the resulting variable. The causal relationship is different from the correlation, and the regression model cannot determine whether there is a causal relationship between the variables. Granger gave a definition of causality from the perspective of prediction, namely Granger causality. The Granger causality test assumes that all relevant and predicted information is included in the time series.

4. Results and analysis

The Granger causality test of LGDP and LE was calculated using Eviews 5.0 (Table 3). The results show that under the confidence level of 10%, the “why LGDP is not Granger reason for LE” is rejected, that is, LGDP is considered to be the Granger reason of LE; but “why LE is not Granger reason for LGDP” cannot be rejected, that is, LE is not the Granger reason of LGDP. So, LE and LGDP have a single causal relationship from LGDP to LE.

Table 3: Granger causality test results

Hypothesis	Lag order	F	P	Result
LGDP is not the Granger reason for LE	2	3.02368	0.07376	Refuse
LE is not the Granger reason for LGDP	2	0.09009	0.91426	Do not refuse

From the study, it’s also found that there exists cointegration relationship between China’s energy consumption and GDP, indicating that in the long run, there is a long-term stable equilibrium relationship between energy consumption and economic growth. In the cointegration regression equation, the coefficient of LE is 1.8, while the coefficient of $\triangle$LE in the error correction model is only 0.19, indicating that the long-term impact of energy on the economy is more obvious than the short-term impact. The Granger causality test shows that energy consumption is not the Granger cause of GDP, and the increase in China’s energy consumption cannot directly lead to an increase in GDP. The reason is that economic growth is also affected by many factors such as capital, labour and technological progress, in addition to energy. However, GDP is the Granger cause of energy consumption, indicating that China’s economic growth has led to a large amount of energy consumption. As China’s economy continues to grow in the future, energy consumption will continue to grow, and energy issues will surely become more prominent.

The extreme condition chosen in this paper is the extreme case where the initial energy intensity is 0 or 10. In these two extreme cases and normal conditions, the changes in net GDP is shown in Figure 2.

Through the simulation of energy demand and energy supply, it can be found that according to the current investment rate of the energy industry, that is, the investment in the energy industry accounts for about 25.8% of the industrial investment, the situation that the energy supply exceeds the energy demand will appear after 2008 (Figure 3). The three main reasons include: First, as China’s energy conservation and consumption reduction efforts deepen, energy intensity will gradually decline; Second, the financial crisis has caused considerable impact on the Chinese economy, making energy demand decline; Third, in recent years, the energy demand has been grown very fast, leading to a higher proportion of investment in the energy industry.

When studying the effects of energy-saving policies, using GDP as the scale of the economy, the impact of economy scale on the energy intensity was studied, finding certain diseconomies of scales in the Chinese economy. By adjusting the impact of GDP on energy intensity, the impact of scale economies on energy intensity can be studied. It is not difficult to find that in the case of scale economy, the energy intensity will be significantly lower than that of uneconomic scale.

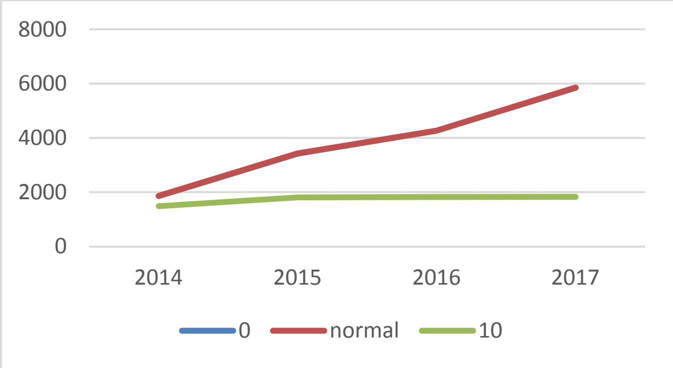

Figure 2: Extreme condition test

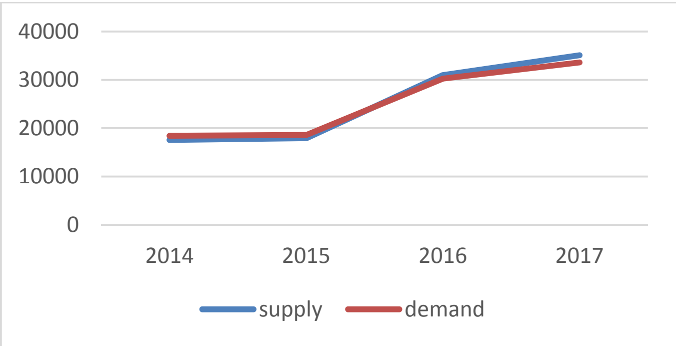

Figure 3: Energy supply and energy demand simulation

Industrial restructuring, upgrading and optimization are the objective requirements of economic development. Governments at all levels must fully understand the importance of industrial restructuring, take the scientific development concept as the fundamental guidance, do not blindly pursue the speed of economic growth, carefully deploy industrial restructuring, optimize the quality of economic operations through the adjustment of industrial structure, and continuously reduce the intensity of energy consumption. The increase in the proportion of the tertiary industry can effectively reduce the intensity of energy consumption. China must seize the opportunity of rapid development for the manufacturing industry and the accelerated transfer of the international service industry, and accelerate the development of service industries in key areas in a targeted manner. It's necessary to give priority to the development of modern logistics, software, finance, business and technology services that complement the manufacturing industry and improve the manufacturing industry, accelerate the development of information services, cultural industries, tourism and real estate with strong industrial relevance and penetration, and actively develop modern commerce and trade services. The development of the tertiary industry is conductive to reducing energy intensity

5. Conclusions

In this paper, the system dynamics model was used to simulate China's energy economic system, and analyse the energy saving effect of China's energy conservation and consumption reduction methods. The study found that energy conservation and consumption reduction are urgent tasks for achieving scientific development in China, and there may be a certain surplus in energy industry capacity.

With the in-depth implementation of the scientific development concept, China's economic structure is likely to undergo major adjustments: the economic development model that relies too much on investment and exports will be changed, and domestic consumption may become the real driving force for economic development. Significant adjustments in the economic structure will have far-reaching and substantial effects on China's energy use and energy consumption per GDP, which requires further in-depth study.

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