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Economic Growth and Coal Consumption in China

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Abstract

In this paper, we used the methods of cointegration and granger causality estimation to test the relationship between China's coal consumption and real GDP based on the data of 1978~2010, the results show that the real GDP and coal consumption have no granger causality, and do not have a long run cointegration, which is different from the existing discovery. Because of following reasons, first of all, this paper selected on the basis of the existing economic data since reform and opening up, and for the first time increased the time span to more than 30 years and the inspection of the data generation process (DGP) to ensure that there is no structural break point; secondary, with the deepening of China's reform and opening up, economic growth dependence on coal consumption is not stable, so the GDP and coal consumption does not exist the long-term cointegration; thirdly, hidden problem of inefficient use of coal in the rapid economic growth, resulting in economic growth and coal consumption causality is not obvious. Finally, policy recommendations are offered according to the analysis of this study.

Keywords*: coal consumption, economic growth, cointegration, granger causality*

1. Introduction

Coal is the principal primary energy source in China and it has a strategic role in the economic growth of the country. In 2010, coal accounted for 68% of the total energy consumption and 76% of the total energy production in China. So coal consumption (CC) and economic growth are closely linked. However, coal also accounts for a large share of greenhouse gas emissions generated by anthropogenic activities, that will affect the coal consumption with greenhouse gas emissions reduction in the carbon-constrained global environment [1].

In the background of increasingly prominent issue of energy depletion and global environment to limit carbon emissions, China faces energy utilization of low efficiency, especially coal using low efficiency, high GDP energy consumption problems [2-4], and how to solve the problem of maintaining economic growth and reducding carbon dioxide emissions at the same time. Completing the domestic economic transformation of the environmental protection, we must properly deal with the relationship between coal consumption and economic growth.

Since the seminal work of Kraft J and Kraft A (1978), the empirical results show that causality is unidirectional between GNP and energy consumption for America based on the data of 1947~1974 [5]. Subsequently, causality method is widely used to study the relationship between economic growth and energy consumption. In recent years, many Chinese scholars use the causality causal model to analyze the relationship between China's economic growth and energy consumption. However, with the different study periods or methods, the conclusions are not the same [6-13] (Table 1).

Shiller and Perron (1985), Perron (1991), Pierse and Shell (1995) et.al. found that the traditional time-series test method was vulnerable to time period, too short time period may cause large errors in the results and too long time period may encounter "structural breaks" problem. Based on existing research, we used the methods of cointegration and granger causality theories to test the relationship between China's coal consumption and real GDP based on the data of 1978~2010, and hope to overcome the time period and structural breaks problem.

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Table 1. Empirical results from causality tests for china

Empirical work	Study period	method used	Causal relationship
Zhi-yong Han, Yi-ming WEI, Jian-ling Jiao, Ying Fan, Jiu-tian Zhang (2004)	1978～2000	Granger causal	GDP ↔ Energy consumption
Chao-qun Ma, Hui-bing Chu, ke Li, Si-qing Zhou (2004)	1954～2002	Cointegration	GDP and energy consumption have a long run cointegration
Shao-fei Ren, Hua Feng(2006)	1975～2004	Cointegration and error correction	GDP→Coal Consumption
Yan Meng, Qi-shan Zhang (2007)	1978～2005	Variable parameter model	a long-term equilibrium relationship between the Chinese coal consumption and economic growth with time changing
Pu-zhao Wu, Guang -yong Li (2007)	1978～2004	Cointegration and Granger causal	GDP→Coal Consumption
Xing-ping Zhang, Xu Zhao, Rui Gu (2008)	1980～2005	Cointegration and Granger causal	GDP→Coal Consumption
Zhao-xiang Zhang, Xian-ling Liao, Xiao-song Wang (2008)	1953～2004	structural break theory	GDP and energy consumption have a long run cointegration

2. Empirical Methodology and Data Description

The empirical strategy employed in this paper can be divided into three main steps. In the first step, we examine the unit root property of the data. In the second step, we examine cointegration between coal consumption and real GDP of the data. Finally, we examine causality between China's coal consumption and real GDP.

2.1. Unit Root Tests

Using a non-stationary time series as a stationary time series to the linear regression analysis will result in the failure of statistics, and thus causes the error of the regression analysis results. Therefore, the time series of stationary test is the basis of empirical research.

ADF test is the expansion of the DF test, this is mainly due to the DF test assumes that the time series by a first-differences autoregressive process with zero mean and with the variance of the random disturbance term AR(1) generated. But in the actual test, the time series may be generated by the higher-differences autoregressive process AR(P), and the regression analysis will have autocorrelation of the random disturbance term, resulting in invalid DF inspection. The ADF models are:

Model 1: $$\Delta y_t = \delta y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + u_t \quad (1)$$

Model 2: $$\Delta y_t = \alpha + \delta y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + u_t \quad (2)$$

Model 3: $$\Delta y_t = \alpha + \beta t + \delta y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + u_t \quad (3)$$

The hypotheses of the ADF test are:

$$H_0: \delta = 0$$
$$H_1: \delta < 0$$

If the null hypothesis is not rejected, there is a unit root.

ADF test operates from Model 3, then model 2, and finally model 1. As long as one of the model test rejected the null hypothesis in the ADF test process, then the time series are stationary; only when the above three models accept the null hypothesis, the time series are non-stationary.

As the unit root test is very sensitive for different lag order, the lag order of the ADF test for the GDP and CC are determined by AIC.

2.2. Cointegration Test

In general, if a non-stationary time series y_t become a stationary time series after d-differences（$\Delta^d y_t=\Delta(\Delta^{d-1}y_t)$）, we marked that the series as I(d). Cointegration test is looking for a long-run balanced relationship when all the variables' order of integrated is the same; if there is no a long-run balanced relationship between variables, then there is no cointegration.

Cointegration test is divided into two-variable testing and multivariate testing. The common cointegration test methods include EG (1987) two-step testing method and the Johansen test method, Johansen test is fit for multivariate testing. As we consider about two variables, so we use the EG two-step testing method.

Step 1: If the two variables y_t and x_t are the same order, then use OLS method to estimates the integration equation $\hat{y}_t=\hat{b}_0+\hat{b}_1x_t$, maintained residual $e_t=y_t-\hat{y}_t$ as the estimated value of the equalization error u_t;

Step 2: Testing the stationarity of the residual term e_t. If the residual term e_t is non-stationary, the variable y_t and x_t are not cointegrated, y_t and x_t have no long-run equilibrium relationship. OLS estimates the following equation as below:

$$\Delta e_t=\delta e_{t-1}+\sum_{i=1}^{p}\delta_i\Delta e_{t-i}+v_t \quad (4)$$

The hypotheses are:

$$H_0:\delta=0$$
$$H_1:\delta<0$$

If the null hypothesis ($t_\delta<\tau$) was rejected, e_t was stationary, and two variables y_t and x_t are cointegrated; Contrary, y_t and x_t are not cointegrated. Be noted that the formula (4) does not include the constant term, because the OLS residuals e_t should fluctuate around the center 0, and the statistics (τ) in ADF test is not suitable for this test. Because the DF or ADF test for the calculated cointegration regression residual e_t, rather than the true non-equilibrium error u_t. As the OLS method uses residual least sum of squares, it is estimated that the amount δ of downward biases often and this will lead to higher opportunity to reject the null hypothesis than the actual situation. So the DF or ADF critical value of e_t stationary test should be even smaller than normal DF or ADF critical value. MacKinnon (1991) has given the critical value through the simulation cointegration test. This article will use the critical value to test the stationary of e_t.

2.3. Causality Test

In order to clarify the causal relationship between the variables, granger causality must be tested. The test requires to estimate the following regression model:

$$y_t=\sum_{i=1}^{q}\alpha_i x_{t-i}+\sum_{j=1}^{q}\beta_j y_{t-j}+u_{1t} \quad (5)$$

$$x_t=\sum_{i=1}^{s}\lambda_i x_{t-i}+\sum_{j=1}^{s}\delta_j y_{t-j}+u_{2t} \quad (6)$$

Where u_{1t} and u_{2t} are white noise.

Equation (5) assumes that the current values of y_t and the past values of y_t and the past values of x_t are relevant, and the equation (6) has the similar assumption for x_t.

For equation (5), The hypotheses are: $H_0:\alpha_1=\alpha_2=\ldots=\alpha_q=0$;

For equation (6), The hypotheses are: $H_0:\delta_1=\delta_2=\ldots=\delta_s=0$.

Noted that the test results of the Granger causality test is very sensitive to the choice of lag length, for the different lag length, may get different results. Therefore, after the AIC test, we take 1 as the lag for the granger causality test of GDP and CC.

2.4. Data Description

The GDP and coal consumption data (1978～2008) employed in our analysis are obtained from the China Compendium of Statistics (1949～2008), and complemented with data from China Statistical Yearbook (2011). The unit of coal consumption is ten thousand tons of standard coal, and we transform nominal GDP sequence into a sequence of real GDP at the constant prices in 1978, and the unit GDP is one hundred million yuan. Figure 1 reflects the trend from 1978 to 2010, China's coal consumption and real GDP changes. All series enter the regressions in natural log form.

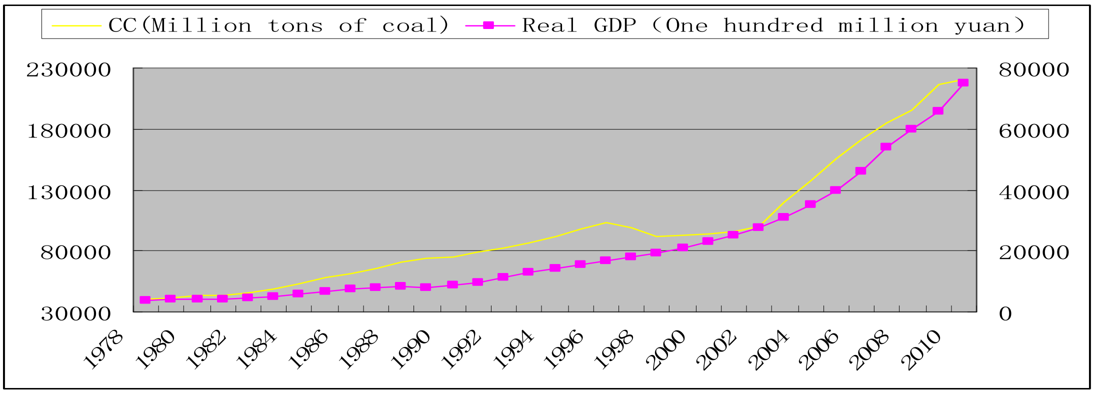

Figure 1. Coal consumption and real GDP trend graph (1978～2010)

3. Empirical Results

3.1. Unit Root Test

The lag order of GDP and CC are 2 and 1. The first-differences and the second-differences unit root test results are shown in Table 2.

Table 2 shows that coal consumption and GDP are I(2), which laid a foundation for the next cointegration test.

3.2. Cointegration Test

Step 1: use OLS method to estimate cointegration regression equation, use Eviews6.0 to produce cointegration regression equation between the two variables:

$$LNGDP=-10.9403+1.8035LNCC \quad (7)$$

(-15.6125) (29.3027)

R^2 =0.9640 DW=0.2294 F=858.6477

Step 2: test the residuals of e_t .Test the unit root residuals according to the AIC order determination criteria to determine the lag order as 1. Based on the ADF unit root test above, we carried out the test of model 3, model 2 and model 1 respectively, the results shown in Table 3.

As can see from Table 3 and Table 4, the ADF values of model 3, model 2 and model1 are greater than the critical value of the MacKinnon significant level 1%, 5% and 10%, with the sample capacity of 25 and 50. Therefore, the residual sequence e_t is not stationary, and there is no cointegration between real GDP and CC.

Table 2. Unit root test

	model	ADF	1% Critical Value	5% Critical Value	10% Critical Value	Conclusion
GDP	Model 3	-3.313	-4.310	-3.574	-3.222	
1st differences	Model 2	-2.866	-3.679	-2.968	-2.623	non-stationary
	Model 1	-0.376	-2.647	-1.953	-1.610	
GDP	Model 3	-3.307	-4.323	-3.581	-3.225	
2nd differences	Model 2	-3.377	-3.689	-2.972	-2.625	stationary
	Model 1	-3.413	-2.650	-1.953	-1.610	
CC	Model 3	-2.654	-4.297	-3.568	-3.218	
1st differences	Model 2	-2.707	-3.670	-2.964	-2.621	non-stationary
	Model 1	-1.672	-2.644	-1.952	-1.610	
CC	Model 3	-4.488	-4.310	-3.574	-3.222	
2nd differences	Model 2	-4.545	-3.679	-2.968	-2.623	stationary
	Model 1	-4.627	-2.647	-1.953	-1.610	

Notes:*MacKinnon (1996) one-sided p-values.

Table 3. Residual unit root test

Model	Model 3	Model 2	Model 1
ADF	-2.6469	-2.4689	-2.5125

Table 4. MacKinnon bivariate threshold cointegration test

Sample size	1% level	5% level	10% level
25	-4.37	-3.59	-3.22
50	-4.12	-3.46	-3.13

3.3. Causality Test

Because Cointegration does not exist between the CC and GDP, the Granger causality test is operated below, and error correction model is no longer established. After the Granger causality test, take the lag order of 1 to the GDP and CC Granger causality test. The results are shown in Table 5.

Table 5. Causality test for GDP and CC

Null hypothesis	Lag	F value	P value	Observations
GDP does not Granger Cause CC	1	2.17792	0.15078	32
CC does not Granger Cause GDP		0.00084	0.97712	

Table 5 shows that the null hypothesis of GDP is not the Granger cause of CC, the maximum probability of rejecting it committing Type Ⅰ error is 0.15078, greater than 0.05, that is only under the confidence level of 95%, we can say that GDP is CC's Granger cause, therefore accept the null hypothesis that GDP is not Granger Cause of CC; the null hypothesis of CC is not the Granger cause of GD, the maximum probability of rejecting it committing Type I error is 0.97712, so CC is not the Granger Cause of GDP. This paper draws the conclusion that the causal relationship does not exist between China's economic growth and coal Consumption.

4. Discussions and Conclusions

After the above empirical analysis, we have the following conclusions:

(1) Based on the data of 1978~2010, we used the methods of cointegration and Granger causality estimation to test the relationship between China's coal consumption and real GDP. The results show that coal consumption and real GDP are both I(2), and the real GDP and coal consumption have no granger causality, and does not have cointegration. This conclusion is not the same as the existing empirical studies' conclusion.

The results of a review of existing literatures, the relationship between GDP and coal consumption causality is unidirectional or bidirectional. We believe that the key point is the selected time span. Summarizing the existing literature, the time span can be divided into two categories: The first kind contains the data before 1978, and the second type contains the data after 1978 (including 1978). For the first kind of time span, the planned economy and the political factors before reform and opening up can cause the data generation process (DGP) mutation for the historical data, and affect the results of the study. Bo Shi(2007) combined vector error correction model with structure mutation to analyze the relationship of Chinese energy consumption and economic growth, and the results indicated that the energy consumption of 1961 had structure mutation. This makes long-run equilibrium relationship does not exist between the energy consumption and economic growth during 1952~2005, but there is a cointegration relationship during 1962~2005 [14]; Li Ma(2010) used the theory of structural breaks analyze the data generation process of China's GDP(1952~2008), and it is concluded that China's GDP obeys a structure mutation trend stable process, any impact to GDP will produce a lasting impact to GDP, and a structure mutation point was found in 1978 [15]. For the second kind of time span, the structural mutation has been excluded, and the major difference lies in the time span of the size. The conclusion difference between this paper and the existing literatures is the time span we choose is the longest in the second type time span, and this derives a question: how exactly long of the time span is reasonable? At present, there are few researches on this problem domestic and abroad, so the selection of interval size of time span is still a problem that deserves to study.

(2) The economic growth and coal consumption does not have causality relationship. This conclusion suggests that after the reform and opening up, the dependence of GDP growth in coal consumption is changing with the continuous deepening of reform and opening up. From the beginning of reform and opening up(1978 to 1990), the economy started to recover. Industry and mining enterprises become active in production, and the demand for coal began rising rapidly. With the deepening of reform and opening from 1990 to 1999, the structure of industry and energy upgraded and optimized. To a great extent, oil replaced coal as the main energy weakened the economy growth's dependence on coal consumption; Since 1999, especially after the start of energy reform, in order to build a resource-conserving and environment-friendly economic environment, the new energy industry grow very fast, which further weakening economic growth's dependence on coal consumption [16]. Therefore, the relationship between economic growth and coal consumption is not stable. Coupled with the instability of China's energy policy, GDP and coal consumption dot not have a long-term cointegration [17-19]. The decreasing degree of economic growth's dependence on coal consumption gradually and low efficiency coal use under such circumstances make economic growth and coal consumption causality not obvious, and lead to GDP and coal consumption does not have a causal relationship.

(3) In the global issues of energy depletion and carbon emissions limit environment, to build an environment-friendly, resource-saving and harmonious society, one of the goals of China's 11th Five-Year Plan is to reduce 20% energy consumption in one unit of GDP. Improving energy efficiency, especially coal utilization efficiency is the focus of the current work. For example, China's carbon dioxide emission in 2007 was 59.6×10^{8} tons, ranking first in the world, but the United States is only 58.2×10^{8} tons. How to reduce carbon dioxide emission is

an urgent problem needed to be solved. Low-carbon technologies in recent years, including carbon technologies (carbon capture and sequestration technology), carbon reduction technology (to improve energy efficiency and energy saving technology) and carbon-free technologies (the use of modern biomass, solar, wind, hydro, geothermal and other renewable energy sources, and even nuclear energy technology) are preferred selections to improve the efficiency of coal use. Another point, in order to reduce greenhouse gas emissions, to achieve the purpose of energy saving, China must speed up the adjustment of the structure of energy consumption, and reduce the proportion of coal in energy consumption gradually. Besides, China must develop new energy positively; pay great attention to the development of low-carbon economy, implement diversified and low-carbon energy consumption structure strategy.

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