Quantitative analysis of energy consumption and economic growth in China

Xiangdong Li 1,2, Dequn Zhou 1, Huaiping Zhang 2

1 Economic and Management Department, Nanjing University of Aeronautics and Astronautics, Nanjing, 210016, China
2 School of Business, Jiangsu University of Technology, Changzhou, 213001, China

*Corresponding author’s e-mail: lxd@jsut.edu.cn

Abstract: Economic development is closely related to the energy industry. With the rapid economic growth and the continuous improvement of people’s living standards, China’s demand for energy is also increasing. How to properly handle the relationship between energy consumption and economic growth is of great significance for the sustainable development in China. In this article, we have made research on co-integration and causality of China’s energy consumption and economic growth. We have obtained conclusions that there is a long-term stable relationship between energy consumption and economic growth, and there is a unidirectional causality from economic growth to energy consumption.

1. Introduction

Energy is an important national strategic resource and also the resource factor which restricts economic and social development. It has played very important role in promoting and protecting national economy and social development. Energy is a major strategic issue which is related to the overall situation of China’s economic and social development. The energy is a material base of human progress and social development. The improvement of economic development level and economic growth need energy as a great support. The research on relationship between energy consumption and economic growth has always been a hotspot of energy economics. In the past 30 years, foreign scholars have done a large number of empirical works in this field, but so far there still have not reached consensus and exist a lot of difference and dispute. Kraft.J. and Kraft.A. made initiative research on relationship between energy consumption and economic growth in 1978. Using data of U.S.A. from 1947 to 1974, they found that there exists unidirectional causality from GNP to energy. However, Akarca and Long(1980) pointed out that the conclusion of Kraft-Kraft was doubtful if the time interval was changed into 2 years. It is worth noting that after making a large number of researches in this field, we have drawn different conclusions if we take different countries for example, or select different time intervals of the same country, and or use different testing methods. For example, Masihet (1996) have analyzed data of relevant country from 1955 to 1990. The result revealed that there is lack of co-integration relationship between energy consumption and economic growth in Malaysia, Singapore, and Philippine, but there is the unidirectional causality from energy consumption to economic growth in India, the unidirectional causality from economic growth to energy consumption in Indonesia, and the bilateral causality in Pakistan.

There are some scholars researching on energy issue by in China as follows: Zhao Lixia (2012) introduced the energy into Cobb-Douglas productive function as the new variable, therefore set up
VAR model, and then drew conclusions that it exists positive correlation between economic growth and energy consumption in our country. Han Zhiyong (2015) analyzed GDP series and data of energy consumption among 1990-2014 years through adopting EG two-step method and standard Granger causality test without considering unstationarity. It was found that there does not exist long-term equilibrium relationship between energy consumption and GDP, but exists the bilateral causality. Using EG two-step method, Ma ChaoQun (2016) analyzed annual data among the 1985-2015 year, and drew conclusions as follows: there exists long-term equilibrium relationship between GDP and total energy consumption, or GDP and consumption of coal. But there does not exist co-integration relationship between GDP and petroleum, GDP and natural gas, GDP and water, or GDP and electricity respectively. Likewise, adopting Granger test method, without considering unstationarity, we have concluded that there exists bilateral causality between energy consumption and GDP.

2. Data collection and pretreatment
In this article, we have chosen the data of total amount of China’s energy consumption and actual GDP in 1988-2016. The reason why we have not chosen the data before 1988 is that China's economy was relatively closed before that time, and was impacted by political event greater. Compared these, China's economic operation environments after 1988 had greater difference. So, analyzing the data in 1988-2016 only, we can reveal relations in all respects between China’s economic growth and energy consumption since China has implemented the policies of reform and opening to the outside world so far.

In analysis of empirical modeling, we have selected annual GDP (adjusted to 1990 price level ) and total amount of energy consumption as research variable, and have marked them y and ec series respectively. The sample has 29 groups of annual data among 1988-2016. In addition, in order to eliminate possible effects of heteroscedasticity, we have made logarithmic processing with annual GDP and energy consumption to obtain Ly and Lec series separately. In the following two diagrams, the trend pictures of these two groups of horizontal variable series are given separately. All data come from annual China statistical yearbook and energy statistical yearbook compiled by State Statistics Bureau of China. If there is no special instruction, we all use Eviews6.0.software to deal with these data.

3. Testing and empirical analysis
3.1 Test of stationarity
As these above pictures show, energy consumption and GDP are all not steady. In the analysis of time series, time series are required stationary, otherwise it will lead to appear spurious regression phenomenon. Therefore, we must have a unit root test on these series before. In this article, we adopt ADF test method (Augmented Dickey-Fuller Test). While having the unit root test, we adopt limited regression equation, which does not include intercept and time trend.
### Table 1. Results of unit root test

| Series                  | ADF test statistic | 5% Critical value | 1% Critical value | Result       |
|-------------------------|--------------------|-------------------|-------------------|--------------|
| Ly                      | 2.8400             | -1.9557           | -2.6649           | Non-stationary |
| First order difference of Ly | -0.0385           | -1.9550           | -2.6607           | Non-stationary |
| Second order difference of Ly | -5.0335           | -1.9550           | -2.6607           | Stationary   |
| Lec                     | 3.3652             | -1.9564           | -2.6694           | Non-stationary |
| First order difference of Lec | -0.9249           | -1.9539           | -2.6534           | Non-stationary |
| Second order difference of Lec | -3.8610           | -1.9581           | -2.6797           | Stationary   |

From the test results, we can know that Ly and Lec series are all non-stationary series, but they are all second-order integration series.

### 3.2. Co-integration analysis of China's energy consumption and economic growth

The basic idea of co-integration is that even if two or more variables in each are non-stationary, but their linear combination may counteract effects of tendency each other to make the combination into a stable variable. Co-integration theory laid a theoretical foundation on searching equilibrium relationship between two or more variables of non-stationary, as well as creating dynamic model with variables which exists co-integration relationship.

Co-integration test methods include EG (Engle-Granger) two-step test and the Johansen test. For testing co-integration relationship among multiple variables, the Johansen test based on vector auto-regression model is often adopted. Engle-Granger test is usually used to test co-integration relationship between two variables. We want to test co-integration relationship of energy consumption and gross domestic product, thus, we adopt Engle-Granger two-step test method. From the result of unit root test, we can find Lec and Ly time series are all second-order stationary and our co-integration test can be divided into two steps:

First, we have made co-integration regression by using ordinary least squares (OLS) to estimate equation between Lec and Ly series and calculate disequilibrium error.

\[
\text{Lec} = 6.4015 + 0.5137 \text{Ly} \quad (1)
\]

\[
(0.1682) \quad (0.0166)
\]

where, Lec is the logarithmic value of ec, Ly is the logarithmic value of y.

Adjusted coefficient of determination is 0.9715, DW = 0.2722

Where, DW is the Durbin-Watson test value, which is used to judge whether series are correlative.

Residual formula is as follows: \( e^t = \text{Lec}^t - 6.4015 - 0.5137 \text{Ly}^t \) (2)

Where, et is the residual value of the equation.

Second, test integration of et to find whether it is a stationary series.

| Test value of ADF | 5% Critical Value | 1% Critical Value |
|-------------------|-------------------|-------------------|
| -2.0322           | -1.9539           | -2.6534           |

It can be seen that the value of ADF is -2.0322, which is less than 5% critical value, -1.9539. We consider residual series e is a stationary series. That is, there exists a smooth linear combination of Lec and Ly, namely, the long-term stable equilibrium relationship between the total primary energy consumption and gross domestic product.

### 3.3. Error correction model

According to Granger's theorem, a group of variables has form of error-correction model. Therefore, on the basis of co-integration tests, we have further established error correction model which includes error correction term, in order to study feature of short-term dynamic changes and long-term adjustment of the model. According to the result of co-integration relationship test, we know there exists co-integration relationship between GDP and energy consumption. The adjusted coefficient of determination is higher, but DW was significantly smaller, and it indicates the residual series is
autocorrelative. So, we made regression analysis of total energy consumption and GDP regression again. Through adding in lagged variables, we established error correction model of single equation as following.
\[
\Delta L_{ec,t} = 0.8563\Delta L_{ec,t-1} - 0.4706\Delta L_{y,t-1} + 0.6962\Delta L_{y,t} - 0.2452(L_{ec,t-1} - 6.3156 - 0.5167L_{y,t-1})
\] (3)

Where, \( \Delta L_{ec,t} \) is the First order difference value of \( L_{ec} \), \( \Delta L_{y,t} \) is the First order difference value of \( L_{y} \).

If value of \( L_{ec} \) is greater than solution of long-term equilibrium (that is, \(-6.3156-0.5167L_{y,t}\)) at (t-1) moment, and ecm is positive, then \( \Delta L_{ec} \) will Reduce.

If value of \( L_{ec} \) is less than solution of long-term equilibrium (that is, \(-6.3156-0.5167L_{y,t}\)) at (t-1) moment, and ecm is negative, then \( \Delta L_{ec} \) will increase.

3.4. Granger causality test

With the co-integration test, it indicates that energy consumption and economic growth have co-integration relationships. However, what on earth is this long-term equilibrium relationship caused by? Whether it is caused by energy consumption or GDP? But we don’t know which one is the cause and which one is the result between energy consumption and GDP, or maybe they are reciprocal causation. It needs to make Granger (Granger) causality test on ec and y series. Lag phase is given 1 and 2 respectively, and we have Granger causality test on ec and y series. The results are as following in Table 3.

| Null hypothesis                                  | Lag order | Observation value | Value of F    | Value of P  |
|--------------------------------------------------|-----------|------------------|---------------|-------------|
| Ly is not the Granger cause of L_{ec}             | 1         | 28               | 0.05726       | 0.81283     |
| L_{ec} is not the Granger cause of Ly             | 1         | 28               | 0.19657       | 0.66131     |
| Ly is not the Granger cause of L_{ec}             | 2         | 27               | 2.98746       | 0.07115     |
| L_{ec} is not the Granger cause of Ly             | 2         | 27               | 0.02025       | 0.97997     |

As can be seen from Table 3, when lag phase is given 1, for the null hypothesis that \( L_{ec} \) is not a Granger cause of \( L_{y} \), the largest probability of rejecting it and committing type I error is 0.66131, which is greater than 0.1. Therefore, at 90% confidence level, we accept the null hypothesis that the \( L_{ec} \) is not a Granger cause of \( L_{y} \). For the null hypothesis that \( L_{y} \) is not a Granger cause of \( L_{ec} \), the largest probability of rejecting it and committing type I error is 0.81283. It means we cannot reject the null hypothesis, that is, \( L_{y} \) is not a Granger cause of \( L_{ec} \). However, when lag phase is given 2, for the null hypothesis that \( L_{y} \) is not a Granger cause of \( L_{ec} \), the probability of rejecting it is 0.07115, lower than 0.1. Therefore, at 90% confidence level, we reject the null hypothesis and we think \( L_{y} \) is a Granger cause of \( L_{ec} \). Therefore, our Granger causality test shows that there is a unidirectional causality between them. GDP is the Granger cause of energy consumption, and GDP growth will lead to the growth of energy consumption. But the energy consumption is not the Granger cause of GDP, and an increase in energy consumption will not lead to increase GDP.

4. Conclusions

There exists co-integration relationship between energy consumption and GDP. Though in a short time, there are fluctuating relationships between them, in the long run, energy consumption and economic growth have a long-term stable equilibrium relationship.

Through the Granger causality test, we can find that the gross domestic product is the Granger cause of energy consumption, and an increase in China's GDP will lead to increase energy consumption directly. The conclusion is different slightly from other discovery by many domestic scholars. For example, Han Zhiyong (2015) made empirical studies and showed that China's energy consumption and GDP exist bilateral causality. The reason why there have differences is scholars selected different time interval. Han Zhiyong (2015) selected related data of energy consumption and GDP from 1978 to 2000 years, but in this article we extended time period from 1988 to 2016 and adjusted GDP to 1990 price levels. All these may cause different results.
In the end, we draw conclusion that there exists unidirectional causality from economic growth to energy consumption.

Acknowledgments
Authors thank financial support from the Provincial Qing Lan Project Foundation of Jiangsu(No.2016038) for this research.

References
[1] Kraft, J., Kraft, A.. (1978) On the relationship between energy and GNP. Journal of Energy and Development,3:159-175.

[2] MasihA.M, MasihR..(1996) Energy consumption, real income and temporal causality: results from a multi-country study based on co-integration and error-correction modeling techniques. Energy Economics, 8:121-134.

[3] Gao D.W., etc. (2013) Co-integration analysis of import trade with energy intensity of various areas in China. Statistics and Decision, 14:65-71.

[4] Chen K., TANG X. Y.. (2015) Econometric analysis of energy consumption in China’s economic growth. Statistics and Decision, 23:49-57.

[5] Liu Z. M., etc. (2016) Analysis of associated model for China's energy consumption and economic growth. East China Economic Management, 11: 42-50.

[6] Han Z. Y., etc. (2015) Research on co-integration and causality of China's energy consumption and economic growth. Engineering, 12:52-61.