Research on Relationship between Cycles of Electric Power and the Economy Growth in China Based on Maximum Entropy Method

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Abstract: Electric power is a basic industry in the national economy in China. It influences the economy growth in China seriously owing to the surplus and shortage of electric power supply from time to time. Thus, the exigent issue that the strategy development plan of Chinese power industry confronted now is that how to predominate the development and cycle changes of the economy and the electric power. Firstly, the paper studies their causality based on the Granger–Causality tests. Then, based on the Maximum Entropy Method, it gives an elementary study and discussion of interaction relationship of the electric power and the national economy cycles in China. The results show that the electricity consumption, the newly added installed capacity, the electricity investment are all the Granger causality of GDP and the electricity investment is the Granger causality of the installed-capacity. The main development cycles of electric power and GDP are both middle ones, thirteen years or so, and the development of power is almost in the same pace of the economy during 1965-2002. The growth of the electricity investment will increase the new added installed-capacity with nearly three years' lead time; the installed-capacity will influence the GDP growth and the lead time is nearly two years at the main cycle. In the mean time, the GDP growth will also influence the development of the electricity consumption with nearly one years lead time at the nearly ten years cycle, but almost at the same pace at the less than ten years cycle. GDP can promote the electricity investment with nearly two to three years lead time at the main cycle and almost at the same step at the less than ten years cycle. The development plan of the electric power should be established upon the development cycle relationship between the electric power and the economy in order to avoid the power surplus and shortage cycle and further promote the sustainable economic development in China[1].

Keywords: China, Electric power, Granger causality, Maximum Entropy Method, National economy;

1 Introduction

In the period from 2003 to 2004 in China, the power shortage spread all over the country and seriously influenced the economy development and the civilian life. Around 1998, the regulation policy of "No establishment of thermal power plant in three years" appeared due to the sufficient electric power supply around 1998, causing scant power investment construction in recent years and power shortage in countrywide situation. Aiming at such an intense state, the relevant departments accelerated the step of power construction. In 2004, the national newly-added generation installed capacity is 53.23GW, while the total installed capacity at the end of the year will reach 442.39GW, 13.02% increase over that of the same period of last year. In 2005, the national newly-added installed capacity is 48GW with increasing rate of 11.4%. It is estimated that the national generation installed capacity will reach 480GW in 2006 and will expectably achieve the national general balance of electric power supply and the demand, which means that a new turn of electric power surplus is probably in the near future. It is crucial for electric power, as a vital material related to Chinese economy, to grasp the principle of economic development and cycle movement for the sake of avoiding entering into the shortage-surplus alternation orbit with scientific power development strategy.

The study on the relationship between energy consumption and the economy began in the 1970s and the studies differ in their methodology, what sorts of data were used, variables chose and the eventual results. Kraft and Kraft (1978) studied the relationship between energy consumption and economic development for the United States based on Granger-Causality (GC) and found unidirectional causality running from income (GNP) to energy use over the period 1947–1974. Empirical studies were later extended to cover other industrial countries such as the United Kingdom, Germany, Italy, Canada, France and Japan [1]. They found different results in different economies during different time period, no causal relationship between GNP and energy consumption in the USA, UK and Poland, while they detect unidirectional causality from GNP to energy consumption for South Korea, and from energy consumption to income in the Philippines during the period 1954-1976, and from income to energy during 1950-1973 and from energy to income during 1950-1982 in Japan. There are some empirical works on the causal relationship between energy consumption and the economy focused on Asian economies [2]-[7]. According to the above results, the relationships between energy and economy vary with the economy type, time period considered and modeling techniques, as well as variables being used, etc. In 2004, the research of Alice Shiu and Pun-Lee Lam on the relationship between electric power and the economy of Chinese Mainland obtains great production, which fills up the gap of this area in China [7]. The research gives the result that the economy development is not a big drive for electric power consumption, but the power's shortage will indeed

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influence Chinese economy, so, China should pay great effort on constructing power plant as well as energy structure optimization and adoption of renewable energy. Still, the research lacks of study of cycles relationship between Chinese power and the national economy. There are many researches on the cycle changes of Chinese national economy development, while papers involved in the cycle changes relationship between Chinese power and the national economy are considerably rare [8] [9] [10].Hu primarily analyzed the relationship between Chinese economy development and the electric power demand based on the intelligent simulation method, consisting of analysis of economic cycle and economy development's influence to the power demand. It educes that the cycle fluctuation of electric power demand is 8 years, but no further research on causal relationship between the cycles of the power and the economy fluctuation is studied.

Based on the Maximum Entropy Method （MEM）, This paper gives an elementary research and discussion of interaction relationship of the power and the national economy cycle in China and provides a reference to the establishment of the electric industry policy and power plan.

2 Cycle analysis model

2.1 Cross spectral density analysis [12]

Spectral analysis method has been applied in confirming the cycle of economic time series. Cross spectral density analysis is a method used in analyzing several economic time series, including evaluate the change of series cycle and the phases, coherency and relativity among series. It also can analyze the relationship of lead or lag time among indexes.

Suppose $\{Y_t\}_{t=-\infty}^{\infty}$ is a covariance stationary process. Its mean is $E(Y_t)=\mu$ and the autocovariance at lag k is:

$$\gamma_k = E[(Y_t-\mu)(Y_{t-k}-\mu)] \tag{1}$$

Suppose these autocovariances are absolute summable. The population spectrum of Y_t is:

$$s_Y(\omega)=\frac{1}{2\pi}\sum_{k=-\infty}^{\infty}\gamma_k\cdot e^{-i\omega k}=\frac{1}{2\pi}\sum_{k=-\infty}^{\infty}\gamma_k[\cos(\omega k)-i\cdot\sin(\omega k)] \tag{2}$$

where ω is a real number. The population spectrum function and the autocovariance series have the same information. The area of the population spectrum function is the unconditional variance's covariance. As shown as formula （3）.

$$\int_{-\pi}^{\pi} s_Y(\omega)e^{i\omega k}d\omega=\gamma_k \tag{3}$$

Suppose Y_t is a $n\times 1$ covariance stationary vector process. Its mean is $E(Y_t)=\mu$ and the autocovariance at lag k is:

$$\Gamma_k = E[(Y_t-\mu)(Y_{t-k}-\mu)'] \tag{4}$$

Suppose autocovariance matrix series $\{\Gamma_k\}_{k=-\infty}^{\infty}$ are absolute summable. The population spectrum is:

$$\mathbf{s}_Y(\omega)=\frac{1}{2\pi}\sum_{k=-\infty}^{\infty}\Gamma_k\cdot e^{-i\omega k} \tag{5}$$

In main diagonal, the elements of population spectrum matrix $\mathbf{s}_Y(\omega)$, $s_{11}(\omega),\ldots,s_{nn}(\omega)$, are real number, called autospectra. Elements Outside the main diagonal, $s_{jk}(\omega)$, $j\neq k$, is called cross spectra. When n=2, cross spectra is between dual stationary time series, also called mutual spectral.

Normally cross spectra is a complex number, not real number.

$$s_{jk}(\omega)=c_{jk}(\omega)-i\cdot q_{jk}(\omega) \tag{6}$$

In the formula (6), real part $c_{jk}(\omega)$ is cospectra. Imaginary part is quadrature spectra. At frequency of ω, the cospectra of y_j and y_k can be explained that covariance between y_j and y_k attributes to frequency ω in cycle.

Cross spectra also can be express in polar coordinates. Sometimes we call the amplitude of polar coordinates gain.

$$R(\omega)=\sqrt{(c_{jk}(\omega))^2+(q_{jk}(\omega))^2} \tag{7}$$

The angle of polar coordinates is called phase spectrum. Phase spectrum is the mean of phase shift which have corresponding frequency between two series. It reflects the relationship of lead or lag among series in different frequency. Usually phase is estimated within the interval $[-\pi,\pi]$.

The phase spectrum of y_j corresponding y_k is defined as:

$$phase(\omega)=\arctan\left(-\frac{q_{jk}(\omega)}{c_{jk}(\omega)}\right) \tag{8}$$

$phase(\omega)/\omega$ represents the time of lead or lag. $phase(\omega)>0$ means y_j leads y_k ,or else y_j lags y_k.

Correlation of y_j and y_k are measured by coherency function, it defines as:

$$ch_{jk}(\omega)=\frac{|s_{jk}(\omega)|^2}{s_{jj}(\omega)s_{kk}(\omega)}=\frac{(c_{jk}(\omega))^2+(q_{jk}(\omega))^2}{s_{jj}(\omega)\cdot s_{kk}(\omega)}, \tag{9}$$

Supposing $s_{jj}(\omega)\cdot s_{kk}(\omega)\neq 0$, when $s_{jj}(\omega)\cdot s_{kk}(\omega)=0$, defines $ch_{jk}(\omega)=0$ .On condition that y_j and y_k are covariance stationary and autocovariance matrix is absolute summable, to all the ϖ there are,

$$0\leq ch_{jk}(\omega)\leq 1 \tag{10}$$

When the $ch_{jk}(\omega)$ has a larger numerical value, it means that the two time series have the same important cycle in frequency of ω.It equals square of coefficient of correlation in time domain analysis.

If the fluctuation of y_j comes from y_k, the transfer function from y_k to y_j can be calculated,

$$h\left(e^{-i\omega}\right)=\frac{s_{jk}(\omega)}{s_{kk}(\omega)} \tag{11}$$

where $s_{kk}(\omega)$ is supposed not zero. When $s_{kk}(\omega)$ equals zero, $h(e^{-i\omega})=0$.

2.2 Maximum Entropy Method (MEM)

The following part will apply MEM, which is one of the parameter estimation models, namely Burg method.

The process of MEM is:

(1)Establish a VAR model using n-dimensions vector of the economic variables：

$$Y_t=c+\Phi_1Y_{t-1}+\Phi_2Y_{t-2}+\ldots+\Phi_pY_{t-p}+\varepsilon_t \tag{12}$$

where C is $n\times 1$ vector which represents constant number; p is optimal lag ; Φ_j is a $n\times n$ matrix of the VAR parameter, j=1，2，…，p; ε_t is a $n\times 1$ white noise vector .

$$E(\varepsilon_t)=0, E\left(\varepsilon_t\varepsilon_\tau^{'}\right)=\begin{cases}\Omega & t=\tau\\ 0 & t\neq\tau\end{cases} \tag{13}$$

where Ω is a （$n\times n$）symmetry positive matrix.
Applying lag operator shows that $\Phi(L)Y_t=c+\varepsilon_t$, where $\Phi(L)=I_n-\Phi_1L-\Phi_2L^2-\cdots-\Phi_PL^P$, and L is the lag operator.

(1)Choose the optimal lag length of the observed data based on AIC,SC,FPE(Final prediction error) criteria，and estimate the parameters based on OLS.

(2)Calculate the population spectrum function with model parameters.

$$s_Y(\omega)=(2\pi)^{-1}\left\{\Phi\left(e^{-i\omega}\right)\right\}^{-1}\Omega\left\{\Phi^{'}\left(e^{i\omega}\right)\right\}^{-1} \tag{14}$$

3 Research on relationships between cycles of power and the national economy in China

3.1 Index selection and data pretreatment

This section selects real GDP which reflects Chinese gross economy, newly-added installation capacity, power investment and electricity consumption of past years which reflects the development of power. In the period of the "great jump" movement began from 1958, electric power demand increased sharply. Without concerning the limitation of economic and technological condition of that time, many generation projects were constructed. The projects were called off or deferred during the five years after 1961 and the power construction began to recover to the normal state from 1964. Thus the abnormal values before 1965 are deleted. From 2003 to 2005, the phenomenon of serious power shortage, blindfold construction came into emergence again and there was big variation of electric power statistics among different departments. So, this paper provides an analysis just based on the data from 1965 to 2002[13]-[16].

Spectral analysis requires the series are stationary. So, the original series are treated and the link relative increasing rates are analyzed, as shown as figure 1. With the assistance of EVIEW5.0 statistic analysis software, it is tested that every link relative increasing rate series are all stationary.

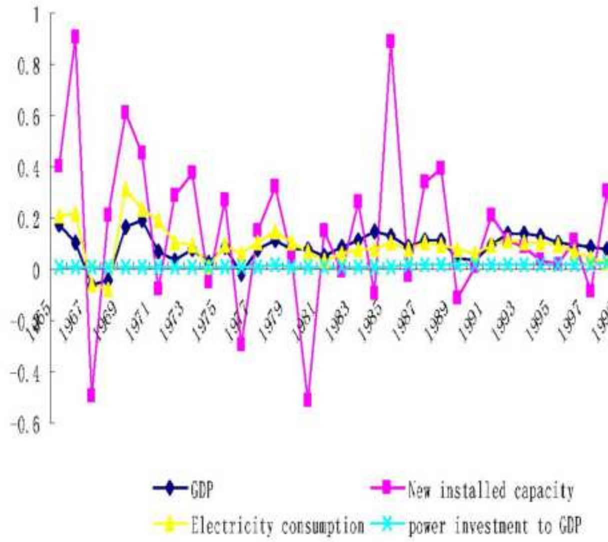

Fig.1 Link relative increasing rates of GDP and electric power in China, 1965-2002

3.2 Analysis of the relationship between cycles of the electric power and the economy in China based on MEM

3.2.1 Granger causality tests on power industry and GDP in China

Tab.1 Results of causality tests on power industry and GDP in China

Null Hypothesis	Lag length	F-Statistic	Probability
YD does not Granger Cause GDP	2	2.728	0.081*
GDP does not Granger Cause YD	2	1.749	0.191
ZJ does not Granger Cause GDP	8	2.486	0.070*
GDP does not Granger Cause ZJ	8	0.643	0.730
TZ does not Granger Cause GDP	6	2.223	0.086*
GDP does not Granger Cause TZ	6	1.344	0.287
ZJ does not Granger Cause TZ	1	0.115	0.736
TZ does not Granger Cause ZJ	1	4.082	0.051*

Note: *, **, *** denote significance at the 10%, 5% and 1% level of significance respectively.

The results of the Granger causality tests on the power industry and GDP are presented in tab. 1. It shows the Granger causality from electrical consumption, new added installed-capacity, power investment to GDP. Causality is significant from power industry to GDP. Power investment is also the Granger causality of installed capacity growth.

3.2.2 Cross spectral density analysis between power industry and GDP

Firstly, the VAR model of the growth rate of power industry and GDP is established and the optimal lag length is chosen based on AIC, SC criteria. The optimal lag length is 4. The coefficients of VAR model are as shown in tab. 2.

Tab. 2 Coefficients of the VAR Model

	GDP	TZ	YD	ZJ
GDP(-1)	0.2661	-0.0033	-0.0995	2.5087
GDP(-2)	-0.0100	-0.0087	-0.5486	-1.1357
GDP(-3)	0.0104	0.0191	-0.1351	0.7538
GDP(-4)	0.1259	-0.0044	-0.2613	1.7436
TZ(-1)	1.1517	1.0395	-1.1520	44.6766
TZ(-2)	1.0933	-0.3986	-6.1598	-50.1356
TZ(-3)	-6.2719	0.2871	8.7310	1.2152
TZ(-4)	1.5909	-0.0059	-1.6511	-31.5064
YD(-1)	0.0446	-0.0035	-0.0488	-0.3282
YD(-2)	-0.2392	-0.0080	0.0034	-0.3280
YD(-3)	-0.0808	-0.0013	-0.2140	-0.1505
YD(-4)	0.0358	-0.0049	-0.1807	-0.7741
ZJ(-1)	-0.0409	0.0032	0.0654	-0.6300
ZJ(-2)	-0.0332	0.0019	0.0560	-0.1324
ZJ(-3)	0.0025	-0.0012	0.0845	0.1129
ZJ(-4)	-0.0210	-0.0012	0.0542	0.1956

Notes: GDP,TZ,YD,ZJ represent the link relative increasing rates of GDP, the electric power investment, the electricity consumption and the new installed capacity respectively.

Applying the coefficients of the VAR model to formula (14), the spectral density function is got , in which w is taken by step 0.02 within [$-\pi,\pi$], and the autospectra, cross spectra, phase and coherency are calculated based on (6) to (11), as show in Fig. 2 and Tab. 3.

Fig. 2 shows that four series have same summit at the point of w=0.46, which corresponds the cycle of 13 years.

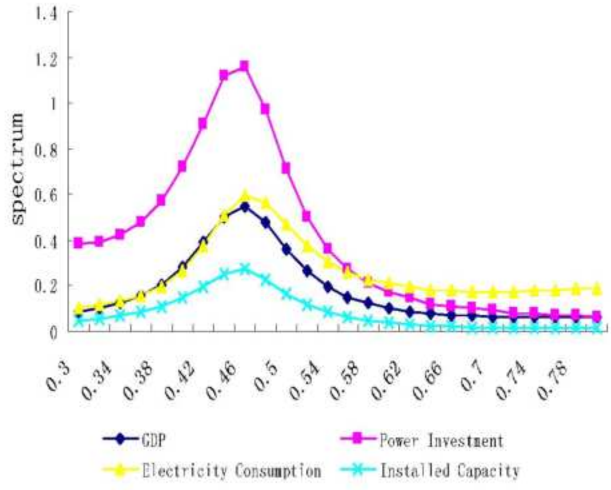

Fig.2 Autospectra of power industry and GDP

Tab.3 Results of cross spectral density analysis of power industry and GDP

Indexes	Frequency/(cycle)	Coherency	Phase
GDP-TZ	0.3(21y)	0.3520	0.7164
	0.46(13y)	0.8918	2.3151
	0.8 (8y)	0.3003	-0.4515
	1.2(5y)	0.2144	-0.0576
GDP-YD	0.3(21y)	0.2188	4.6963
	0.46(13y)	0.7786	1.1380
	0.8 (8y)	0.1178	-0.1257
	1.2(5y)	0.5589	0.0729
GDP-ZJ	0.3(21y)	0.6435	-3.0063
	0.46(13y)	0.9518	-1.9166
	0.8 (8y)	0.5918	-0.1442
	1.2(5y)	0.5861	0.3285
TZ-ZJ	0.3(21y)	0.8042	-3.9232
	0.46(13y)	0.9607	2.5455
	0.8 (8y)	0.5557	0.4179
	1.2(5y)	0.4280	0.0649

3.3 Results analysis

From Tab. 3, we could see that the values of six coherency functions at 0.46 are higher, 0.89, 0.77, 0.95 and 0.96 respectively, while they are comparatively lower at other frequency area. This illustrates that the obvious correlation between the fluctuation of GDP and electric power indexes on major frequencies is existed, and has a certain transmission relationship. It also can further approve that cycle fluctuation is existed in the economic activities that each index represents; also, the index fluctuations are closely correlated. Learning from the results of test of Chinese economic cycle and electric power industry cycle, it presents that their main cycle are all a relatively middle major cycle, 13 years or so.

According to the phases in tab. 3, GDP leads three years ahead of electric power investment and one year of electricity consumption at the major cycle. This could be translated that the development of GDP is able to drive the rise of electric power investment and electricity consumption. But they are almost at the same pace at the less than ten years cycle.

Electric power investment leads three years ahead of the newly-added installation at the major cycle, which is about the thermal power plant construction time. GDP lags one and a half year behind the installation, which means that the newly-added installation is an antecedent index and these two indexes are influenced mutually.

Time periods and the influence of the changes of Chinese power policy in each phase also need to be paid enough attention. Before reform and open, electric power was mostly controlled by plan economy with frequent fluctuations and short cycles. After reform and open, the situation is evidently changed. Market economy substitutes the former plan economy; fluctuations become mild and cycles are longer. This shows that driving force of our country's economy makes a great alternation; market plays a more significant role in present economy. Hence, economy fluctuation is a kind of running mode of market economy and the development of electric power can hardly deviate from this principle.

4 Conclusion

The electric power is the Granger causality of GDP in China according to the results of the Granger causality tests on them during 1965-2002 and its transmission direction is from the electric power to GDP growth. Based on MEM, we can know that the cycles of Chinese gross economy and power industrial economy has closer relationship. The main cycles of the economy and the electric power in China nearly go on at the same step, 10 years around .The shortage of power supply, which can hinder the economy growth, can nearly appear at the same time, So maintaining of the sufficient power supply not only has urgent realistic meaning, but also accelerating the development of power industry is the necessary condition for the long-run sustainable growth of the economy in China. Under the restriction of the installing capacity resource etc., we should strengthen the Demand Side Management (DSM) in order to guarantee the electric power supply. Based on the models, it can be estimated that the power is in the surplus state during 2007-2008 and the economy and electric power appear at a same peak during 2012-2013. Power industry should hold the cycle of the economic changes, coordinate the plans of power network and power generation, including the power reserve plan that satisfies the national economy and social developments, so as to accommodate the cycle changes of the economic and avoid the big rise and fall of power supply.

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