Short-term Relationship Between Electricity Consumption and Economic Growth

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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 is analyzed from a causal perspective, the short-term fluctuations between variables are analyzed from a relative effectiveness 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. There is a constant or decreasing returns to scale between electricity consumption and GDP, and the demand for electricity consumption still needs to be met urgently.

1. Introduction

Electricity is an indispensable material basis for national economic production and residents' life. Electricity consumption is often regarded as a barometer of economic growth. Scholars generally believe that there should be a long-term stable positive correlation between electricity consumption of the whole society and economic growth, and there should be no large deviation. Some studies believe that the electricity consumption of urban and rural residents should also present a long-term positive relationship with economic growth. However, in 2018, the electricity consumption of the whole society increased by 8.5% year-on-year, and the growth rate was 2.0% higher than that of the same period of last year. The electricity consumption of urban and rural residents increased by 10.4% and 2.6% compared with the same period of last year. The growth rate of electricity consumption of the whole society increased by 8.5% year-on-year, and the growth rate was 2.0% higher than that of the same period of last year. The electricity consumption of urban and rural residents increased by 10.4% and 2.6% compared with the same period of last year. The growth rate of electricity consumption of the whole society was relatively large, which was in sharp contrast to the slowdown of GDP growth. The phenomenon of deviation caused widespread concern of the public. It is of great significance to study the relationship between the whole society's electricity consumption and economic growth for guiding the development and layout of power consumption.

The research on the relationship between electricity consumption and economic growth is a hot issue in academic circles. Scholars discuss the relationship between electricity consumption and economic growth from different angles. Lee et al (2008) analyzed the relationship between energy consumption and economic growth in 16 Asian countries, and the results showed that there is a cointegration relationship between energy consumption and economic growth when considering national differences. Zhang Yantao (2012) studied the relationship between China's economic growth and various components of energy consumption, and found that there is a linear cointegration relationship between economic growth and power consumption and oil consumption, and a nonlinear cointegration relationship with other energy consumption. Liu Shenglong (2014) analyzed the
relationship between the whole society's electricity consumption and economic growth based on China's provincial panel data, and believed that there was a cointegration relationship between the two, and the whole society's electricity consumption was the cause of economic growth. Sun Yan (2016) used the quantile regression method to analyze the marginal effect of China's electricity consumption on economic growth, and found that the marginal effect showed a non fixed relationship that increased with the increase of GDP. Liu Yanan (2017) believed that China's electricity consumption and economic growth have a high overall correlation, and they are positively correlated.

Generally speaking, scholars use the combination of qualitative analysis and quantitative analysis to study the relationship between electricity consumption and economic growth. They 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, less uses quarterly data or monthly data with higher collection frequency. In the selection of electricity consumption indicators, most studies choose the whole society's electricity consumption, less consider the various components of the whole society's electricity consumption. In the analysis of variable relationship, the research mostly considers the relationship between the two from the perspective of correlation or causality. The volatility of electricity consumption is not discussed from the perspective of relative efficiency.

Based on the quarterly data of various types of electricity consumption and economic growth in China, this paper discusses the long-term relationship between the two from the perspective of causality, analyzes the short-term fluctuation between the two from the perspective of relative effectiveness, identifies the appropriate indicators reflecting the change of GDP from various components of the whole society's electricity consumption, and explains the reasons for the rapid growth of urban and rural household electricity consumption.

2. Index selection and model method

2.1. Data and indicators
This paper uses the quarterly data of electricity consumption and economic growth from 2011 to 2018. The data are collected from the official data of the National Bureau of statistics and China Electric Power Enterprises Federation. In terms of statistical caliber, the power consumption of the whole society is composed of four parts, namely, "power consumption of the whole society = power consumption of the primary industry + power consumption of the secondary industry + power consumption of the tertiary industry + power consumption of the residents". This paper mainly investigates the relationship between the power consumption of the whole society and its components and GDP. Since all kinds of electricity consumption and GDP show seasonal trend, it is easy to affect the judgment of their long-term relationship when modeling. In this paper, we use X12-ARIMA seasonal adjustment method to eliminate the seasonal fluctuation factors in the time series when we study the long-term relationship between the variables.

2.2. Model method

2.2.1. Granger causality test.
Granger causality test reflects the causality through the "lead lag" relationship between time series. If the lagged variable of one variable X can affect the prediction of another variable Y, and adding the model can improve the degree of interpretation, it is considered that there is Granger causality between variables. Granger causality test sets the original hypothesis $H_0$: X is not the Granger cause of Y, and tests whether the two conditional distributions $F(Y_t|Y_{t-1},...,X_{t-1})$ and $F(Y_t|Y_{t-1},...,)$ of Y are equal. If $F(Y_t|Y_{t-1},...,X_{t-1}) \neq F(Y_t|Y_{t-1},...)$, the original hypothesis is rejected and X is considered as the Granger cause of Y.
## 2.2.2. DEA model.

DEA model evaluates the relative effectiveness of comparable units of the same type by using linear programming method according to multiple input and output indexes. The commonly used DEA models include CCR model and BCC model. The results of the models can obtain pure technology scale, efficiency scale and comprehensive scale, and also can calculate the optimal factor input or output combination. In this paper, the BCC model is adopted, assuming that the return to scale is variable. \( X_0 \) is the total input. \( Y_0 \) is the total output. \( X_{ij} \) is the \( i \)th input of the decision-making unit \( j \)th. \( Y_{rj} \) is the \( r \)th output of the decision-making unit \( j \)th. \( h_j \) is the efficiency index. \( \lambda_j \) is the weight parameter. \( S^- \) and \( S^+ \) are relaxation variables. The basic form of BCC model is as follows:

\[
\begin{align*}
\sum_{i=1}^{n} X_{ij} + S^-_i &= \theta X_0 \\
\sum_{j=1}^{n} X_{rj} - S^+_r &= Y_0 \\
\sum_{j=1}^{n} \lambda_j &= 1 \\
S^-, S^+, \lambda_j &\geq 0
\end{align*}
\]

(1)

## 3. Causality between electricity consumption and economic growth

In order to determine the causal relationship between the variables, Granger causality test was conducted on the total GDP and the electricity consumption of the whole society. The lag order was determined as 1 and the significance level was 5\% by using SIC criterion. The test results are shown in Table 1.

### Table 1. Granger causality test results of GDP and electricity consumption of the whole society.

| Null Hypothesis                                      | F value  | Prob  |
|------------------------------------------------------|----------|-------|
| GDP is not the Granger cause of electricity consumption | 18.8888  | 0.0002|
| electricity consumption is not the Granger cause of GDP  | 0.0681   | 0.7961|

The test results in Table 1 show that the fluctuation of economic growth is ahead of the fluctuation of electricity consumption growth of the whole society. Economic growth is the reason for the growth of power consumption of the whole society, while the growth of power consumption of the whole society is not the cause of economic growth, which further verifies that the power consumption of the whole society is an appropriate index to reflect the change of GDP.

Previous studies have shown that there is a non cointegration relationship between GDP and electricity consumption of primary industry, tertiary industry and residents. In order to determine the causal relationship between variables, Granger causality test was conducted on GDP, power consumption of the secondary industry and industrial power consumption. The lag order was determined to be 1 by SIC criterion, and the significance level was 5\%. The test results are shown in Table 2.

### Table 2. Granger causality test results of GDP and various types of electricity consumption.

| Null Hypothesis                                          | F value  | Prob  |
|----------------------------------------------------------|----------|-------|
| GDP is not the Granger cause of electricity consumption of secondary industry | 23.0699  | 0.0000|
| electricity consumption of secondary industry is not the Granger cause of GDP  | 0.0307   | 0.8621|
| GDP is not the Granger cause of electricity consumption of industry  | 23.8273  | 0.0000|
| electricity consumption of industry is not the Granger cause of GDP  | 0.0225   | 0.8817|

The test results in Table 2 show that the fluctuation of economic growth is ahead of the fluctuation of power consumption growth of the secondary industry and that of the industrial power consumption.
Economic growth is the reason for the two types of power consumption growth, but the two types of power consumption growth is not the cause of economic growth. It further verifies that the power consumption of the secondary industry and industrial power consumption are the appropriate indicators to reflect the change of GDP, which further illustrates that the electricity consumption of the secondary industry and the industrial power consumption are the appropriate indicators to reflect the change of GDP. The strong index is scientific and reasonable in citing the growth rate of industrial power consumption.

4. Short term fluctuation relationship between electricity consumption and economic growth

Since not all kinds of electricity consumption have long-term equilibrium relationship with GDP, the conventional error correction model is not suitable for studying the short-term fluctuation relationship between various types of electricity consumption and economic growth. At this time, combined with the conclusion of Granger causality test above, economic growth can be regarded as the reason for promoting the growth of various types of electricity consumption, and the relative effectiveness of various types of electricity consumption growth can be calculated by using DEA model, and the short-term fluctuation relationship among variables can be explored by analyzing the rationality of various power consumption structures.

According to the conclusion of Granger causality test, taking GDP as input index, taking four kinds of electricity consumption as output index, and 32 quarters from the first quarter of 2011 to the fourth quarter of 2018 as the decision-making unit, the BCC model is established to calculate the relative effectiveness of input or output in each year. The empirical results show that the two periods of increasing returns to scale are in 2015 and the first quarter of 2016. The electricity demand caused by the increase of GDP in the current period is larger, and the actual power consumption level in the current period is higher than the estimated ideal level. The period of constant return to scale is the first quarter and the third quarter of each year, and the electricity demand caused by the increase of current GDP is unchanged. The international electricity consumption level is close to the ideal level, which is in line with the actual situation that the industrial power consumption and residential electricity load are relatively high in these two seasons. In other periods, the return to scale is decreasing, the electricity demand caused by the increase of GDP in the current period is smaller, and the actual power consumption level in the current period is lower than the ideal level. On the whole, although the power consumption demand caused by economic growth in each period is increasing, the actual power consumption caused by economic growth in most periods is lower than the ideal level estimated. The current level of power consumption still can not fully adapt to the economic growth level. There is still a large space for growth in the second quarter and the fourth quarter.

Based on BCC model, the target values of various types of electricity consumption corresponding to GDP in different periods are calculated. By comparing the target output value of electricity consumption with the real output value, the deviation of various power consumption output can be calculated by formula (2), and the short-term fluctuation relationship between various types of electricity consumption and economic growth in different years can be analyzed. Where \( Y \) is the real output value and \( Y_{opt} \) is the target output value.

\[
D = \frac{Y - Y_{opt}}{Y_{opt}} \times 100\%
\]

Based on BCC model, the annual fluctuation deviation of various types of electricity consumption is calculated, and the results are shown in Table 3.

| Year | primary industry | secondary industry | tertiary industry | resident |
|------|------------------|--------------------|-------------------|---------|
| 2011 | -6.78%           | 0.00%              | 0.00%             | -0.53%  |
| 2012 | -12.59%          | -0.44%             | -5.66%            | -7.54%  |
According to table 3, the annual fluctuation deviation of all kinds of electricity consumption is non-positive, and the average real power consumption in each year is lower than the target power consumption. From the perspective of power consumption type, the deviation degree of residential electricity consumption is larger, while the deviation degree of secondary industry power consumption is the smallest. From the perspective of power consumption year, the deviation of all kinds of power consumption from 2012 to 2014 is larger, and that of other years is smaller. Overall, with the economic and social development, China's various types of electricity consumption level can not fully adapt to the level of economic growth, there is still a large room for improvement.

The reason is that China's industrial structure is in a period of continuous adjustment, the proportion of the output value of the primary industry and the secondary industry is declining, and the proportion of the output value of the tertiary industry is rising. Under this background, the proportion of the power consumption of the primary industry and the secondary industry is decreasing year by year, and the proportion of the power consumption of the tertiary industry and the residents is increasing year by year. From the perspective of relative efficiency, due to the low proportion of output value and growth rate, the actual power consumption of the primary industry deviates from the target level of measurement to a certain extent. According to the above research, there is a co-integration relationship between the power consumption of the secondary industry and economic growth, and the deviation degree of the power consumption of the secondary industry is the smallest. The power consumption of the tertiary industry belongs to the external power consumption of residents. Thanks to the upgrading of residents' consumption and the adjustment of industrial structure, the growth rate of power consumption in the tertiary industry has increased year by year. In recent years, the deviation between the actual power consumption of the tertiary industry and the target power consumption has decreased year by year, and the deviation degree measured in the last two years is 0. Residential electricity consumption belongs to the internal power consumption of residents. Affected by the high consumption demand and consumption upgrading of residents, the residential electricity consumption of conditioning, heating and cooling equipment, health care, entertainment and other aspects is increasing. It is worth noting that when the GDP growth rate slows down for a long time, the consumption level of residents should decline, but consumption has a "ratchet effect". In the short term, the slowdown of economic growth will not significantly affect and reduce the consumption level of residents. In addition, the consumption upgrading has a significant promoting effect, on the contrary, the household electricity consumption will show a significant increase trend. Therefore, the growth rate of residential electricity consumption has increased year by year, which is consistent with the power consumption of the tertiary industry. The deviation of the actual consumption of residents from the target power consumption has been decreasing year by year in recent years.

On the whole, the relationship between GDP and electricity consumption in most periods is shown as constant returns to scale or decreasing returns to scale, that is, all kinds of power consumption levels are just or can not adapt to the current economic growth level. There are few phenomena that the power consumption level exceeds the current economic growth level, and the power consumption demand still needs to be met. From the perspective of relative efficiency, the short-term fluctuation relationship between various types of electricity consumption and economic growth shows that except for the power consumption of the secondary industry, the consumption amount of various types of electricity consumption in the past years can not meet the requirements of economic growth. Due to
the long-term equilibrium relationship between electricity consumption of the secondary industry and economic growth, there is a certain deviation between the growth rate of electricity consumption and GDP growth in the short term, but the degree of deviation is not obvious. In recent years, the power consumption of the tertiary industry and residents has increased rapidly, and the gap between them and the target value of electricity consumption adapting to the economic growth level has been continuously narrowed. The growth rate of the two is obviously faster than that of the economic development, and the growth rate deviates obviously in the short term. In the long run, there is still room for improvement in the total amount of various types of electricity consumption, and the growth rate of electricity consumption of the tertiary industry and residents is still possible to improve, and the deviation between the growth rate of electricity consumption and GDP will be more obvious.

5. Conclusion
Electricity consumption is closely related to economic growth. It is of great significance to discuss the short-term fluctuation relationship between various types of electricity consumption and GDP, and to identify the electricity consumption indicators reflecting the change of GDP. From the perspective of causality and input-output, this paper discusses the relationship between the whole society's electricity consumption and its components and GDP, and conducts an empirical study on the data from the first quarter of 2011 to the fourth quarter of 2018. The results show that the fluctuation of economic growth is ahead of that of the growth of secondary industry and industrial power consumption. Economic growth is the cause of two kinds of power consumption growth, but the two kinds of power consumption growth is not the cause of economic growth. The relationship between GDP and electricity consumption shows the same or decreasing returns to scale. All kinds of power consumption levels just or can not adapt to the current economic growth level, so the power consumption demand still needs to be met. With the adjustment of industrial structure and the upgrading of consumption, the power consumption of the tertiary industry and the consumption of residents will continue to grow rapidly, and the growth rate of electricity consumption and economic growth will still deviate many times.

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