Long-term Relationship between Electricity Consumption and Economic Growth

Xia Liyu[1*], and He Wan[1]

[1]State Grid Energy Research Institute, Beijing, 102209, China

Abstract. Electricity is an indispensable material basis for economic development. It is necessary to study the relationship between different electricity consumption and economic growth. Based on the quarterly data of China's electricity consumption and economic development from 2011 to 2018, the long-term equilibrium relationship between variables are analyzed from a causal perspective, and electricity consumption indicators for reflecting economic development are identified. The results show that there is a long-term equilibrium relationship between secondary industry electricity consumption, industrial electricity consumption and GDP. The demand for electricity consumption still needs to be met urgently.

1 Introduction

Electric power is an indispensable material basis for the production of national economy and the life of residents, and electricity consumption is often regarded as a barometer of economic growth. Academic research and industry practice generally believe that there should be a long-term and stable positive correlation between the electricity consumption of the whole society and economic growth, and there should be no major deviation. Some studies believe that the electricity consumption of urban and rural residents should also show a long-term positive relationship with economic growth. However, in 2018, the electricity consumption of the whole society in China increased by 8.5%, 2.0 percentage points higher than that of the same period of last year, and the electricity consumption of urban and rural residents increased by 10.4%, 2.6 percentage points higher than that of the same period of last year. The growth rate of the electricity consumption of the whole society and urban and rural residents is relatively large, which is in sharp contrast with the slowdown of GDP growth, "Deviation" phenomenon has aroused widespread concern of the public. It is of great significance to study the relationship between the whole society's electricity consumption and its components and economic growth for the rational analysis of economic growth and the guidance of electricity development layout.

Scholars mostly use the combination of qualitative analysis and quantitative analysis to study the relationship between electricity consumption and economic growth, and generally believe that there is a long-term stable relationship between electricity consumption and economic growth, but the judgment of the causal relationship between the two is not consistent. In terms of data frequency of empirical research, the existing research mostly uses annual data, and less uses quarterly data or monthly data with higher collection frequency. In terms of the selection of electricity consumption indicators, most studies choose the whole society's electricity consumption, less considering the components of the whole society's electricity consumption.

2 Indicator selection and model method

2.1. Data and indicators

Our empirical study uses the quarterly data of various types of electricity consumption and economic growth from 2011 to 2018, which are collected by the official data of the National Bureau of statistics and the China Electricity Enterprise Federation. In terms of statistics, the whole society's electricity consumption consists of four parts, namely, the whole society's electricity consumption includes the first industry's electricity consumption, the second industry's electricity consumption, the third industry's electricity consumption and the residents' electricity consumption. This paper mainly studies the relationship between electricity consumption and GDP. Because all kinds of electricity consumption and GDP show seasonal trend, it is easy to affect the judgment of the long-term relationship between them when modeling. When studying the long-term relationship between variables, X12-ARIMA seasonal adjustment method is used to eliminate the seasonal fluctuation factors in the time series. X12-ARIMa seasonal adjustment method introduces the method of stochastic modeling, and adjusts the time series by autoregression and moving average method, mainly including three stages: modeling, seasonal adjustment and diagnosis.

* Corresponding author: xialiyu@ruc.edu.cn

2.2. Model method

2.2.1 ADF test

ADF test is a high-order form of DF test, which is used to test the stationarity of time series. For the high-order autoregressive process AR(P), if the autoregressive coefficient is $\varphi_1,\ldots, \varphi_p$, then the original hypothesis and alternative hypothesis of ADF test are that the model contains unit root and the model does not contain unit root, that is H_0:$\rho=1$,H_1:$\rho<1$, and $\rho=\varphi_1+\ldots+\varphi_p$. The process of autoregression is established, and ADF statistic $\tau=\rho/s(\rho)$ is constructed, which $s(\rho)$ is sample standard deviation. When τ is larger than the test critical value, the original hypothesis is rejected, and the model does not contain unit root, and the time series is stable. If the time series is stable after d-difference and unstable after d-1 difference, then the original sequence is called d-order single integer, which is recorded as I(d).

2.2.2 EG two-step method

EG two-step method is used to test the cointegration relationship between variables and determine whether there is a long-term stable equilibrium relationship between time series. If the single integral order of time series is different, it can be directly determined that there is no cointegration relationship between variables; if the single integral order is the same, it needs to build regression model for further test. For the time series with first-order single integration, the EG two-step method sets the original hypothesis H_0: there is no cointegration relationship and alternative hypothesis H_1: there is cointegration relationship. By constructing the least square regression model and calculating the residual, ADF method is used to calculate the test statistics for the residual. The critical value of the test is calculated according to the formula $C=\varphi_0+\varphi_1T^{-1}+\varphi_2T^{-2}$, where φ is the parameter in the Mackinno table and T is the sample size.

3 Relationship between electricity consumption and economic growth in the whole society

Use the data from the first quarter of 2011 to the fourth quarter of 2018 to draw the trend chart of the GDP and the electricity consumption of the whole society in each quarter over the years. It can be found that GDP and electricity consumption of the whole society show a trend and seasonal characteristics, that is, GDP and electricity consumption of the whole society show a trend of increasing year by year with the passage of time, and show periodic fluctuations in each quarter of each year, which is shown as increasing quarter by quarter in each year, and the fourth quarter of last year is higher than the first quarter of that year. The change direction of GDP and electricity consumption of the whole society is the same, and there may be a synergistic relationship between them.

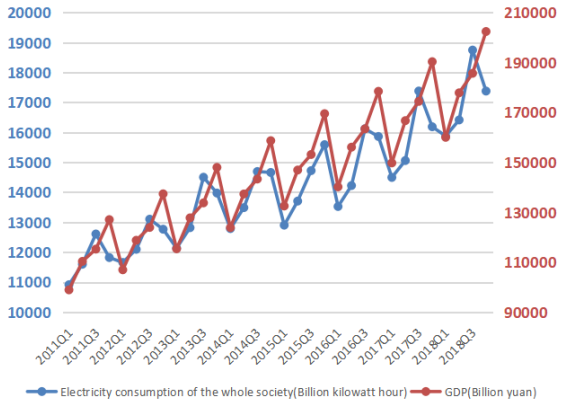

Fig. 1. GDP and electricity consumption of the whole society in each quarter over the years.

EG two-step method is used to test the cointegration relationship between China's GDP and electricity consumption of the whole society (E_A). First of all, the stationarity of the seasonally adjusted variables (GDP, E_A) and their first-order difference variables (DGDP, DE_A) is tested. The unit root test results based on the ADF method are shown in Table 1.

Table 1. Unit root test results of GDP and electricity consumption of the whole society.

Variable	Test type (c,t,p)	ADF statistics	5% critical value	Prob	Result
GDP	(c,0,1)	0.6987	-2.9640	0.9901	unstable
E_A	(c,0,1)	0.3816	-2.9640	0.9787	unstable
DGDP	(c,0,0)	-5.7602	-2.9640	0.0000	stable
DE_A	(c,0,0)	-10.2770	-2.9640	0.0000	stable

Note: c indicates that there is a constant term in the test regression equation, t indicates that there is a trend term, and the lag order p is determined by AIC criterion.

Table 1 shows that GDP and electricity consumption of the whole society are unstable, and the first-order difference variables of the two variables are stable. GDP and electricity consumption of the whole society are first-order single integration, i.e. DGDP ~ I(1) and DE_A ~ I(1), which meet the conditions of cointegration test with EG two-step method. Then, the cointegration regression equation (1) is established, and the OLS estimation is made by using the seasonally adjusted time series samples to get the residual variable e_a.

$$E_A = \beta_0+\beta_1 GDP \quad (1)$$

ADF test is carried out for the residual variable e_a, the test type is no constant term, no trend item, the lag order p is determined by BIC criterion, and the significance level is 5%. The sample size is N = 32, and the 5% critical value $C_{0.05}$ in Table 2 is calculated by Mackinno table, and the test results are shown in Table 2.

Table 2. Test results of the stability of the residual e_a.

Variable	Test type (c,t,p)	ADF statistics	5% critical value	Result
e_a	(c,0,0)	-4.7278	-3.5562	cointegration

In Table 2, the ADF statistic is -4.7278, which is less than the 5% critical value of -3.5562, so the two variables are cointegrated, that is, from the perspective of absolute quantity, there is a long-term equilibrium relationship between GDP and the electricity consumption of the whole society. The electricity consumption of the whole society is a suitable indicator reflecting the change of GDP.

4 Relationship between various types of electricity consumption and economic growth

Use the data from the first quarter of 2011 to the fourth quarter of 2018 to draw the trend chart of the total GDP and various types of electricity consumption in each quarter of the past year. China's GDP and various types of electricity consumption show seasonal characteristics, that is to say, there are periodic fluctuations in each quarter of the year. Among them, GDP and the electricity consumption of the second industry, the third industry and residents show an obvious increasing trend year by year. The electricity consumption of the first industry reaches the maximum in the third quarter of each year and increases year by year, while the electricity consumption of other quarters changes little in each year. Comparing the trend of GDP and various electricity consumption, we can find that the consistency between the change trend of various electricity consumption and the change trend of GDP is from high to low, which are the second industry electricity consumption, residential electricity consumption, the third industry electricity consumption and the first industry electricity consumption. In contrast, among the components of electricity consumption of the whole society, the change of electricity consumption in the secondary industry is the most appropriate indicator to reflect the change of GDP.

It is worth noting that the industrial electricity consumption is an important part of the secondary industry electricity consumption, and the industrial electricity consumption growth rate is an important component of Keqiang index. Keqiang index is an index created by the economist to evaluate China's GDP growth. Its equation is "Keqiang index = growth rate of industrial electricity consumption × 40% + growth rate of medium and long-term loan balance × 35% + growth rate of railway freight volume × 25%". Empirical research shows that the trend of Keqiang index is consistent with that of GDP in general, but the performance of the former is much stronger than that of the latter. Use the data from the first quarter of 2011 to the fourth quarter of 2018 to draw the trend chart of GDP and industrial electricity consumption in each quarter of the past year. China's GDP and industrial electricity consumption show relatively consistent trend and seasonal characteristics, and there may be a synergistic relationship between them.

EG two-step method is used to test the cointegration relationship between China's GDP and the first industrial electricity consumption (E_1), the second industrial electricity consumption (E_2), the industrial electricity consumption (E_m), the third industrial electricity consumption (E_3) and the residential electricity consumption (E_R). Similarly, before the cointegration test, X12-ARIMA method is used to adjust the data seasonally to eliminate the influence of seasonal factors. Firstly, the stability of the seasonally adjusted variables (E_1, E_2, E_m, E_3, E_R) and their first-order difference variables (DE_1, DE_2, DE_m, DE_3, DE_R) are tested. The unit root test results based on the ADF method are shown in Table 3.

Table 3. Unit root test results of various types of electricity consumption.

Variable	Test type (c,t,p)	ADF statistics	5% critical value	Prob	Result
E_1	(c,0,0)	-2.6376	-2.9604	0.0965	unstable
E_2	(c,0,1)	0.9171	-2.9640	0.9171	unstable
E_M	(c,0,1)	-0.2774	-2.9640	0.9171	unstable
E_3	(c,0,0)	1.4778	-2.9604	0.9988	unstable
E_R	(c,0,1)	0.5825	-2.9604	0.9868	unstable
DE_1	(c,0,0)	-8.1288	-2.9640	0.0000	stable
DE_2	(c,0,0)	-9.7600	-2.9640	0.0000	stable
DE_M	(c,0,0)	-9.7496	-2.9640	0.0000	stable
DE_3	(c,0,0)	-4.4767	-2.9640	0.0013	stable
DE_R	(c,0,0)	-9.6749	-2.9640	0.0000	stable

Table 3 shows that various types of electricity consumption are unstable and the first-order difference variables are stable. The integration order of each variable is the same as GDP, which is the first-order integration, and meets the conditions of cointegration test using EG two-step method.

The cointegration regression equation (2)-(6) are established, and the OLS estimates of equation (2)-(6) are made by using the seasonally adjusted time series samples. The residual variables e_1, e_2, e_m, e_3 and e_r are obtained.

$$E_1 = \beta_0 + \beta_1 GDP \quad (2)$$

$$E_2 = \beta_0 + \beta_1 GDP \quad (3)$$

$$E_M = \beta_0 + \beta_1 GDP \quad (4)$$

$$E_3 = \beta_0 + \beta_1 GDP \quad (5)$$

$$E_R = \beta_0 + \beta_1 GDP \quad (6)$$

ADF test is carried out for the residual variables, the test type is no constant term, no trend item, the lag order p is determined by BIC criterion, and the significance level is 5%. The test results are shown in Table 4.

The results of cointegration test show that the first industrial electricity consumption, the third industrial electricity consumption, the residential electricity consumption and GDP are non cointegration, that is, the first industrial electricity consumption, the third industrial electricity consumption, the residential electricity consumption and GDP do not have a long-term equilibrium relationship. The second industrial electricity consumption, the industrial electricity consumption and GDP have a long-term equilibrium relationship. The second industrial electricity consumption and the industrial electricity consumption are the most appropriate indicator to reflect the change of GDP in all components of the electricity consumption of the whole society, while the residential electricity consumption is not the most appropriate indicator to reflect the change of GDP. Therefore, when considering the long-term equilibrium relationship between electricity consumption and economic growth, we should mainly refer to the second industry electricity consumption and industrial electricity consumption. It is not scientific to overemphasize and analyze the synergistic relationship between non co integrated electricity consumption such as residential electricity consumption and economic growth.

Table 4. Test results of the stability of various types of residuals.

Variable	Test type (c,t,p)	ADF statistics	5% critical value	Result
e_1	(c,0,0)	-2.7085	-3.5562	non-cointegration
e_2	(c,0,0)	-5.2868	-3.5562	cointegration
e_m	(c,0,0)	-5.3684	-3.5562	cointegration
e_3	(c,0,0)	-1.1799	-3.5562	non-cointegration
e_r	(c,0,1)	-2.1112	-3.5562	non-cointegration

5 Conclusion

Electricity consumption is closely related to economic growth. It is of great significance to discuss the long-term fluctuation relationship between various types of electricity consumption and GDP, and to identify the electricity consumption indicators that reflect the change of GDP. From the perspective of cointegration, this paper discusses the relationship between the whole society's electricity consumption and its components and GDP, and conducts empirical research on the data from the first quarter of 2011 to the fourth quarter of 2018. The results show that there is a long-term equilibrium relationship between the total GDP and the electricity consumption of the whole society, which is a suitable indicator to reflect the change of GDP. There is a long-term equilibrium relationship between the second industry electricity consumption, industrial electricity consumption and the total GDP, while there is no long-term equilibrium relationship between the first industry electricity consumption, the third industry electricity consumption, residential electricity consumption and the total GDP. The second industry electricity consumption and industrial electricity consumption are the most appropriate indicators reflecting the change of GDP in each component of the whole society.

References

1. Lin Weibin, Su Jian, Shi Faqi. Economic growth, energy consumption intensity and power consumption: analysis of the reasons for the deviation between power consumption and GDP growth rate [J]. Economic science, 2010 (05): 15-22.
2. Tan Xiandong, Dan Baoguo, Wu Shanshan, Dan Baoping. Research on the gap between the growth of electricity consumption and GDP in China under the new normal of economy [J]. China power, 2017,50 (12): 5-9.
3. Lin Boqiang. Power consumption and China's economic growth: a study based on production function [J]. Management world, 2003 (11): 18-27.
4. Chen Hanli, Ma Chaoqun, Qin Tao. Analysis of the relationship between power consumption and China's economic growth [J]. Systems engineering, 2007 (08): 68-73.
5. Guo Jianping, he Jianmin, Wu Guofu. Analysis of the equilibrium relationship between China's power consumption and economic growth [J]. China power, 2006 (09): 60-62.
6. Liu Ling, Ma Xiaoqing. Correlation between regional economic growth and power consumption [J]. Systems engineering, 2015,33 (06): 84-90.
7. Lee Chienchiang, Chang Chunping. Energy consumption and economic growth in Asian economies: A more comprehensive analysis using panel data[J]. Resource & Energy Economics, 2008, 30(1):50-65.
8. Zhang Yantao. A further study on the relationship between economic growth and energy consumption -- an analysis based on threshold co integration [J]. Journal of Guizhou University of Finance and economics, 2012 (01): 19-26.
9. Liu Shenglong, Gao Yuning, Hu Angang. Power consumption and China's economic growth [J]. Industrial economic research, 2014 (03): 71-80.