Research on the Cointegration Relationship of Energy Consumption and Economy Growth in Beijing

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Abstract: - This paper studies the relationships between total energy consumption (EC) and GDP, also industrial EC and their respective value-added (VA) in Beijing based on cointegration theory. The results indicated that there existed a Granger causality relationship running from GDP to EC growth, embodied mainly by the tertiary industry. Moreover, the Granger causality relationship is bidirectional in the tertiary industry. At the same time, it shows us cointegration relationships between GDP and EC. The total EC increases 0.427% while the total VA gets a 1% growth, and for the tertiary industry, every 1% more EC can bring about 0.97% VA. There is an impulse response to EC caused by economic growth which is mainly embodied in the third period. The impulse response also exists between EC and VA growth of the tertiary industry. But the promoting effect is more obvious from VA growth to EC in the tertiary industry than EC to VA growth, which shows that the energy conservation policy will not effect the economic growth in Beijing.

Key-Words: - Beijing; Energy; Industry Economy; Cointegration; Impulse Response

1 Introduction

With rapid economic development and the improvement of living standards, the energy consumption (EC) in Beijing has been becoming larger and larger. In 2007, the gross EC was 62.901mtec with 6.54% growth comparing to it in last year. Because of resources shortage, energy supply and environmental pollution has become the most important issues impeding urban sustainable development in Beijing. At first, the judgment of the relationship between the economic development and energy demand should be done to solve this problem, so that we can provide scientific evidence for energy industrial policies in Beijing.

The study on the relationship between EC and economic development began in 1978 when Kraft did the pioneering research work for the United States [1]. He got a conclusion of causal relationship between EC and GDP by analyzing data during 1947-1974 in US, the same conclusion to Stern's (2000)[2], but different from the result of Yu and Jin's(1992)[3]. Empirical studies were later extended to cover other countries such as the United Kingdom, Germany, Italy, etc. [4]-[17]. The main methodologies applied are the Granger-Causality (GC), the Vector Error Correction Model (VECM), the Vector Auto-Regression (VAR) and Panel Data Model. Wankeun and Kihoon(2004) studied the data during 1981-2000 of South Korea based on VECM, and found that in the short term there was no causal relationship between GDP and EC, but in the long run there existed a one-way causal relationship and energy-saving policy will not affect economic development[5]. Yamane (2005) applied cointegration Model for analyzing EC and GDP data during 1971-2001 of 19 African countries [6]. The results detected that there existed cointegration relationship between EC and economic development only in 10 countries. At the same time, Lee (2005) used complete correct OLS and Panel cointegration Analysis Model to explore the causal relationship on the data during 1975-2001 of 18 developing countries, and found there existed a one-way causal relationship running from EC to GDP and energy-saving policy will harm economic development [7]. The EC and GDP data of 11 oil-exporting countries were studied based on Panel data model [8]. The results show that a one-way causal relationship existed between economic growth and EC and energy-saving policy will not affect economic development. Mahmoud(2006) applied GC and Panel Cointegration model for analyzing the relationship between EC and GDP in the six countries of Gulf Cooperation Council (GCC) and got that there existed a one-way causal relationship running from GDP to EC and energy-saving won't

have a negative impact on the economy[9] . Wietze and Kees (2007) used the data of Turkey during 1970-2003 and got that there existed a cointegration relationship between GDP and EC and energy-saving policy have no impact on economic growth [10]. Some researches have also been done on the relationship between economic growth and various components of energy, such as electricity consumption for Asian countries [11]-[17], but unfortunately they could not reach unanimous conclusions. It is same for China. Based on the data during 1985-2003 in China, Ben and Yang studied the relationship between industrial EC and economy and found there were one-way causal relationships running from economy to industrial EC in the primary and secondary industries [18]. Based on the data during 1953-2003, Yan (2006) got the conclusions of a one-way Granger causal relationship running from GDP to power consumption, no significant causal relationship between coal consumption and GDP and bidirectional causal relationship and cointegration between the gross EC and GDP [19]. Wang (2006) got the conclusion that there was variable parameter cointegration relationship between China's EC and GDP growth based on the statistical data of 1953-2002[20]. Han (2004) discovered a bidirectional causal relationship, but no long-term cointegration between EC and GDP growth based on the data during 1978-2000[21]. Lin (2001) applied Cointegration and ECM Technology for doing further study of the determining factors to China's energy demand [22]. The result showed a long-term equilibrium among the EC, GDP.

The conclusions were inconsistent may due to the differences of the study time, the methods used, the economic level and structure etc. What worth mentioning is that there is no study on the relationship between EC and GDP in Beijing till now and the above conclusions got are inapplicable for Beijing.

This paper studied the cointegration relationships between the total EC and economic growth, industries' EC and VA in Beijing. Then the stability of the cointegration relationships was tested and their impulse response functions and variance analysis were studied. Finally, some rational proposals for energy-saving policy in Beijing were put forward.

2 Relationship Analysis Model

The process for studying the relationship between EC and the economy is first the stationary test of the time series, then GC test, following cointegration test, and finally ECM analysis.

2.1 Stationary Test of Series

ADF (Augmented Dickey-Fuller) and PP (Phillips and Perron) tests are used to test the stationarity. We test the null hypothesis, H_0, series y_t being non-stationary. The tests are based on the following model,

$$\Delta y_t = \alpha + \beta t + \rho y_{t-1} + \sum_{i=1}^{k} \xi_i \Delta y_{t-i} + \varepsilon_t \quad (1)$$

where α, β, ρ, ξ are coefficient and ε error term; k is the appropriate lag length. Information criteria like AIC and BIC are used to select k. If the ADF test value is bigger than the critical value at a defined level of significance, it represents the acceptance of the null hypothesis of non-stationary; otherwise, it represents the rejection of the null hypothesis of non-stationary and y_t is stationary.

2.2 Granger Causality Test

The basic ideology of GC test supposes that if the movement of variable x_t is the causation of the movement of variable y_t, the variable x_t leads y_t, and x_t is significance for forecasting y_t. It can increase the explaining ability when introducing the lagged x_t into y_t forecasting. Normally, the model used is equation (2),

$$y_t = c + \sum_{i=1}^{r} \alpha_i y_{t-i} + \sum_{j=1}^{q} \beta_j x_{t-j} + \varepsilon_t \quad (2)$$

where c is constant; q and r are the lag length of x_t and y_t respectively. The null hypothesis of F test is $\beta_j = 0$ (j=1 , 2 , … , n) . If the F-statistics value is bigger than the critical value, it represents rejection of the null hypothesis, in other words, x_t Granger causes y_t.

2.3 Cointegration Test

There are two kinds of cointegration test. One is based on regression residual, such as DF test and ADF test. Another is based on regression coefficients, such as Johansen test. This paper adopts Johansen Cointegration test [23].

2.4 Error Correction Model (ECM)

The basic form of ECM is as follows.

$$y_t = \beta_0 + \beta_1 \chi_t + \beta_2 y_{t-1} + \beta_3 \chi_{t-1} + \varepsilon_t \quad (3)$$

After being transformed, model (3) can be turned into equation (4):

$$\Delta y_t = \beta_0 + \beta_1 \Delta \chi_t + (\beta_2 - 1)\{y - \frac{\beta_1 + \beta_3}{1 - \beta_2} \chi\}_{t-1} + \varepsilon_t \quad (4)$$

The equation (4) is the ECM, where $y - \frac{\beta_1 + \beta_3}{1 - \beta_2} \chi$ is the Error Correction term marked z. It relates the change in *y* to the change in *x* and the past period's disequilibrium.

The equation (4) can be shortened to:

$$\Delta y_t = \beta_0 + \beta_1 \Delta \chi_t + \lambda z_{t-1} + \varepsilon_t \quad (5)$$

Finally, stability test of the energy and economy cointegration model should be done. The relationship of EC and economic growth should also be studied based on the generalized impulse response function and variance analysis.

3 Results and Discussions

3.1 Data Sources

This paper is based on the data of gross VA and EC and that of various industries in Beijing during 1978-2006, and the data are collected from "Beijing's Statistics Year-book" [24]. In order to make the series comparable, the nominal VA is deflated by the VA deflator (1978=1) and the real VA is used for analysis.

3.2 Causality Analysis

In order to exclude the heterosedasticity of the series, we use the logarithm of the variables, LG_i (i =0, 1, 2, 3, representing the logarithm of gross VA, primary, secondary and tertiary industrial VA respectively) and LQ_i (i =0, 1, 2, 3, representing the logarithm of gross EC, primary, secondary and tertiary industrial EC respectively).

3.2.1 Stationarity Test

ADF tests are used to test the stationarity of series. Table 1 shows the results.

Table 1 ADF tests for unit roots of LG_i , LQ_i(i=0, 1, 2, 3)

Variables	Level	First differences	Second differences
LG0	-2.663	-4.861***	
LQ0	-2.960	-4.424***	
LG_1	-2.413	-2.357	-4.369***
LQ_1	-3.179	-5.739***	
LG_2	-4.016**		
LQ_2	-2.933	-1.611	-10.208***
LG_3	-1.440	-7.306***	
LQ_3	-2.918	-15.550***	

Notes: *** Represents the rejection of the null hypothesis of nonstationarity at 1% level of significance.
**Represents the rejection of the null hypothesis of nonstationarity at 5% level of significance.

From Table 1, we can conclude that LG_2 is I (0), LG_1 and LQ_2 are I (2) and other series are all I (1). It also means LG_0 and LQ_0, LG_3 and LQ_3 integrated of the same order.

3.2.2 Granger-Causality Tests

After we test the series' stationarity, we will study the GC relationship based on the GC test. The results of causality tests are presented in Table 2.

Table 2 Results of GC tests on LG_i, LQ_i(i=0, 3)

Null hypothesis	Lag length	F value	Adjoint probability
LQ_0 is not the causation of LG_0	1	1.25	0.275
LG_0 is not the causation of LQ_0	1	10.26	0.004***
LQ_3 is not the causation of LG_3	3	5.74	0.027**
LG_3 is not the causation of LQ_3	3	35.82	0.0001***

Note: ***, ** Represents 1%, 5% level of significance respectively.

The results detect that the one-way GC are running from the gross VA to EC. Namely, economic development is the main reason of EC growth in Beijing. For the tertiary industry, there exists bidirectional GC between VA and EC.

3.2.3 Cointegration Test and Error Correction Model

Since LG_0 ~ I(1) and LQ_0 ~ I(1), Johansen tests method is used to test the cointegration of LG_0 and LQ_0. Results are presented in Table 3.

Table 3 Johansen's cointegration tests on LG_0 , LQ_0

Eigen value	Likelihood Ratio	5% Critical value	Number of Cointegration
0.607	34.122	20.262	none***
0.349	10.749	9.165	1 at least

Note: *** Represents 1% level of significance.

From Table 3, we can conclude that LG_0 is co-integrated with LQ_0 and establish the ECM. The cointegration is:

$$LQ_0\text{-}0.427LG_0\text{ -}5.319=0 \quad (6)$$

ISSN: 1790-5079

From the equation (6), we can see that when the gross VA rises 1%, the EC will grow 0.427%.

We also can get the cointegration relationship of EC and VA for the tertiary industry based on the same theory:

$$LG_3\text{-}0.970LQ_3\text{+}0.793\text{=}0 \qquad (7)$$

From the equation (7), we can see that there is a mutual promotion between EC growth and VA growth in tertiary industry. When the EC grows 1%, the VA will rise 0.97%.

3.2.4 Stability Test of Cointegration Models

The stability test is done based on the recursive regression. Figure 1 shows the result of stability test on the cointegration model of LG_0 and LQ_0. Figure 2 shows the result of stability test on the cointegration model of LG_3 and LQ_3. From the figures, we can get the cointegration models are stable.

Figure 1 Recursion residue error of LG_0 and LQ_0 cointegration model

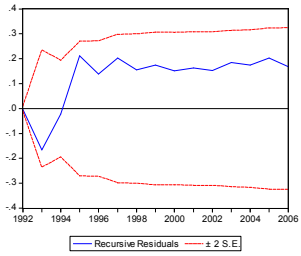

Figure 1 Recursion residue error of LG_3 and LQ_3 cointegration model

3.2.4 Generalized Impulse Response Function Tests and Variance Analysis

Based on the long-run equilibrium relationship of energy and economy, the tests of the generalized impulse response function and variance analysis are done to discuss their dynamic characteristics. Figure 2 and Figure 3 show the curves of impulse response functions. Horizontal axis stands for the lagging number and vertical axis stands for the degree of impulse response.

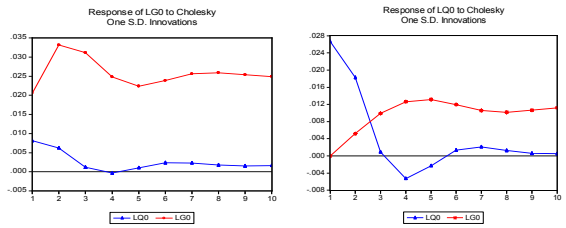

Figure 2 Impulse Response Function Curves of Unit Innovation of LG_0 and LQ_0

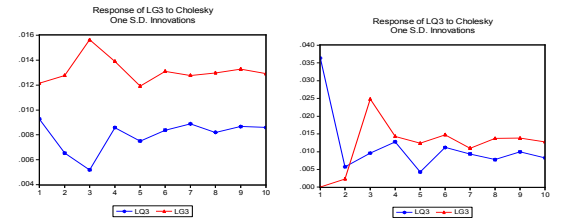

Figure 3 Impulse Response Function Curves of Unit Innovation of LG_3 and LQ_3

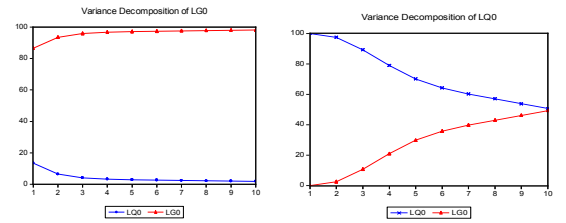

Figure 4 Variance Analysis Curves of LG_0 and LQ_0

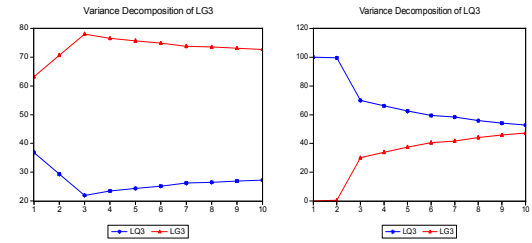

Figure 4 Variance Analysis Curves of LG_3 and LQ_3

It is showed in Figure 2 that LG_0 has a strong impulse response on its standard deviation innovation. But this response becomes weak gradually and it is strongest at the second period. The response of LG_0 on LQ_0's standard deviation innovation is stronger at the beginning, and then it becomes weak at the following periods which prove that there is no Granger causality relationship from LQ_0 to LG_0. LQ_0 has a strong impulse response on its standard deviation innovation and it becomes weak gradually to a steady value. The response to LG_0's standard deviation innovation becomes stronger and stronger to maximum at the third period and changes to a steady value. The influence from LG_0 to LQ_0 is strong. Figure 3 shows that LG_3 and LQ_3 has a strong impulse response on its standard deviation innovation and it becomes weak gradually later to a steady value. LQ_3 affects LG_3 strongest at the third period, and then it becomes weak gradually. The

ISSN: 1790-5079

response of LG_3 of the third period to the standard deviation innovation of LQ_3 is weak in the beginning and becomes stronger gradually. So there is a certain impulse response from LQ_3 to LG_3.

Figure 4 and Figure 5 show the Variance Analysis Curves. The result of forecasting variance analysis of LG_0 and LQ_0 show that the growth of LG_0 can be mainly explained by its own innovation whose proportion is 86.55% at lowest. The growth of LQ_0 is affected by LG_0 at almost 50% finally. The result of forecasting variance analysis of LG_3 and LQ_3 show that the growth of LQ_3 is both affected by itself and LG_3, and the proportion of LG_3's influence up to 47%. LG_3 affects itself stronger and affects LQ_3 weakly, about 27% finally.

4 Conclusions

Through studying on the cointegration relationship between EC and the economy based on the data of gross VA and EC, and that of various industries during 1978 - 2006 for Beijing, we can make the following conclusions:

(1)Economic development promotes EC growth and the gross VA Granger causes EC. EC has a strong the impulse response to the gross VA.

(2)The relationship between economic growth and EC growth in Beijing is embodied primarily by the tertiary industry, which conforms to the economic characteristics of metropolitan Beijing, and there is a mutual promotion relationship between EC growth and VA growth in tertiary industry.

(3)The economic development and EC are co-integrated in the long term in Beijing, so does in the tertiary industry. The gross EC increases 0.427% with the gross VA's 1% growth. For the tertiary industry, every 1% EC growth can bring about 0.97% VA growth. But the promoting influence is more obvious in economic growth to EC in the tertiary industry than EC to economic growth.

(4)The economic development of Beijing will not have a serious hindrance by restructuring the industrial structure, reducing the proportion of high-energy-consuming industries and implementing the policy of promoting environmental protection.

(5)In order to save energy, optimize energy efficiency and promote sustainable economic development under conditions of limited resources, Beijing should strengthen the secondary industry EC management, optimize the industrial structure, improve the technical level of industrial production, lower the unit EC of industrial products and vigorously develop hi-tech industries such as electronics based on the above analysis.

Acknowledgements

The work described in this paper was supported by research grants from Humanities and Social Science project of the Ministry of Education of China (Project number: 07JA790092) and National Science Foundation of China (70771039, 70671042).

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