# Research on the Relationship between Energy Consumption and Economic Growth

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## Abstract

**VAR model is used in this paper to discuss the relationship among energy consumption and economic growth in China from 2000 to 2018. The results of empirical research show that: (1) There is a co integration relationship between energy consumption and economic growth. Although there are some fluctuations between them in the short term, from the perspective of long-term development, energy consumption and economic growth can achieve a long-term stable equilibrium relationship. (2) The causality between energy consumption and economic growth can be said that the national energy GDP is the cause of energy consumption, which proves that China's economic growth is not entirely energy consumption. (3) There is a high positive correlation between the energy consumption of the secondary industry and the tertiary industry and economic growth in the short run, but it is stable in the long run.**

## Keywords

**Energy Consumption; VAR Model; Economic Growth; Impulse Response.**

## 1. Introduction

With the rapid development of China's economy, especially the development of the secondary and tertiary industries, China's energy is facing great challenges. On the one hand, economic growth is strongly dependent on energy, and energy supply will directly affect economic growth; on the other hand, rapid economic development will also stimulate energy demand and upgrade energy consumption. To study the relationship between China's economic growth and energy consumption is of great significance to promote the sustainable development of China's economy.

The relationship between energy consumption and economic growth has been widely concerned by researchers. Many scholars at home and abroad have done a lot of research on the relationship between energy consumption and economic growth. It is the first time for American scholars to study the causal relationship between energy consumption and GDP. The conclusion shows that there is a dynamic relationship between energy consumption and economic growth, that is, economic growth can effectively drive the growth of energy consumption. However, many scholars disagree with this research result: whether there is a causal relationship between energy consumption and economic growth. Since then, there has been an upsurge of applying Granger causality test to explore the relationship between economic growth and energy consumption, and a large number of excellent research results have been achieved.

In the early 1990s, in order to make up for the deficiencyof the Granger causality test method which can only analyze the stationary series, some scholars used the co-integration analysis method to study the relationship between energy consumption and GDP with non-stationary data. Fallahi uses Markov regime transfer vector autoregressive model to discuss the causal relationship between energy consumption and GDP in the United States from 1960 to 2005. Kahouli used unit root test, cointegration test, vector error correction model and autoregressive distribution lag model to analyze the short-term and long-term causality between economic growth, energy consumption and financial development level of southern Mediterranean countries from 1995 to 2015. Domestic scholars have also conducted many research on this issue. Zhao Jinwen (2007) and Zhang Youzhi (2016) used STR

model to study the internal structure compliance relationship between China's energy consumption and economic growth, and found that there is a long-term equilibrium relationship between energy efficiency and economic growth, which is reciprocal causality. Liang Jingwei (2014) studied the relationship between China's energy consumption and economic growth from 1953 to 2008 by using the two zone Markov state transition model, and found that there was a one-way Granger causality between energy consumption and economic growth in the region of moderate economic growth, and a two-way Granger causality between energy consumption and economic growth in the region of rapid economic growth. Guo Sidai (2012) and Ma Hongwei (2012) used Granger causality test and linear regression model to study the relationship between China's new energy utilization and economic growth, and found that there is no two-way Granger causality between energy consumption and economic growth in the short term, but in the long term, economic growth is the Granger cause of energy consumption.Taking time series data as the research object, Li Qian verified the one-way causal relationship between China's energy consumption and economy, and finally found the key reason of energy consumption, namely economic development. Jia Qingying et al. Studied and analyzed the relationship between energy consumption and GDP growth data in China from 1978 to 2000 through E-G two-step method and Granger causality test without considering sequence balance, and concluded that there is a bidirectional causality between energy consumption and GDP growth. Domestic and foreign research results show that some scholars believe that there is a one-way causal relationship between economic growth and energy consumption, while some scholars believe that there is no relationship between economic growth and energy consumption in the short term, including one-way causal relationship; but in the long term, there is a causal relationship between them. Although the research on the relationship between energy consumption and economic growth has drawn different conclusions, it is certain that the relationship between energy consumption and economic growth will change with the change of time, and will not always maintain a single relationship.

Using VAR model and impulse response, this paper studies the relationship between energy consumption and economic growth in China from 2000 to 2018.

## 2. Empirical Research

In this paper gdp represents gross demestic product, d2cy represents gross energy consumption of the secondary industry, d3cy represents gross energy consumption of the tertiary industry, and lgdp represents the logarithmic conversion value of the original gdp data, ld2cy represents the logarithmic conversion value of the original data of energy consumption of the secondary industry, and ld3cy represents the logarithmic conversion value of the original data of energy consumption of the tertiary industry. The data of GDP and gross energy consumption from 2000 to 2018 are derived from the websites of Zhonghong. (because of the tiny section of the energy consumption of the primary industry, energy consumption of the primary industry is ignored in this paper )

From the trend chart of Figure 1, it can be seen that the GDP, the gross energy consumption of the second industy and the tertiary industry show an obvious upward trend with the change of time, with trend and intercept. it can be judged basically that the time series of GDP and the gross energy consumption of the second industy and the tertiary industry have non-stationary characteristics. in order to examine the relationship between GDP and gross energy consumption, this paper uses VAR model to analyze the relationship.

The basic assumption of Var model is the stability of time series. In order to ensure the validity of regression and avoid the occurrence of pseudo-regression, time series data first need to pass the stationarity test. In this paper, the ADF method is used to test the stability of the sequence.

As can be seen from Table 2, the ADF test values of LGDP, LD2CY and LD3CY, are all greater than the critical values at the significant levels of 1%, 5% and 10%, and there are unit roots, all the time series of rgdp, LD2CY and LD3CY are unstable. However, the first-order difference is stable at the significant level of 5%, and all the time series of LGDP, LD2CY and LD3CY are one-order single

integral at the significant level of 1%. So, there may be a long-term equilibrium relationship among them, that is, cointegration relationship.

Table 1. Dataset of 2002-2019.

| year | gdp | d2cy | d3cy |
|---|---|---|---|
| 2000 | 40259.7 | 105221 | 20816 |
| 2001 | 43855.6 | 109392.62 | 20714.91 |
| 2002 | 47776.3 | 116010.01 | 21927.32 |
| 2003 | 55363.8 | 133888.58 | 25183.96 |
| 2004 | 65776.8 | 155621.11 | 29369.12 |
| 2005 | 77960.5 | 191400.19 | 35535.81 |
| 2006 | 92238.4 | 188706.18 | 35874.26 |
| 2007 | 111693.9 | 204658.9 | 38806.75 |
| 2008 | 131727.6 | 213114.68 | 40422.17 |
| 2009 | 138095.5 | 223759.18 | 42793.91 |
| 2010 | 165123.1 | 266910 | 50001 |
| 2011 | 195139.1 | 252313.12 | 51520.03 |
| 2012 | 208905.6 | 258630.15 | 56651.34 |
| 2013 | 222333.2 | 298147.6 | 65179.77 |
| 2014 | 233197.4 | 303206 | 67293 |
| 2015 | 234968.9 | 299972 | 71603 |
| 2016 | 245406.4 | 298246 | 74820 |
| 2017 | 275119.3 | 303042.55 | 78935.05 |
| 2018 | 301089.3 | 319836 | 82873 |

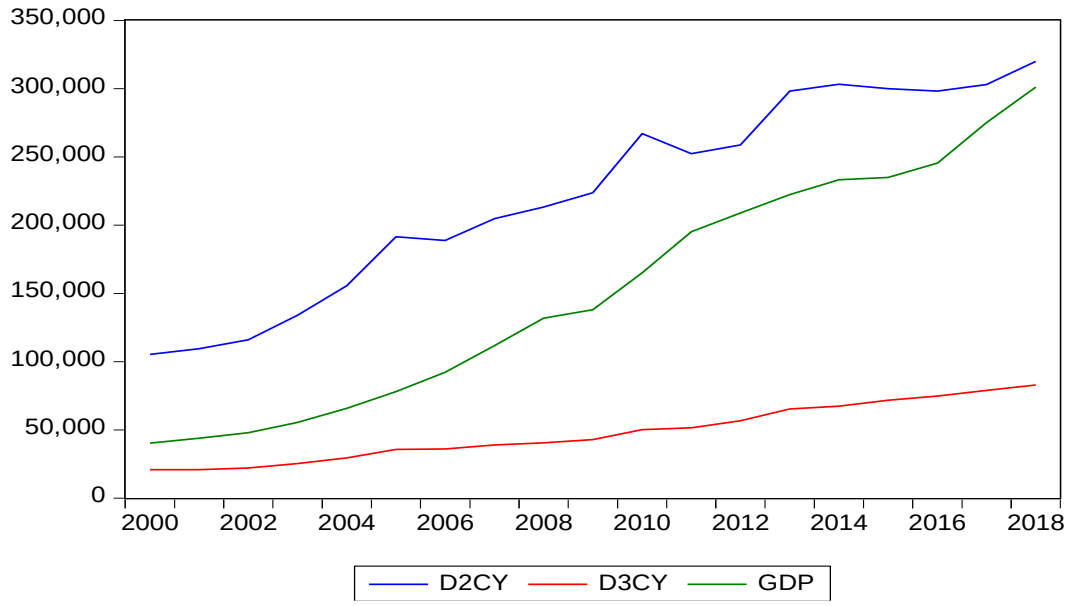


Fig. 1 GDP, gross investment and gross consumption

Table 2. Results of Stationarity Test

| | lgdp | ld2cy | ld3cy | dlgdp | dld2cy | dld3cy |
|---|---|---|---|---|---|---|
| adf | -1.085991 | -1.112338 | -1.578085 | -4.342823 | -4.692501 | -5.906324 |
| 1% | -4.616209 | -4.571559 | -4.571559 | -4.728363 | -4.728363 | -4.667883 |
| 5% | -3.710482 | -3.690814 | -3.690814 | -3.759743 | -3.759743 | -3.733200 |
| 10% | -3.297799 | -3.286909 | -3.286909 | -3.324976 | -3.324976 | -3.310349 |
| p | 0.9014 | 0.8981 | 0.7609 | 0.0190 | 0.0106 | 0.0012 |
| Check Type | c,t,1 | c,t,1 | c,t,1 | c,t,1 | c,t,1 | c,t,1 |
| | Non-stationary | Non-stationary | Non-stationary | stationary | stationary | stationary |

Table 3. Results of Cointegration Test.

| | | | | | |
|---|---|---|---|---|---|
| Trace Test | Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
| | None * | 0.800185 | 51.43080 | 29.79707 | 0.0000 |
| | At most 1 | 0.653311 | 25.66495 | 15.49471 | 0.0011 |
| | At most 2 | 0.420003 | 8.715709 | 3.841466 | 0.0032 |
| Maximum Eigenvalue | Hypothesized No. of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
| | None * | 0.800185 | 25.76585 | 21.13162 | 0.0103 |
| | At most 1 | 0.653311 | 16.94924 | 14.26460 | 0.0184 |
| | At most 2 | 0.420003 | 8.715709 | 3.841466 | 0.0032 |

Table 3 shows that the trajectory test results reject the original hypothesis that there is no co-integration relationship, which indicates that there is one co-integration relationship among economic growth, LD2CY and LD3CY at the 5% significant level. At the same time, the maximum eigenvalue test supports the result of trajectory test.

Lag period must be designed to set VAR model. If the lag period K is too small, it will lead to inconsistent of parameters estimation. In VAR model, increasing lag variables properly can eliminate the existence of autocorrelation, but the larger lag period K will lead to reduced degrees of freedom, which affect the effectiveness of parameter estimation. In this paper, the AKaike information criterion AIC is used to select the lag period. The lag period k is designed to be 2 by testing, and the model is set to VAR (2). The result of parameter estimation is expressed in matrix form as follows:

$$\begin{pmatrix} LGDP \\ LD2CY \\ Ld3CY \end{pmatrix} = \begin{pmatrix} -0.990125 \\ 3.714533 \\ 2.477122 \end{pmatrix} + \begin{pmatrix} 1.002529 & -0.015857 & 0.391252 \\ -0.032921 & -0.179856 & 1.090302 \\ -0.065572 & -1.032110 & 2.011220 \end{pmatrix} \begin{pmatrix} LGDP(-1) \\ LD2CY(-1) \\ LD3CY(-1) \end{pmatrix}$$
$$+ \begin{pmatrix} -0.232767 & 0.290931 & -0.353758 \\ 0.257471 & 0.835448 & -1.285373 \\ 0.254471 & 0.887251 & -1.278387 \end{pmatrix} \begin{pmatrix} LGDP(-2) \\ LD2CY(-2) \\ LD3CY(-2) \end{pmatrix}$$

The test results of the VAR model show that the eigenvalues are all in the unit circle (see Fig. 1), and the residual sequence obeys normal distribution, and there is no hetero-scedasticity and autocorrelation, that is, there is no deviation in Var model.

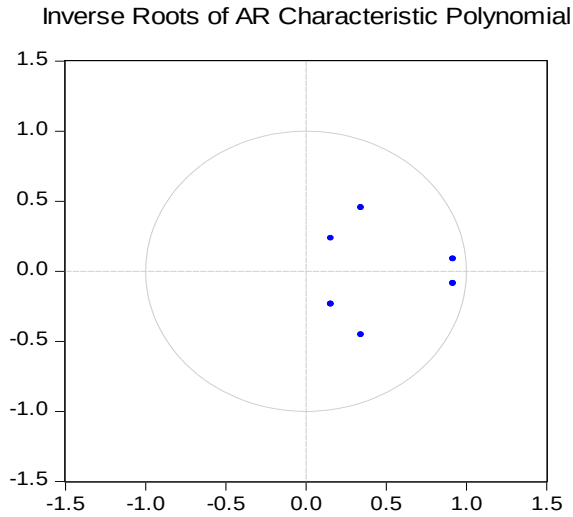


Fig. 2 Inverse Roots of AR Characteristic Polynomial

## 3. Impulse Response Analysis

Since the OLS parameters estimators of VAR model has only consistency, it is difficult to interpret the single parameter estimators economically, so it is necessary to analysis the impulse response of

the system. Impulse response function (PRF) is the response of an endogenous variable to an random error shock. It describes the impact of a standard deviation shock on the current and future values of the endogenous variable, Figure 3 shows the results of inpluse response:

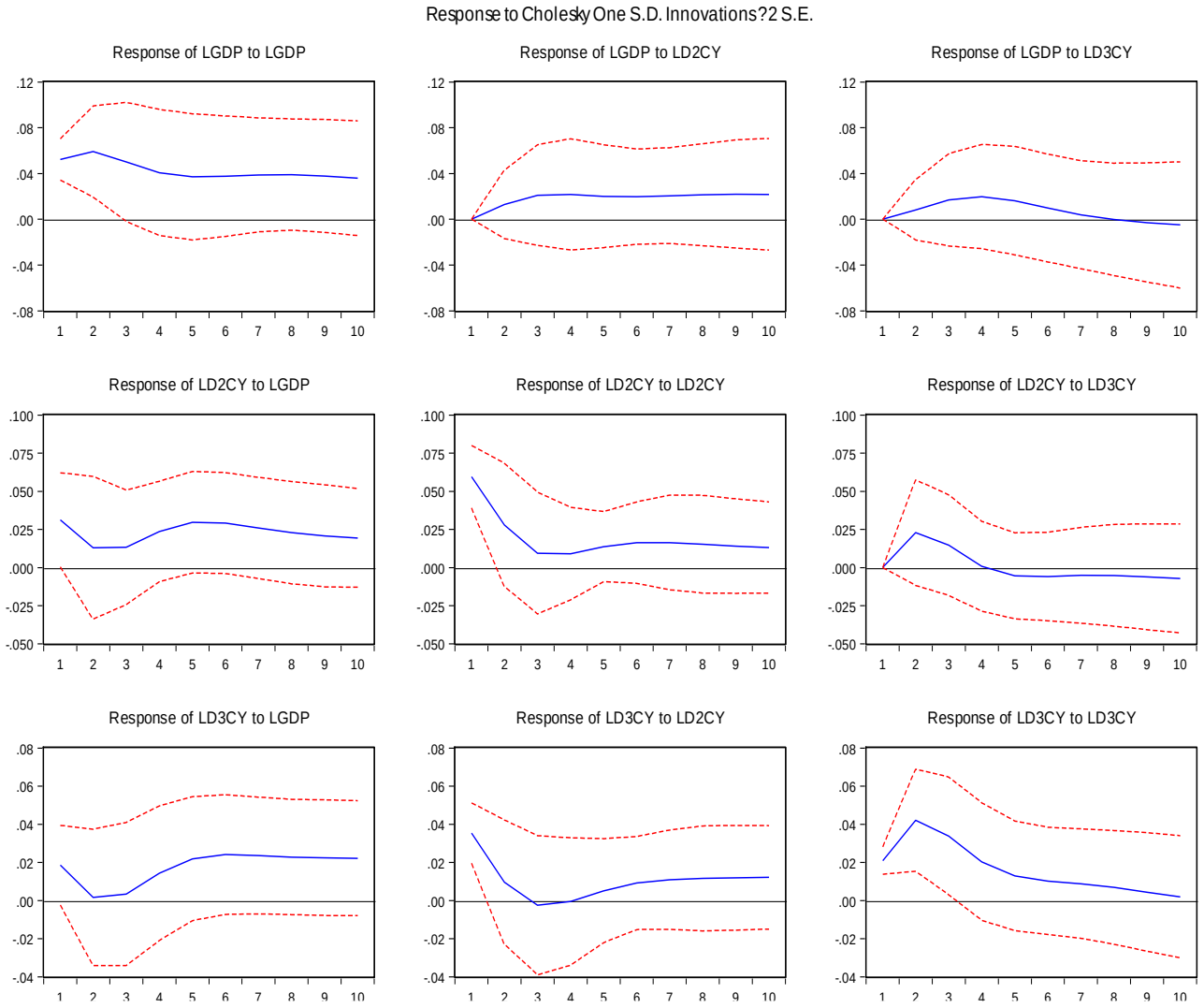


Fig. 3 Inpluse Response

Given a standard deviation shock to the economic growth, the energy consumption of the second industry is accelerating from the first to the fourth. The fourth to the seventeenth periods maintain a basically synchronous growth with economic growth. This shows that in the short term, the development of the secondary industry drives economic development, and has limited long-term effect, Given a standard deviation shock to economic growth, energy consumption is also a growth trend from the first to the fourth, and the fourth to the tenth is a downward trend. Therefore, the demand for energy consumption in the early stage of the development of the tertiary industry is increasing, and the demand for energy consumption will be greatly reduced when the third industry develops to a certain stage, this shows that the main factors which promote the development of the tertiary industry are not related to energy consumption.

Given a standard deviation shock to the energy consumption of the secondary industry, energy consumption of the secondary industry has the same trend with the economic growth, which showing a downward trend from the first period to the fourth period, an upward trend from the fourth period to the fifth period, and a stable trend after the sixth period. this means that the energy consumption of the secondary industry is positively related to economic development. Economic growth drives

energy consumption. Especially in the short term, economic growth is the main reason for energy consumption. The continuous improvement of the utilization rate of various kinds of energy will reduce the intensity of energy consumption. In the period of economic rise, the energy consumption of the secondary industry is high, while in the period of economic decline, the energy consumption of the secondary industry is low. Given a standard deviation shock to the energy consumption of the second industry, there is an upward trend from the first to the second period, and a downward trend in the third period. This means that the initial development of the third industry can promote the demand for the second industry, leading to the increase of energy consumption of the second industry, but with the development of the third industry, the demand for the second industry will gradually reduce, which making the energy consumption of the second industry increase The energy consumption is reduced.

Given a standard deviation shock to the energy consumption of the tertiary industry, the energy consumption of the tertiary industry has the same trend as economic growth, the first period to the fourth period showed a downward trend, the fourth period to the fifth period showed an upward trend, after the sixth period showed a stable trend. It shows that the energy consumption of the tertiary industry is positively correlated with economic development. In the period of economic rise, the energy consumption of the tertiary industry is high, while in the period of economic decline, the energy consumption of the tertiary industry is low. Given a standard deviation shock to the energy consumption of the tertiary industry shows a downward trend from the first period to the third period, an upward trend from the fourth period to the fifth period, and a stable trend after the sixth period. It shows that the decline of the secondary industry will cause the decline of the tertiary industry at the initial stage, and the rise of the energy of the secondary industry will cause the rise of the energy of the tertiary industry, and there is a stable trend thereafter.

## 4. Conclusion and Suggestion

China's energy growth rate is slower than the economic growth rate, which can not meet the energy demand of economic development. The urgent task is to improve the utilization rate and efficiency of energy. This means to optimize the existing industrial production capacity, eliminate the backward industrial production capacity, and implement strict and effective control over the new industrial production capacity. This can effectively avoid unnecessary waste in the process of energy development. In the short run, a large amount of energy consumption will lead to GDP growth, and GDP growth will also promote energy consumption. In the long run, the large consumption of energy will lead to the demand for environmental governance, and the high cost of environmental governance will have a certain impact on economic growth.

Optimizing the structure of energy consumption and innovating energy supply system. government should establish a fully competitive and open and orderly energy market, and increase the openness of natural gas import and export, and improve the coal market trading system. At the same time, government should promote the coordinated development of renewable energy: promote the construction of large hydropower base; improve the service system of wind power supporting industry, promote the development of wind power; promote the development of photovoltaic industry; promote the large-scale development of biogas.

Government should promote energy saving and loss reduction, increase resource utilization, and change from low energy consumption development to high energy consumption development, which is conducive to the stable development of the country. Industrial structure adjustment has a significant impact on economic development, which shows that optimizing industrial structure is the driving force of China's economic development and can improve the rationality of China's energy consumption. Enhance the concept of energy conservation. Strengthen the idea of energy conservation, such as public service advertising and media publicity; set up corresponding incentive and restraint mechanisms to criticize enterprises with excessive energy consumption and require them to transform in time; set up energy-saving funds to carry out various energy-saving work and provide economic encouragement to advanced energy-saving enterprises.

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