International Journal of u- and e- Service, Science and Technology
Vol.8, No. 7 (2015), pp.63-70
http://dx.doi.org/10.14257/ijunesst.2015.8.7.06

Based on Co-integration Test and Granger Causality Test for Economic Growth and Consumption of Conventional Energy Resources

Liu Xin[1,2], Song Yongpeng[1], Zhang Qianqian[1], Pang Bo[1] and Qin Mingzhou[1*]

[1]*College of Environment and Planning, Henan University, Kaifeng, 475004, China*
[2]*Development & Investment Administration Center of Land and Resources of Henan province, Zhengzhou, 470000, China*
liuxin123liuxin@126.com
**Corresponding author email, qinmingzhou@henu.edu.cn*

Abstract

The relationship between economic growth and consumption of conventional energy resources in Henan Province is analyzed empirically, Calculated using Eviews software for the data in Henan Statistical Yearbook. The result of co-integration test indicates that there exists long term equilibrium between GDP and EC, so the text establishes a long-term equation and error correction model. Forecast of the long term demand of energy in Henan Province indicates that the implementation of economic growth should rely on immense amounts of energy. Granger causality test indicates EC is Granger cause of GDP in Henan Province, that is to say, EC leads to GDP directly, but GDP is not Granger cause of EC. So, for the double goals of energy-saving & cost-reducing and economic growth, the key of government's effort are to change the way of economic growth and adjust the economic structure.

Keywords**:** *energy consumption, economic growth, co-integration analysis, error correction model, granger causality test*

1. Introduction

The model of quantitative research about the relationship between energy consumption and economic growth aroused the international concerns in the 1970s. A lot of researches are empirical researches about the energy and economic growth in the United States, Kraft and Kraft [1], Akarca and Long [2], Yu and Hwang [3] use different interval time data to test, Yu and Jin [4] use E-G two-step to test, Stern [5] uses 4 variable (Gross Domestic Product or GDP, labour force, capital and energy) vector auto regressive (VAR) model of causality test, then uses the single equation of static co-integration analysis and multivariate dynamic co-integration analysis to expand its own analysis. Above those researches can not reach a consensus about the long term co-integration equilibrium relationship between energy and economic growth. Some domestic scholars use the data of China to research the relationship between them, too. Zhao Lixia, *et al.*, [6] put energy as a new variable into the cobb-douglas production function and establish VAR model, Lin Boqiang [7-8] uses co-integration and error correction model researching the relationship between electricity consumption and economic growth in China. Ma Chaoqun, *et al.*, [9] use EG two-step, Ben Xingzhen, *et al.*, [10] use co-integration analysis, error correction model and Granger causality test method, Ren Biao, *et al.*, [11] by using gray correlation analysis respectively on the energy consumption and environmental pollution control investment impact on economic development and energy has carried on the analysis to the influence of environmental pollution control investment consumption.

ISSN: 2005-4246 IJUNESST

The above research content mainly uses the measuring tool to analyse, reflects the relationship between the economic growth and energy consumption, but most of the studies focus on the China economic and energy consumption situation, not more on regional comparison and provincial research. Our country is currently in the construction of socialist market economy, relatively large regional differences, regional development strategy for the implementation also have different emphasis in different periods. The leading role played by the Henan Province in the central region is growing, the comprehensive economic strength of Henan province significantly enhanced, for many years, Henan Province has maintained a high growth rate, which is to realize the transformation from a big agricultural province to a strong industry province. But in terms of energy consumption, Henan Province has a large gap compared with developed country, area, that to say, the extensive mode of economic growth in Henan Province has formed a "path dependence", so the Henan energy saving and economic development task is very arduous, need to study the relationship between energy consumption and economic growth, which provides solutions. Therefore, it is necessary to analyse and study the relationship between the economic growth and consumption of conventional energy in Henan Province.

2 The Co-integration Analysis between the Economic Growth and Consumption of Conventional Energy in Henan Province

According to the previous research on economic growth and energy consumption, the reality of the situation in Henan Province, now the relationship between economy and energy in Henan Province is identified as linear equations:

$$EC_t = \alpha + \beta GDP_t + \mu_t$$

EC represents the Henan energy consumption, *GDP* represents economic growth, *t* represents time, μ_t represents random perturbation.

2.1. Indicators and Data

The choice of indicators for the total energy consumption of Henan (*EC*) and economic growth of Henan (*GDP*), the time interval from 1980 to 2007, the constant GDP in 1980 for the elimination of price fluctuations, total energy consumption data is not processed.

2.2. Unit Root Test

By the co-integration theory, the first step of variable co-integration test is that take unit root test method to judge the stability of single variable series, to see whether the same between different variables is integrated of order sequence. Thus, first, draw respectively GDP (1980 constant prices, unit: million) and energy consumption (*EC*: million tons of standard coal) two variables sequence and its first order difference, second, order difference sequence line chart (Figure 1, 2, 3). It can be seen from Figure 1, the two variables of *GDP* and *EC* increase with time obviously. Selecting test equations should include constant and trend equations of the unit root test in stable primary sequence of the two economic variables when take unit root test method to judge the stability of these two economic variables sequence. After inspection, found that the original series is non-stationary, then need to inspect its first order difference sequence whether is stable. According to the Figure 2, the two variable first order different sequence still trends to rise roughly with time, therefore, still inspect it with inspection equations which include constant term and tendency item. According to the Figure 3, the two variables of the second order difference sequence has O-mean, change with time fluctuating near 0-mean, and no significant time trend, Therefore, if the first order difference sequence is not stable, need to inspect the stationarity of the second order difference sequence.

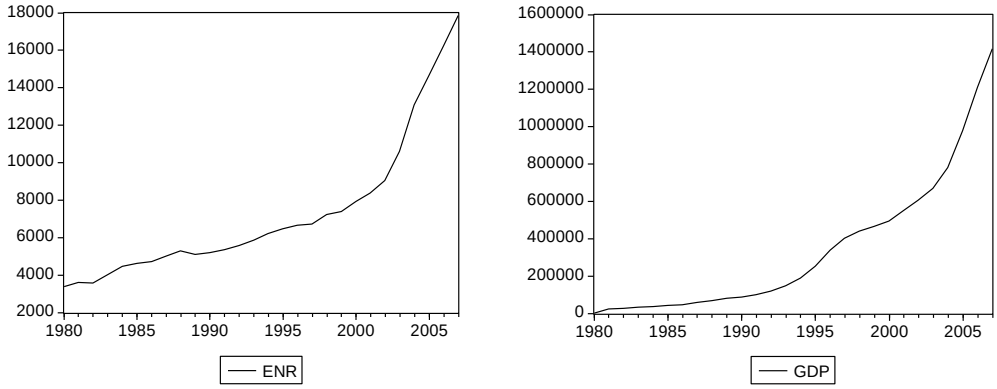

Figure 1. Line Charts of Variable Sequence

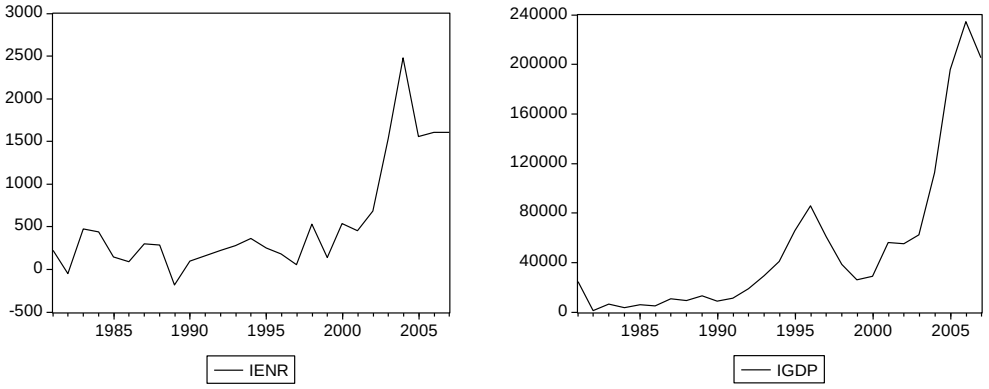

Figure 2. Line Chart of Variable First Order Difference Sequence

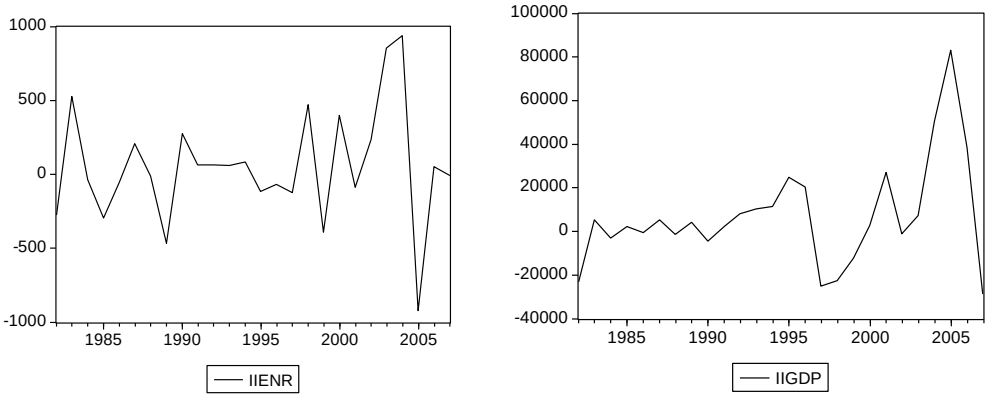

Figure 3. Line Chart of Variable Second Order Difference Sequence

According to the above analysis, use the eviews4.0 to test the variable series stationarity, mainly use the Augmented Dickey-Fuller test (ADF: Augmented Dickey-Fuller test) method in the unit root test process. At the same time, use PP test as an auxiliary means of test in order to avoid the possible error of single testing method. Unit root test method, test process, inspection of each variable results and conclusions are shown in Table 1.

Table 1. Unit Root Test and Variable Stationarity Test

variable	ADF test				PP test	conclusion
	t	1%	5%	10%		
GDP	4.2843	-3.7880	-3.0124	-2.6461	6.8366	non stationary
△GDP	1.7178	-3.1315	-3.0100	-2.6552	0.6380	non stationary
$\triangle^2$GDP	-4.0749*	-3.7379	-2.9919	-2.6355	-2.6486*	stationary
EC	6.81248	-3.6999	-2.9763	-2.6274	-5.7226	non stationary
△EC	-1.1419	-3.7115	-2.9810	-2.6299	-0.9715	non stationary
$\triangle^2$EC	-5.8587*	-3.7241	-2.9862	-2.6326	-4.8381*	stationary

Note: * represents significant difference at 1% level, △ represents variable first order difference, $\triangle^2$ represents variable second order difference.

From the test results, the original sequence of *GDP* and EC and the first difference sequence are non stationary sequences. But the ADF test and the PP test of the two variables second difference sequence are under the 1% level smoothly through the unit root test, is a stationary series, that is GDP ~ I, EC ~ (2) I (2), GDP and EC are the same as the two order single whole sequence.

2.3. The Co-integration Equation and the Generalized Difference Equation

From the above analysis, GDP～I(2), EC～I(2) meets the necessary conditions of co-integration, Then according to the second step of Grainger two-step test whether the residual sequences of variable regression model are stable, if it is, it can be shown the co-integration relationship among variables.

Because GDP, EC ~ I (2) and residual belong to the I (0) smooth sequence, use OLS method to establish co-integration equation between energy consumption and national income GDP in Henan:

$$EC = \underset{(20.89436)}{3859.104098} + \underset{(27.37310)}{0.009926} \times GDP$$

The partial correlation coefficient test, the results shows Table 2.

Table 2. Direct Estimation Equation Variable in the Correlation Coefficient and Partial Correlation Coefficient

auto-correlation	partial correlation		AC	PAC	Q-Stat	Prob
. |****** |	. |****** |	1	0.789	0.789	19.347	0.000
. |*** |	****| . |	2	0.435	-0.493	25.469	0.000
. |* . |	. | . |	3	0.136	0.043	26.090	0.000
. | . |	. | . |	4	-0.052	-0.041	26.183	0.000
.**| . |	.**| . |	5	-0.215	-0.294	27.871	0.000
***| . |	. *| . |	6	-0.357	-0.090	32.750	0.000
****| . |	. *| . |	7	-0.465	-0.182	41.393	0.000
****| . |	. | . |	8	-0.465	0.028	50.473	0.000
***| . |	. | . |	9	-0.367	-0.023	56.418	0.000
.**| . |	. **| . |	10	-0.263	-0.203	59.637	0.000
.**| . |	. *| . |	11	-0.211	-0.136	61.843	0.000
. *| . |	. *| . |	12	-0.176	-0.098	63.473	0.000

As can be seen, there are two order auto-correlation. Use AR (m) method to establish the generalized difference regression equation between Henan energy consumption and national income, the original equation is modified, as the formula (2):

$$EC = \underset{(11.26032)}{4047.397917} + \underset{(15.38886)}{0.009488} \times GDP + [AR(1) = \underset{(6.938427)}{1.259220}, AR(2) = \underset{(-3.109637)}{-0.554217}]$$

From the indicators (Table 3), the revised model improves the goodness. From the partial correlation coefficient test results, the model no longer exists auto-correlation.

Table 3. The Generalized Difference Equation Variable in the Correlation Coefficient and Partial Correlation Coefficient

auto-correlation	partial correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	0.037	0.037	0.0398	
.** | . |	.** | . |	2	-0.193	-0.195	1.1734	
. | . |	. | . |	3	-0.022	-0.006	1.1880	0.276
. |* . |	. |* . |	4	0.141	0.109	1.8446	0.398
. *| . |	. *| . |	5	-0.136	-0.160	2.4866	0.478
. | . |	. |* . |	6	0.004	0.069	2.4871	0.647
.** | . |	.** | . |	7	-0.193	-0.266	3.9133	0.562
.** | . |	.** | . |	8	-0.219	-0.228	5.8455	0.441
. *| . |	. *| . |	9	-0.100	-0.150	6.2726	0.508
. |* . |	. *| . |	10	0.079	-0.073	6.5538	0.585
. | . |	. *| . |	11	-0.057	-0.076	6.7092	0.667
. | . |	. | . |	12	-0.006	-0.038	6.7110	0.752

At this time, use the unit root test to test the residual of the equation. The results showed (Table 4), at the same time the residual sequence through the ADF test and PP test, which shows that there exists a long-term co integration relationship between GDP and EC.

Table 4. Residual Series Stationarity Test

residual	ADF test				PP test	conclusion
	t	1%	5%	10%		
resid	-4.698405	-3.724070	-2.986225	-2.632604	-4.697616	stationary***

Note: * * * mean significant at 1% level.

Thus, generalized regression model results of Henan energy consumption and national income with satisfactory statistical properties which more can reflect the long-term equilibrium relationship between the two than the direct co-integration equation. The regression coefficient of the model variable is 0.009488 which indicates that the total energy consumption of a corresponding increase 9.488 thousand tons of standard coal while Henan GDP for each additional 1 billion yuan (100 million yuan). Figure 4 shows the fitting effect result of the model.

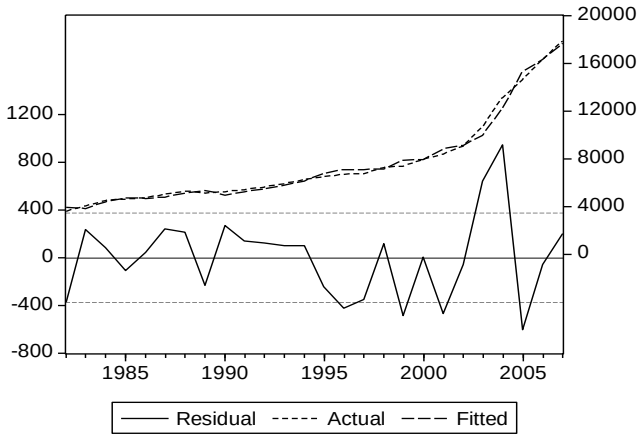

Figure 4. Generalized Difference Equation Fitting Chart

The energy supply of Henan Province to achieve its economic goals can be eliminated based on these two equations. If the GDP of Henan Province will be four times what it was in 2000 by 2020, while GDP will reach 20211.96 billion yuan (base year 1980), eliminating the total energy consumption respectively in Henan in 2020 according to the co-integration equation of main generalized difference equation of the energy consumption, the total energy consumption is estimated respectively in Henan in 2020.

According to the co-integration equation (1):

$$EC_{2020} = \underset{(20.89436)}{3859.104098} + \underset{(27.37310)}{0.009926} \times GDP_{2020}$$

According to the generalized difference equation (2):

$$EC_{2020} = \underset{(11.26032)}{4047.397917} + \underset{(15.38886)}{0.009488} \times GDP_{2020}$$

According to the above equation, can be calculated: Assume that the current energy consumption and energy utilization technology does not change，the total energy consumption by 2020 in Henan will be 239215 thousand tons of standard coal and 232245.056 thousand tons of standard coal, is respectively 7.06 times, 6.85 times in 2000. That is to say, if do not change the Henan province's energy use and efficiency to achieve its economic growth target in 2020, there must be a lot of energy as the support, and the world total energy storage and exploitation amount is fixed, energy prices will be rising, there would be an enormous cost in the absence of assuming a lot cheaper new energy has been developed out to achieve the economic growth goals.

2.4. Error Correction Model

Because GDP～I(2)、EC～I(2), using the OLS estimation results to the GDP and EC shows that there are two order auto-correlation, the GDP and the EC error correction model of dynamic equilibrium between the short-term is GDP and EC two order differential equilibrium regression model sequence. Therefore, put the two order time-delay terms into the short term disequilibrium model, the model is:

$$EC_t = \alpha_0 + \alpha_1 GDP_t + \alpha_2 GDP_{t-1} + \alpha_3 GDP_{t-2} + \gamma_1 EC_{t-1} + \gamma_2 EC_{t-2} + \mu_t$$

Use OLS method to estimate , the result is:

$$EC_t = -60.666675 + 0.003155 * GDP_t - 0.008977 * GDP_{t-1}$$
$$+ 0.007340 * GDP_{t-2} + 1.376816 * EC_{t-1} - 0.360475 * EC_{t-2} + \mu_t$$

There is no auto-correlation by using the Lagrange multiplier test. After identical deformation, the error correction model is:

$$\Delta EC = 0.360475 + 0.003155 \Delta GDP_t - 0.007340 \Delta GDP_{t-1}$$
$$+ 0.016341 (EC_{t-1} - 3712.5436 + 0.092895 GDP_{t-1}) + \mu_t$$

The short-term elasticity of GDP on EC is 0.003155, when the error correction coefficient is positive, consistent with positive correction mechanism. The regression result shows that short-term changes of GDP has a positive effect on EC, GDP changes increase every 1% while EC will increase by 0.003155%, the previous GDP changes increase every 1% while the period of EC change will reduce 0.00734%, the previous EC change also has positive effect on the phase of EC changes, previous EC changes every increase 1%. There will be in 1.6341% efforts to drag the non-equilibrium state back to the equilibrium state when the short-term fluctuations EC deviate from long-term equilibrium EC.

From the above results, the long-term elasticity of EC on GDP is 0.009926, the

short-term elasticity is 0.003155, illustrates that the changes of GDP in Henan has more long-term efforts on EC.

3. Grainger Causality between Economic Growth and Energy Consumption in Henan

Because EC and GDP lose part of the information after two order difference, may not fully reflect the actual correlation among the original variables. However, because EC and GDP are the same order integration, can carry on Granger causality test to no difference variable sequence. Considering the self correlation and Akaike information criterion, determine the time lag of 2, test results are shown in Table 5.

Table 5. Granger Causality Test of GDP and Energy Consumption

The null hypothesis	F	P	lag phase	conclusion
EC is not the Grainger reason caused by GDP	2.27149	0.12792	2	refuse
GDP is not the Grainger reason caused by EC	19.4454	1.7E-05		accept

Known that there exists a one-way casual relationship from EC to GDP between energy consumption and the total GDP of Henan, but there is no obvious causal relationship from GDP to EC. This research shows that: On the one hand, Henan's energy consumption is the Grainger reason of regional GDP, namely the increase of energy consumption in Henan province directly leads to the increase of GDP, which means that by the energy input to support economic growth, which reflects the economic growth in Henan province has not changed and is difficult to change, saving energy and reducing consumption has great pressure. However, GDP is not the Grainger reason of energy consumption, namely GDP growth does not necessarily lead to the growth of energy consumption, and it provides a possible to look for new economic growth points.

The reason of this result is the following aspects:

First, Henan Province industry structure status, especially the industrial structure causes the Henan economic growth relying too much on the energy consumption. Second, the weak technical innovation capability in Henan is the main reason of the low energy utilization efficiency and the extensive mode of economic growth. Third, Henan's energy structure is dominated by traditional energy, new energy development and utilization is not enough.

4 Conclusions and Suggestions

According to the above empirical analysis, we can draw the following conclusions: There is a strong correlation between economic growth and the increase of energy consumption in Henan Province, the increase of energy consumption is the main reason of economic growth, which shows that Henan's economic growth mostly depends on the increase of energy consumption. Economic growth does not necessarily lead to energy consumption growth which means between energy consumption and economic growth was not a alternative relationship.

So, the double goals of energy-saving & cost-reducing and economic growth, the key of government’s effort are to change the way of economic growth and adjust the economic structure.

Acknowledgment

This publication has been funded under the National Natural Science Foundation of China (41171439), The development program of science and technology of Henan (142400410684), The tender subject of government decision and study of Henan

(2014207), Henan province social science research program (SKL-2014-3405) and Henan university natural science fund project (2013YBZR001). Its content does not represent the official position of the Chinese government and is entirely the responsibility of the authors.

References

[1] J. Kraft and A. Kraft, "On the relationship between energy and GNP", Energy Development, no. 3, **(1978)**, pp. 401-403.
[2] A. T. Akarca and T. V. Long, "On the relationship between energy and GNP: re-examination", Journal of Energy and Development, no. 5, **(1980)**, pp. 326-331.
[3] S. H. Y. Eden and B. K. Hwang, "The Relationship between Energy and GNP: Further Results", Energy Economics, vol. 6, no. 3, **(1984)**, pp. 186-190.
[4] S. H. Y. Eden and J. C. Jin, "Cointegration Tests of Energy Consumption, Income and Employment", Resources and Energy, vol. 14, no. 3, **(1992)**, pp. 259-266.
[5] D. I. Stern, "A Multivariate Co-integration Analysis of the Role of Energy in the US Macroeconomy", Energy Economics, vol. 22, **(2000)**, pp. 267-283.
[6] Z. Lixia and W. Weixian, "Study on model of economic growth and energy", Prediction, no. 6, **(1998)**, pp. 32-49.
[7] L. Boqiang, "Structural change, efficiency improvement and energy demand forecasting --illustrated by the example of Chinese power industry", Economic Research, no. 5, **(2003)**, pp. 57-65.
[8] L. Boqiang, "Electricity consumption and economic growth: The research based on the production function", Management of The World, no. 11, **(2003)**, pp. 18-27.
[9] M. Chaoqun, H. B. Chu, L. Ke, *et al.*, "The co-integration and error correction model of Chinese energy consumption and economic growth", Systems Engineering, vol. 22, no. 10, **(2004)**, pp. 47-50.
[10] B. Xingzhen and Y. Baochen, "Co-integration analysis of relationship between energy consumption and economic growth in China", Journal of Harbin University of Science and Technology, vol. 10, no. 8, pp. 117-120.
[11] R. Biao and L. Shaoying, "Grey correlation analysis of Chinese energy consumption and environmental pollution and economic development", Statistical Information Forum, vol. 22, no. 1, **(2007)**, pp. 46-49.

