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Cointegration and Co-feature Analysis on Electricity Consumption and Economic Growth in China

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Abstract: - The paper applies the cointegration theory to examine the causal relationship between electricity consumption and real GDP (Gross Domestic Product) for China during 1978–2004. Our estimation results indicate that real GDP and electricity consumption for China are cointegrated and there is only unidirectional Granger causality running from electricity consumption to real GDP but not the vice versa. Then H-P filter is applied to decompose the trend and cycle component of the GDP and electricity consumption series. The estimation results indicate that there is cointegration between not only the trend components, but also the cycle components of the two series, which implies that, the Granger causality is related with the business cycle. Then Granger causality between the cycle components indicates that there is bidirectional causality between them. The estimation results are of policy implication to the development of electric sector in China.

Key-Words: - Energy economics; China; Cointegration; Co-feature

1 Introduction

In the past two decades China has achieved rapid economic growth and emerged as the second largest electricity consumption country in the world, just behind the United States. In the end of 2004 the installed generation capacity in China amounted to more than 4.2 TW and electricity generated is 21,302 TWH.

However electricity supply and economic growth has never been coincided in China. Historically there was widespread electricity shortage since 60th of the last century. In 1997 with the decrease of economic growth rate there emerged electricity surplus for the first time. However electricity shortage again emerged since 2002 and worsened in 2004. Because electricity is one of the vital driving force in modern economic development electricity shortage is apt to cause over-reaction of the government and the investors. It is stated that in the early of 2005 that the current under-construction generation project with legal permission amounted to as high as 1.25 TW.

The inconsistence between electricity supply and economic growth in China proposes an important question: does there exist long-term equilibrium between electricity consumption and economic growth in China? How do they influence each other in the short term? Properly reply to the question is helpful for electricity supply long-term strategy and planning in China.

The study of causal relationship between energy and economic growth started with the seminal work of Kraft and Kraft (1978), in which causality was found to run from GNP to energy consumption in the United States. Empirical studies were later extended to cover other industrial countries like the United Kingdom, Germany, Italy, Canada, France and Japan (Yu and Choi, 1985; Erol and Yu, 1987). In the subsequent studies, instead of relying on the standard Granger causality test, the cointegration and error-correction models were applied to test for stationarity of the variables in the time-series. Moreover some studies (e.g. Stern, 1993; Stern, 2000) tested for Granger causality in a multivariate setting by using a vector auto-regression model.

However little effort has been paid to the causal relationship between electricity consumption and economic growth in China (Lin 2003; Alice Shiu and Lam 2004). Because of the sensitivity of causal relationship analysis result to the sampling period, and because that since 1978 with the opening to outside world and reform, China has stepped to the regular road of economic growth gradually, it is important to analyze the causal relationship between electricity consumption and economic growth in China after 1978. However no research has covered the period form 1978 to 2004. Moreover no research has devoted to the relationship between the fluctuation components of the two series. Our work is an effort at this direction.

2 Methodology and Data

2.1 Stationarity, cointegration and error correction model

According to Engle and Granger (1978), a linear combination of two or more non-stationary series (with the same order of integration) may be stationary. If such a stationary linear combination exists, the series are considered to be cointegrated and long run equilibrium relationships exist. Incorporating these cointegrated properties, an error-correction (ECM) could be constructed to test for Granger causation of the series in at least one direction. In this paper the ECM is specifically adopted to examine the Granger causality between real GDP and electricity consumption in China.

Since the use of ECM requires the series to be cointegrated with the same order, it is essential to first test the series for stationarity and cointegration. A series is said to be nonstationary if it has non-constant mean, variance, and autocovariance over time. If a nonstatioary series has to be differenced d times to become stationary, then it is said to be integrated of order *d*: i.e. *I(d)*.

When both series are integrated of the same order, we can proceed to examine for the presence of cointegration. The Johansen Maximum likelihood procedures are used for the test (Johansen and Juselius, 1990). Any long-tem cointegrating relationship found between the series will contribute an additional error-correction term to the ECM. The Johansen procedure is a vector autogressive (VAR) based test on restriction imposed by cointegration in the unrestricted VAR. The null hypothesis in consideration is Ho, that there are a different number of cointegration relationship, against H1, that all series in the VAR are stationary.

The ECM used in this paper is specified as follows:

$$\Delta y_t = \alpha_2 + \beta_2 ECT_{t-1} + \sum_i \alpha_{21}(i)\Delta y_{t-i} + \sum_i \alpha_{22}(i)\Delta x_{t-i} + \varepsilon_{2t} \qquad (1)$$

$$\Delta x_t = \alpha_1 + \beta_1 ECT_{t-1} + \sum_i \alpha_{11}(i)\Delta y_{t-i} + \sum_i \alpha_{12}(i)\Delta x_{t-i} + \varepsilon_{1t} \qquad (2)$$

Where Yt and Xt represent natural logarithms of real GDP and electricity consumption, respectively, and (□Y_t, □X_t) are the differences in these varibles that capture their short-run disturbances, $\varepsilon_{1t}, \varepsilon_{2t}$ are the serially uncorrelated error terms, and ECT_{t-1} is the error-correction term (ECT), which is dereived from the long-run cointegration relationship and measures the magnitude of the past dsiequilibrium.

In each equation, change in the endogenous variable is caused not only by their lags, but also by the previous period's disequilibrium in level, i.e. ECT_{t-1}. Given such a specification, the presence of short and long-run causality could be tested. Consider Eq.(1), if the estimated coefficients on lagged values of electricity consumption are statistically significant, then the implication is that the electricity consumption Granger causes real GDP in the short-run. On the other hand, long-run causality can be found by testing the significance of hte past disequilibrium term.

2.2 The Hodrick-Prescott filter

The HP filter gives an estimate of the unobserved variable as the solution to the following minimization problem (Basdevant, 2000):

$$\min_{Ty_t} : \sum_{t=1}^{T} (y - T_{yt})^2 + \lambda(\Delta^2 T_{yt})^2 \quad (3)$$

Where y is the observed variable, T_{yt} is the unobserved variable being filtered, σ_c^2 is the variance of the cyclical component y-T_{yt} and σ_T^2 is the variance of the growth rate of the trend component. And

$\lambda = \sigma_T^2 / \sigma_c^2$ is the smoothing coefficient.

After applying H-P filter, we can get the cyclical component

$$C_{y_t} = y_t - T_{yt} \qquad t = 1,2,\Lambda\ ,T \quad (4)$$

2.3 The Data

Our empirical study uses the time series data of real GDP and electricity consumption for the 1978-2003 period for China. Nominal GDP and electricity consumption data for China are obtained from the National Bureau of Statistics (2004), China Electricity Power Information Center (2004). In this paper, electricity consumption is expressed in terms of billion kilowatt hours (kWh) or terawatt hours (TWh) and nominal GDP is deflated by the GDP deflator (using 1990 as the base year) to obtain the figure of real GDP in billion yuan.

In the paper, the Granger relationship between the un-filtered series of real GDP and electricity consumption for China is tested firstly. Then H-P filter is applied to decompose the trend and cyclical component of the two series and Granger causality test is applied to the corresponding H-P trend and cyclical components.

3 Empirical Result

3.1 The Result between un-filtered Data

Table 1 reports the results of the ADF and PP tests on the integration properties of the real GDP and electricity consumption for China. Results of the two tests indicate that the two series are found to be nonstationary. However first differences of these series lead to stationarity. These indicate that the integration of real GDP and electricity consumption of China is of order one, i.e. I(1).

Tab 1 Unit root test results of GDP and electricity consumption logarithmic series

Variables	ADF test		PP test	
	Level	First difference	Level	First difference
LGDP	-0.57	-3.63	-0.36	-2.99
LELEC			1.09	-3.10
5% critical value	-2.9907		-2.985	

Given that integration of the two series is of the same order, we continued to test whether the two series are cointegrated over the sample period. Table 2 shows the results of the Johansen test.

The likelihood ratio (LR) test rejects the hypothesis of none cointegrating equation at the 1% significance level, i.e. there is a long-run relationship between real GDP and electricity consumption for China. The normalized cointegrating coefficients (0.88) are shown in the last row of table 2, and the signs of the variables conform to the theory in literature, i.e. there is positive relationship between electricity consumption and real GDP.

Following the detection of the cointegrating relationship between real GDP and electricity consumption, an ECM was set up for investigating short and long-run causality. In the ECM, the first difference of each endogenous variable (real GDP or electricity consumption) was regressed on a one period lag of the cointegrating equation and lagged first differences of all the endogenous variables in the system.

Table 3 shows the results of causality. We have performed several tests for Granger causality: (1) short-run causality-the significance of the sum of lagged terms of each explanatory variable by joint F test; (2) long-run causality-the significance of the error-correction terms by t-test; and (3) short-run adjustment to re-establish long-run equilibrium-the joint significance of the sum of lagged terms of each explanatory variable and the ECT by joint F test.

Short-run causality is found only from electricity consumption to real GDP, but not the reverse, i.e. there is unidirectional Granger causality. The coefficient of the ECT is found to be significant in the real GDP equation, which indicates that given any deviation in the ECT, both variables in the ECM would interact in a dynamic fashion to restore long-run equilibrium. Results of the significance of interactive terms of change in electricity, along with the ECT in the GDP equation are consistent with the presence of Granger-causality running from electricity consumption to real GDP. These indicate that whenever there is the presence of a shock to the system, electricity consumption would make short-run adjustment to re-establish long-run equilibrium.

Tab 2 Johensan cointegration estimation result between GDP and electricity consumption

Egenvalue	Likelihood ratio	5%critical value	1% critical value	Number of cointegraiton
0.663132	29.99184	12.53	16.31	None **
0.240581	6.054447	3.84	6.51	At most 1 *
Normalized Cointegration equation	LELEC=0.88*LGDP			

Note□**□*□is 5%□1%□critical level. L.R.test indicates the existence of one cointegration relation at 1% level.

Tab 3 Estimation result of Error Correction Model

Source of causality	Short-run		ECT	Joint short/long term test	
Variables	ΔGDP	ΔELEC	ECT	ΔGDP and ECT	ΔELEC and ECT
	F-statistics		t-statistics	F-statistics	
ΔGDP	—	2.76**	1.768***	—	2.92**

ΔELEC	0.67	—	-0.3518	0.76	—

Note：ΔGDP and ΔELEC are the first difference series of LGDP and LELEC respectively; ECT is the Error correction term. The lag is decided by AIC criterion as 4. ** is 10% critical level and *** is 5% critical level.

3.2 The Results between Filtered Data

Then the trend and cyclical components of the two series are obtained by H-P filter, as shown in Fig 1 and 2. It is evidently that the trend components of real GDP and electricity consumption in China are almost of the same linear trend while the cyclical components of the two series are of the almost same cyclical characteristic. It hints that there maybe exists cointegration relationship between the cyclical components of electricity consumption and economic growth in China, which is of important policy implication. It is also noted that before 1990 the peak and valley of electricity consumption lagged one to two years of GDP while after 1990 the relationship was inverse.

Unit root test shows that the trend and cyclical components of the both series are of order one and we then proceed to cointegration test.

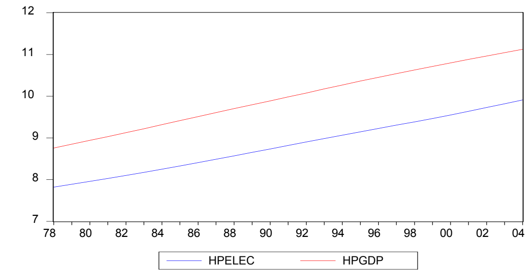
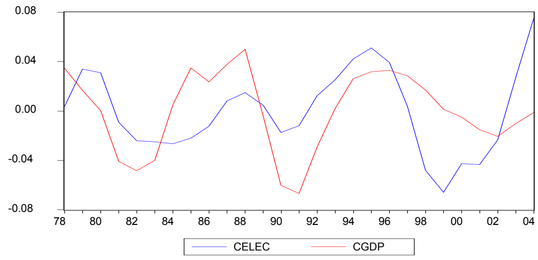


Fig. 1 Trend component of logarithm series of GDP and electricity consumption by HP filter

Fig. 2 Cyclical component of logarithm series of GDP and electricity consumption by H-P filter



Tab 4 Johensan cointegration estimation result between trend component of logarithm series of GDP and electricity consumption

Egenvalue	Likelihood ratio	5%critical value	1% critical value	Number of cointegraiton
0.482793	22.49653	12.53	16.31	None **
0.304593	7.991670	3.84	6.51	At most 1 **
Normalized Cointegration equation	HPELEC=0.91*HPGDP			

Note：** is 5% critical level. L.R.test indicates the existence of two cointegration relations at 5% level. HPGDP and HPELEC are the HP trend components of LGDP and LELEC.

Tab 5 Johensan cointegration estimation result between cycle component of logarithm series of GDP and electricity consumption

Egenvalue	Likelihood ratio	5%critical value	1% critical value	Number of cointegraiton
0.567234	28.84428	19.96	24.60	None **
0.305308	8.742876	9.24	12.97	At most 1
Normalized Cointegration equation	CELEC=-1.477*CGDP			

Note：** is 5% critical level. L.R.test indicates the existence of one cointegration relations at 5% level. CGDP and CELEC are the HP cyclical components of LGDP and LELEC.

Tab 6 Granger casuality estimation result between cycle component of logarithm series of GDP and electricity consumption

Source of causality	Short-run		ECT	Joint short/long term test	
Variable	ΔCGDP	ΔCELEC		ΔCGDP and ECT	ΔCELEC and ECT
	F-statistic		t-statistic	F-statistic	
ΔCGDP	—	5.33*	-4.12**	—	17.01**
ΔCELEC	14.07**	—	-3.77**	7.04**	—

The likelihood ratio (LR) test of the trend components of electricity consumption and GDP rejects the hypothesis of none cointegrating equation at the 1% significance level, i.e. there is a long-run relationship between real GDP and electricity consumption trend component for China. The normalized cointegrating coefficients (0.91) are shown in the last row of table 4, which is significantly higher than that of unfiltered series. The test result in Tab 5 shows that there is also cointegration relationship between cyclical components of the two series. Form the normalized cointegration equation the relationship between the cyclical components is negative, i.e. there exists restricting relationship between the fluctuation of GDP and electricity consumption and it is rightly the reason that the cointegration coefficient of unfiltered series is lower filtered ones. In fact granger test indicates that the cyclical components of them are bi-casual. The test of HP filtered series show that there exist not only co-trend but also co-fluctuation relationship between electricity consumption and economic growth in China.

4 Conclusions and Policy Implication

The causality relationship analysis between electricity consumption and economic growth is helpful for us to understand the role of electricity power in the process of boosting economic growth. The long-run equilibrium implies that in China the policy of “electricity supply must lead economic growth” should be insisted for a long period. Particularly the short-run Granger cause running from electricity consumption to GDP indicates that electricity shortage even in short-run will constrain the regular pace of economic growth, which is evident from 2003.

The cointegration relationship between the cyclical components of electricity consumption and economic growth indicates that even the short-term fluctuation between economic growth and electricity consumption are cointegrated in the long-run, hinting us to further research the relationship of electricity consumption and economic growth from perspective of business cycle, which is our future research direction.

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