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The Relationship Between Energy Consumption and Economic Growth Based on Vector Error Correction Model

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In this paper, the author studies the relationship between economic growth and energy consumption. Based on the vector error correction model (VECM), the author conducts an in-depth study on the connections between economic growth and energy consumption and analyzes the characteristics and connotations, which provides an important reference for reducing energy consumption and improving economic efficiency. Understanding the rules between energy consumption and economic growth is of great significance to the development and utilization of energy and the increase in economic growth. The results of study on the relationship between energy consumption and economic growth based on VECM provide an important reference basis for the promotion of sustainable economic and social development. Therefore, it has a certain value of promotion and application.

1. Introduction

In the era of global economy, people's quality of life and economic level are increasing, but in such a context, ecological issues and environmental pollution are becoming increasingly serious, which has greatly affected the sustained economic growth and even may endanger people's health. Therefore, countries all over the world have vigorously carried out activities focusing on energy conservation and emission reduction. At the same time, research on the relationship between economic growth and energy consumption has also become a hot topic in the energy economy industry. With the passage of time, the research results have become more mature. Most scholars believe that there is a one-way causal relationship between energy consumption and economic growth. This indicates that for an energy-dependent economy, it is not conducive to the implementation of energy-saving policies, because such policies will bring a negative impact on the economy. On the contrary, for the economy not dependent on energy, the implementation of energy-saving policies will not only promote economic development, but also help achieve the goal of energy-saving and emission reduction. If there is a two-way causal relationship between energy consumption and economic growth, then the energy consumption of the economy is in an interdependent relationship with economic growth. In the process of implementing energy conservation policies, the consumption of customers can be reduced accordingly. If there is no causal relationship, it satisfies the so-called neutral hypothesis, then there is no effective connection between the economic growth of the economy and energy policy, so it can achieve the strategic goal of sustainable development.

2. Literature review

In the course of the study of the relationship between energy consumption and economic growth, most scholars rely on the theory of economic growth to establish an economic growth model. The ultimate goal is to examine the dependence of economic growth on energy, or to determine what extent the energy consumption constrains the sustained development of the economy. Scholars at home and abroad mainly study this problem from two aspects. On the one hand, it is the study of technological progress as an exogenous variable. In this respect, Nordhaus has achieved remarkable results. In his study done in 1992, he considered the technological progress in the economic growth model as a remedy for the depletion of resource constraints. In order to achieve sustainable economic growth, he also made limitations in the growth rate of

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technology progress. On the other hand, because of the emergence and gradual development of the new economic growth theory, researchers have begun to consider the relationship between energy consumption and the sustainable growth of the economy, including endogenous technological progress. With the increasing depletion of world resources and environmental pollution, many scholars have begun to take into account the negative external effects of energy consumption. Hossein and others used co-integration and error correction modeling technology to study the causality between the energy consumption and economic growth of OPEC countries, and added the environmental pollution factor – the increase of the carbon dioxide emissions caused by economic growth to the economic growth model. They believed that a lot of energy consumption was unlikely to bring significant economic growth, but it would lead to an increase in carbon dioxide emissions (Hossein et al., 2012). Therefore, for low - income OPEC countries, it is very important to adopt appropriate energy policies to promote their economic growth.

With the rise of China's economy, many domestic and foreign scholars have studied China's economic growth and energy consumption. Li and Zheng believed that energy consumption and economic growth could not be separated. With the expansion of economic scale and the increase of energy consumption in China, huge energy consumption greatly exceeds China's energy supply capacity, causing serious environmental pollution and threatening sustainable development of China's economy. They studied the relationship between China's energy consumption and economic growth, and put forward relevant recommendations through the error correction model to the long-term equilibrium relationship between energy consumption and economic growth (Li and Zheng, 2012). Zhang used semi parametric panel data addition model to study the impact of coal, electricity and the impact of oil consumption on regional economic growth. The results show that the direction and intensity of coal, electricity and oil consumption on GDP are different in eastern, central and Western China. They are determined by combinations of linear and nonlinear effects (Zhang, 2012). Shahbaz and others studied the relationship between energy utilization and economic growth through financial development, international trade and capital, because the financial development, international trade and capital are the important factors in China's production function during the 1971-2011 periods. The ARDL boundary test method of co-integration is used to test the long-term relationship between variables, - the structural fracture test is used to test the stability of the variables, and the long-term relationship between variables is confirmed. The research has made important contributions to energy economics, opening new directions for policymakers to explore new energy and alternative energy sources to meet the energy needs of sustained economic growth (Shahbaz et al., 2013). Herrerias and others studied the relationship between energy consumption and economic growth in China from 1995 to 2009. They believed that most of the previous studies ignored regional and cross sectional dependence in the provinces, and the impact of different energy policies on energy intensity by the government improved over time in 1990s and deteriorated from 2000. Therefore, it is necessary to examine these two periods, respectively.

In addition, the total energy consumption is decomposed into electricity, coal, coke and crude oil consumption and its relationship with economic growth, which can provide new ideas for the design of energy policy in China. They used panel technology to test the long-term and short-term operational directions of these different types of energy consumption and economic growth, and proposed the advice to adopt energy conservation policies without interruption of the growth path (Herrerias et al., 2013). Wang and other studied and suggested that a better understanding of the relationship between economic growth, energy consumption and CO2 emissions was necessary so that the Chinese government would formulate a strategy for energy conservation and emission reduction, to cope with the impact of climate change. There are economic growth, energy consumption and carbon dioxide emissions in China in terms of co-integration, temporal dynamics and causality. The study developed a comprehensive conceptual framework and found a two-way causal relationship between economic growth and energy consumption (Wang et al., 2016). Kareem and others studied the relationship among carbon dioxide emissions, energy consumption and China's economic growth. The study introduced industrialization and capital as additional variables. The research believed that the government could develop the environment by reducing the energy use, and do not bring serious impact on the economic growth, so as to realize the protection and management of the environment. It is necessary to mitigate emissions by developing carbon markets, carbon taxes and subsidies to promote faster technological progress (Kareem et al., 2012). Li and Zheng believed that energy was one of the most basic materials in the national economy and played an important role in national production and life. Since the energy crisis occurred in the 70s of last century, the relationship between energy consumption and economic growth has always been a matter of concern. Li and Zheng also studied the relationship between energy consumption and economic development based on the 1990 China time series 2009 VAR model, and then used impulse response function and variance decomposition to describe the correlation between economic growth and energy consumption. The results show that there is a one-way causality between energy consumption and GDP, and energy consumption has an obvious promoting effect on economic development (Li and Zheng, 2012).

To sum up, the above research work mainly uses co-integration test, panel technology and error correction model to study the relationship between energy consumption and economic growth, while the study of the relationship between energy consumption and economic growth is less by using vector error correction model. Therefore, based on the above research status, this paper uses vector error correction model to analyze the relationship among energy consumption, capital stock, labor force and economic growth, and provides a theoretical reference for the possible problems and measures to be faced in the future development and utilization of new energy in China.

3. Research methods

In this paper, the author combines the VECM and conducts an in-depth study and analysis on the relationship between energy consumption and economic growth in Japan, the United States, Taiwan, South Korea, Greece and other countries or regions as well as various provinces in China. Because there are great differences in economic development level, industrial structure and energy consumption structure between different regions and provinces in China, it is necessary to use data at provincial level to explore the relationship between economic growth and energy consumption. In this paper, the author examines the time series characteristics of energy consumption and economic growth in Yunnan Province and use the Granger causality test and error correction model to study the causality and long-term and short-term elasticity between the two, aiming to provide a reference to energy saving and economic development planning. The data used in this paper is the annual data of a province's energy consumption and GDP in 1978-2007. The economic growth is expressed in terms of GDP in 100 million RMB Yuan; EC refers to that province's energy consumption in tons of standard coal. In order to eliminate the impact of price factors and heteroscedasticity, EC and nominal GDP are adjusted by using the price index in 1978 as the base period and then the natural logarithm of EC and GDP is taken and denoted by LEC and LG respectively. It can be seen from Figure 1 and Figure 2 that the sequence LG and LEC have similar fluctuation trends and there may be a long-term stable equilibrium relationship between the two.

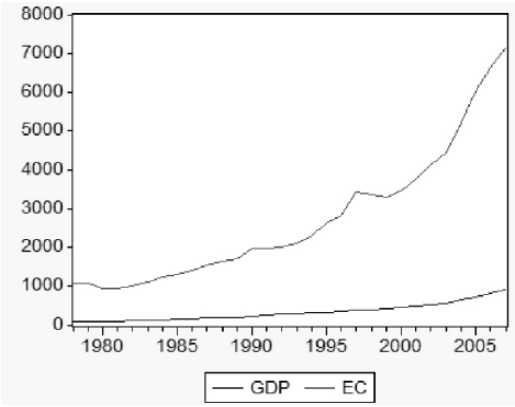

Figure 1: GDP and EC time series.

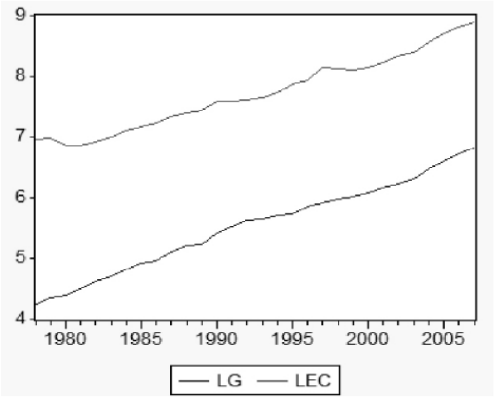

Figure 2: Time sequence diagram of LG and LEC.

4. Results and discussions

4.1 Study on VAR-Based VECM

On the basis of examining the co-integration relationship, an error correction model linking short-term fluctuations with long-term equilibrium is established. The traditional economic model usually expresses a "long-term equilibrium" relationship between variables, while the actual economic data is generated by the "non-equilibrium process. " Therefore, the dynamic non-equilibrium process of data needs to be used to approximate the long-term equilibrium process of economic theory, and an error correction model is needed to reflect this short-term dynamic change. The error correction model was first used by Sargan in 1964 and later further improved by Hendry-Anderson and Davision.

4.1.1 Unit root test - ADF test

The test of stationarity for time series is mainly based on three considerations: (1) Stock and Watson (1989) found that the causality test is very sensitive to the smoothness of the sequence; (2) Nelson and Plosser (1982) pointed out that many macroeconomic sequences are unstable; (3) Estimating directly using ordinary least squares (OLS) estimation is prone to spurious regression. Therefore, it is necessary to check the stability of the time series before modeling. In general, the stationarity test includes a graphic method, a sample autocorrelation function method, a definition method, a unit root test method and a characteristic equation method. The essence of the unit root test is to test the significance of the lagged variables in the autoregressive model. The commonly used methods are DF test and ADF test. The difference between the two is that the former is only applicable to the first-order autoregressive model and the white noise characteristic of the random interference term cannot be guaranteed, so the ADF test is generally used more often.

4.1.2 Co-integration test and error correction model - EG two-step method

For non-stationary time series, the direct least squares estimation is prone to spurious regression; if the difference is estimated after the model, it can avoid the occurrence of false regression, but it ignores the important information of the variable level value and cannot reflect the sequence between The long-term relationship. Therefore, the simple difference can not solve all the problems encountered in the non-stationary time series. How to avoid the spurious regression while reflecting the long-term relationship between the sequences becomes the key to the non-stationary time series modeling. The emergence of co-integration tests and error correction models solves this problem. They believe that if a linear combination of non-stationary time series is stationary, an error correction model can be established to express the long-term relationship between them.

4.1.3 Granger causality test

Granger causality test is a method used to examine whether the sequence x is the cause of the sequence y. If sequence x contributes to predicting y and y does not contribute to predicting x, the sequence x is called the Granger cause of y. The original hypothesis of Granger causality test is that sequence x(y) is not the cause of sequence y(x), i.e. $\beta 1=\beta 2=\ldots=\beta k=0$, which can be judged appropriately based on the F statistics given by Eviews and its adjoint probability.

4.2 Test of stationarity of variables

Table 1: Energy consumption and economic growth ADF unit root test.

variable	ADF test value	Retrieval regression(c , t , k)	The critical value	conclusion
LG	- 1. 75	(c , t , 0)	- 3. 57	Not smooth
LEC	- 2. 00	(c , t , 3)	- 3. 60	Not smooth
△LG	- 5. 53	(c , 0 , 0)	- 2. 97	Not smooth
△LEC	- 3. 92	(c , 0 , 0)	- 2. 97	Not smooth

Before co-integration analysis and Granger causality test on variables, the stability of the variables must be tested. Therefore, ADF is used to test the stationarity of LG and LEC. The results are as follows: Note: c, t, k in the test regression equation represent the intercept term, time trend term and lag order, respectively; The lag order k is determined one by one according to the minimum principle of AIC and SIC; The critical values in the table are calculated from the data given by Machinnon and represent the critical value at the 5% level of significance; △ represents the difference operator.

It can be seen from Table 1 that the ADF values of the energy consumption and economic growth level series are all greater than the critical value at a significant level of 5%, indicating that both LEC and LG are non-stationary time series; However, the ADF values of the first-order differential two time series are less than the critical value of 5% significant level, indicating that both LG and LEC are I(1) order and there may be a long-term equilibrium relationship between the two.

4.3 Co-integration test

Although the horizontal time series LEC and LG are non-stationary, according to the stationarity test results, there may be a long-term equilibrium relationship between the two. Therefore, the E-G two-step method can be used to perform co-integration test on LEC and LG. LM test results show that the model (2) There has been no autocorrelation and the existence of a co-integration relationship between LEC and LG depends on the smoothness of the residual level sequence. If the residual sequence itself is stationary, then there is a co-integration relationship between the two; If the residual sequence is stable after several differences, it means that there is no strict co-integration relationship between the two. Since model (2) has an intercept term, the no-intercept term, the lag order is determined by the test regression model determined by the AIC principle and the residual sequence is tested for stationarity, as follows: It can be seen from Table 2 that the ADF value of the residual level sequence is less than 10%. The critical value at the significant level indicates that the residual sequence itself is stable and there is a long-term stable equilibrium relationship between energy consumption and economic growth. Model (2) is the co-integration regression equation.

Table 2: Stationarity test of residual sequence.

		t statistics	The probability of
ADF		- 5. 24	
The critical value	1% level	- 2. 65	
	5%level	- 1. 95	
	10% level	- 1. 61	

4.4 Granger causality test

Table 3: Energy consumption and economic growth Granger causality test.

Null hypothesis	F statistic	P values	conclusion
LG is not the Granger cause of LEC	6.464	0.017	There are
LEC is not the Granger cause of LG.	1.141	0.295	There is no

Table 4: Unit root test of residual sequence

		t statistics	The probability of
ADF		- 4.51	0.0001
The critical value	1% level	- 2.65	
	5%level	- 1.95	
	10%level	- 1. 61	

Granger's representation theorem holds that if there is a co-integration relationship between two time series, there must be a Granger causality in a certain direction. To determine the causal relationship between economic growth and energy consumption, a Granger causality test is required for LEC and LG, as follows: It can be seen from Table 3 and Table 4 that the p-value of the original hypothesis “LG is not a LEG Granger cause” is less than 0. 05, so the original hypothesis is rejected, that is, LG is the Granger cause of LEC; The p-value of the null hypothesis "LEC is not Granger cause of LG" is greater than 0. 05. There is no reason to reject the null hypothesis, so LEC is not the Granger cause of LG. This shows that there is a one-way causal relationship between economic growth and energy consumption in that province from 1978 to 2007, that is, economic growth leads to an increase in energy consumption, indicating that the province's economy is a non-energy-dependent economy and the implementation of energy-saving policies will not result in economic development. Significant negative effects.

4.5 Error correction model

Co-integration test and Granger causality test show that there is a long-term stable equilibrium relationship between LEC and LG in the province and there is a one-way causal relationship between LG and LEC. Since the error correction model can simultaneously show the long-term and short-term relationships between variables, an error correction model between energy consumption and economic growth can be established.

5. Conclusions

Based on the above results, it can be proved that by introducing VECM in the process of study on the relationship between energy consumption and economic growth can provide an important reference for the research to ensure the validity of results. Granger causality test, co-integration test and unit root test in the VECM are used to study the relationship between economic growth and energy consumption. The results are as follows: The results of Granger causality test show that economic growth is a Granger cause of energy consumption. However, energy consumption is not a Granger cause of economic growth. This proves that the economy is a non-energy-dependent economy. Therefore, the implementation of energy-saving policies will not cause significant negative impact on economic growth. The results of co-integration test and unit root test are identical, which indicates that LG and LFC belong to I (1) order. Therefore, there is a long-term and stable equilibrium relationship between energy consumption and economic growth. The error correction model shows that the error correction term helps to balance the relationship between energy consumption and economic growth.

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