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EMPIRICAL ANALYSIS OF REGIONAL ENERGY CONSUMPTIONS AND ECONOMIC GROWTH

FULEI WEI, CAIMEI HU

School of Economic and Management, Heilongjiang Institute of Science and Technology, Harbin 150027, Heilongjiang, China.

ABSTRACT

The relationship between economic growth and energy consumption is one of the hot topics in economic research. There are many literatures concern about this topic from theoretical and empirical viewpoint. This paper applies panel unit root, heterogeneous panel cointegration and production function to investigate the relationship between energy consumption and economic growth within a multivariate framework that includes capital stock and labor input for three regions of China during the period of 1995-2007. The empirical results show that energy consumption has had a significant impact on change in GDP in the three regions. The elastic coefficient of EC is 0.25%, 0.20% and 0.18% in the north region, the south region and the west region respectively. The elastic coefficient of capital stock is 0.58, 0.36 and 0.02, and the elastic coefficient of labor input is 0.11, 0.21 and 0.06 respectively. Furthermore, it gives some suggestions on how to realize win-win situation of economic growth and energy saving and reduction.

Keywords: *Economic Growth, Energy Consumption, Energy Conservation, Regional Economies*

1. INTRODUCTION

The sustainable growth of economic is the representation of the development of a country or region, and it determines the living standard of people in this country or region at some level. It also impacts on the status of the country in world politics and economic activity. So pursuit rapid and stable economic growth is one of the focuses which attract attention of every country. But the factors which affect economic growth are complicated; we must handle the relationships between them properly in order to ensure the sustained and healthy growth of economic. As the material foundation, energy has important impact on the economic growth. So study the relationship between economic growth and energy consumption has significant meaning.

The relationship between economic growth and energy consumption can be divided into four categories based on the direction: unidirectional causality runs from economic growth to energy consumption; unidirectional causality runs from energy consumption to economic growth; none causality and bi-directional causality between them. If there exists unidirectional causality runs from economic growth to energy consumption, and this economic is non-energy-dependent economy, then the negative impact on economic growth that caused by the implementation of energy saving policy will be little, and even none negative impact [1]. If there exists unidirectional causality runs from energy consumption to economic growth, and this economic is energy-dependent economy, then the implementation of energy saving policy will bring negative impact to economic growth [2]. If there is none causality between them, which satisfy the so-called "neutrality hypothesis", then there is no necessary link between economic growth and energy policy [3]. If it exists bi-directional causality between them, then economic growth and energy consumption depend on each other. In order to keep the adaptation of a region’s economic growth and energy consumption, we must acknowledge the relationship between them.

China is in the key stage of industrialization and urbanization. Energy demand is growing and energy is a kind of strategic resource to drive economic development in China. Energy consumption mainly depends on disposable energy. How to achieve a win-win situation of energy conservation and stable development of economy and society has aroused extensive concern in the government and society. China has a vast territory and rich resources, but there is considerable difference in the regional distribution of resources and economic development. Research on the relationship between energy consumption and economic growth from the overall of one country can not explain the real relationship between energy consumption and regional economic growth. So it is necessary to research regional energy consumption and economic development respectively.

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2. LITERATURE REVIEW

After the outbreak of oil crisis in 1970s, foreign literatures about the relationship between economic growth and energy consumption gradually increase. The research in this area can be basically divided into three stages according to research methods.

At the first stage, researches are based on short-term dynamic relationship limited by the statistic method of that time.

As a major industrialized country, the oil crisis had profound influences to United States, so at the beginning the literatures in this area are mainly about United States. The seminal work was done by Kraft, J. and Kraft, A. (1978), they used Sims' causality procedures and found the unidirectional causality running from GNP to energy consumption in USA. And based on this evidence, they got the conclusion that energy conservation policy will not have negative impact on the economic growth of USA [4]. However, Akarca and Long (1980) considered that war, variable discrepency and the time delay from cause to effect also can influent the result of research. They used the same data, but change the time interval into two years, and found that there is no causality between energy consumption and GNP of USA [5]. Yu and Hwang (1984) reexamined the causality between GNP and energy consumption of USA. They found that there is no causal relationship between GNP and energy consumption based on yearly data (1947~1979); but there is unidirectional causality running from GNP to energy consumption based on quarterly data (1973~1981) [6].

As time goes by, the research in this area no longer limited to USA, but extended to other countries and regions. Yu and Choi (1985) extended the research of Yu and Hwang (1984) from two aspects. They examined the causality between GNP and energy consumption of five countries which in different development stage from international perspective, which made the study more generalization. They also analyzed the causality between GNP and different energy consumption (solid fuels, liquid fuels, natural gas, hydro, nuclear and electricity). According to their research, the causality is very sensitive to the sample. They found there is bi-directional causality between GNP and energy consumption in USA, Britain and Poland; unidirectional causality running from GNP to energy consumption in Korea; and unidirectional causality running from energy consumption to GNP in Philippines [7]. Erol and Yu（1987）studied the causality between energy consumption and real income in six industrialized countries (Britain, Germany, Italy, Canada, France and Japan). The result showed that there is no causality between energy consumption and real income in Canada, Britain and France; unidirectional causality running from energy consumption to real income in Germany; and unidirectional causality running from real income to energy consumption in Japan and Italy [8].

The testing methods in previous literatures just describe the short-term dynamic relationship of study object, but can't obtain the long-term equilibrium relationship. And researchers gradually realized the defects of tradition methods as the development of time series analysis methods, so they started to use cointegration test and vector error correction model in the empirical study of the causality between energy consumption and economic growth. Nachane, Nadkarni and Karnik (1988) applied cointegration theory to test the long-term equilibrium relationship between energy consumption and economic growth. They analyzed the data from sixteen countries which include eleven developing and five developed countries, and find different types of causality between energy consumption and GDP for each country [9]. Masih A. M and Masih R (1996) analyzed the cointegration between energy consumption and real income of six Asian countries (India, Pakistan, Malaysia, Singapore, Indonesia and Philippines) using Johansen's multivariate cointegration tests and dynamic vector error correction model. The result revealed that cointegration only exist in India, Pakistan and Indonesia, and in India the unidirectional causality running from energy consumption to economic growth, in Indonesia the unidirectional causality running from economic growth to energy consumption, in Pakistan the causality was bi-directional[10]. Soytas and Sari (2003) researched the causality between GDP and energy consumption in the top 10 emerging markets excluding China and G-7 countries using vector error correction model. In all these countries, both series appear to be stationary in first differences. And there exists a stationary linear cointegration between the variables in seven countries. They found bi-directional causality in Argentina, unidirectional causality running from GDP to energy consumption in Italy and Korea, unidirectional causality running from energy consumption to GDP in Turkey, France, Germany and Japan [11].

Fatai, Oxley and Scrimgeour (2004) analyzed the data of New Zealand, Australia, India, Indonesia, Philippines and Thailand using Engle and Granger OLS approach and the autoregressive distributed

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lag regression approach. They discovered that there exists unidirectional causality running from GDP to energy consumption in New Zealand and Australia; unidirectional causality running from energy consumption to GDP in India, Indonesia; and bi-directional causality in Philippines and Thailand. At last they concluded that reducing of energy consumption has no significant impact on economic growth for industrialized countries based on the result of analysis [12]. Zhiyong Han (2004) conducted research on the relationship between energy consumption and GDP. The research found that during the period form 1978 to 2000 there is causality running between energy consumption and GDP, but lack long-term cointegrated relationship between them [13].

Lee (2005) studied the causality relationship between energy consumption and GDP in 18 developing countries based on data during the period 1975 to 2001. In this literature, it employed the heterogeneous panel cointegration and panel-based error correction models. The result showed that long-run and short-run causalities running from energy consumption to GDP in these countries. And it indicated that energy conservation may have negative effect to economic growth in developing countries [14].

Some researchers think that it's not appropriate just consider two variables in the study of causality between energy consumption and economic growth, because the economic activity refers to many factors. Stern (1993) built a vector auto regression model include GDP, energy use, capital, and labor inputs. And he tested the Granger causality between them by using the data from 1947 to 1990 of USA. He didn't find evidence support the causality between gross energy consumption and GDP, but a measure of final energy consumption adjusted for changing fuel composition Granger cause GDP [15]. Masih A.M and Masih R（1998）analyzed the data of total energy consumption, real income and price level of Thailand and Sri Lanka by using Johansen's multiple cointegration tests and dynamic vector error-correction model. They found cointegration between these variables, and measured the shocks of each variable to others by using impulse response graphs [16]. Stern（2000）extended his previous research(1993) , analyzed the causality of GDP and energy consumption of USA in the post-war period by single equation static cointegration and the multivariate dynamic cointegration, and found there were significant cointegration between GDP, capital, labor, and energy [17]. Asafu-Adjaye (2000) analyzed the causality between energy consumption, energy price and economic growth for India, Indonesia, Philippines and Thailand by using cointegration and error correction model. The result indicated that unidirectional causality running from energy consumption to economic growth in India and Indonesia, and bidirectional causality in Thailand and Philippines. At the same time energy consumption, economic growth and energy prices were mutually causal in Thailand and Philippines [18]. Wankeun Oha and Kihoon Lee (2004) constructed a multivariate model include capital, labor, energy consumption and GDP, and analyzed the data of Korea form 1981 to 2000 by VECM. The result suggested that no causality between energy consumption and GDP in the short run, but unidirectional causality running from GDP to energy consumption in the long run [19]. Lee & Chang (2008) applied heterogeneous panel cointegration and panel-based error correction models to re-investigate co-movement and the causal relationship between energy consumption and real GDP for 16 Asian countries during the period from 1971 to 2002 within a multivariate framework that includes capital stock and labor input. The empirical results found economic growth and energy consumption lack short-run causality, but exit long-run unidirectional causality running from energy consumption to economic growth [20]. Zhenming Li (2010) applied error correction models to investigate the relationship between energy consumption and GDP for China during the period from 1953 to 2008 within a multivariate framework that includes capital stock and labor input. The empirical results found there is bidirectional causality running between energy consumption and economic growth [21].

The study of the relationship between energy consumption and economic growth is one of the focuses in economic area. Through the review of literatures, we can find in different countries or regions the relationship between these two variables is different, even for the same country or region the relationship may also different in different development stage. In addition, according to different data and methods, the research result may be different too. But there is some type of relationship between energy consumption and economic growth for most countries and regions. The research in this area is very important. It can supply meaningful reference to the decision of energy policy of government.

3. EMPIRICAL ANALYSIS

Research on the relationship between energy consumption and economic growth has already

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made many valuable achievements in China. Differing from previous study, based on the inter-provincial panel data during the period of 1995～2007, incorporating energy consumption into the production function, this paper has an empirical research on the relationship between energy consumption and economic growth in the areas of the north region, the south region and the west region.

3.1 The Model

Growth theories from the "Harrod–Domar" growth model, Characterized by "knife edge" analysis, to the well known theory referred to as the "Solow-Swan"growth model, claim that energy has nothing to do with the production function. But energy economists view energy as a crucial production factor in the production process in that it can be directly used as a final product. Pokrovski (2003) advocates that energy-driven equipment functions in lieu of manual labor, and as a result the production of output is determined by capital stock, labor and energy service [22]. The new growth theory internalizes technology into production functions. According to Thompson (2006), energy input generates work that moves or transforms matter and physical capital and combines various energy inputs into an aggregate [23]. In this paper we consider energy as a required input in the productive process, and employ the function (1).

$$Y = AK^{\alpha} L^{\beta} E^{\gamma} e^{\mu} \qquad (1)$$

Where Y is the aggregate output represented by GDP, A is technological progress coefficient； K is capital stock； L is labor input； E is energy consumption ； α , β , γ represent elasticity coefficient of capital, labor and energy consumption respectively. μ is stochastic disturbance. To eliminate the heteroscedasticity that might exist between variables we apply a logarithmic transformation as function (2).

$$\ln Y = \ln A + \alpha \ln K + \beta \ln L + \gamma \ln E + \mu \qquad (2)$$

3.2 Region Division and Data Description

3.2.1 Region division

In this paper we merge eight economy regions into three regions, which are the north region, the south region and the west region. The northeast, the northern coast and the middle Yellow River are merged into the north region, including nine provinces and two cities. They are Liaoning, Jilin, Heilongjiang, Beijing, Tianjin, Hebei, Shandong, Shaanxi, Shanxi, Henan, and Inner Mongolia. East coast, south cost and middle Yangtze River are merged into the south region, including nine provinces and one city. They are Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Hainan, Hubei, Hunan, Jiangxi and Anhui. The northwest and southwest are merged into the west region, including five provinces, four and autonomous regions and one city.

3.2.2 Data description

Economic growth: In this paper GDP is chosen to represent economic growth. Data of annual GDP (1994=100) by region comes from China statistical yearbook 2009. The unit is 100 million RMB.

Capital stock: In this paper stock of physical capital is chosen to represent capital stock. We adopt perpetual inventory method which is generally used in academic world to calculate stock of physical capital, as in (3).

$$K_t = K_{t-1}(1-\delta_t) + I_t \qquad (3)$$

Where K_t is stock of physical capital in time t . δ_t is depreciation rate in time t . I_t is gross fixed capital formation in time t . We use the research result of Jun Zhang (2004) for reference and choose 9.6% as the depreciation rate. Annual gross fixed capital formation is converted into actual value using price indices of investment in fixed assets (1994=100). The data of gross fixed capital formation and price indices of investment in fixed assets by region are from China statistical yearbook 2009. The unit is 100 million RMB.

Labor input: In this paper is number of employed persons at year-end by three strata of industry chosen to represent labor input. The unit is 100 million persons. The data are form China statistical yearbook 2009.

Energy consumption: Total energy consumption by region is chosen to represent energy consumption. The unit is million ton standard coals. The data from 1996 to 1999 are from China energy statistical yearbook 1997~1999. The data from 2001 to 2003 are from China energy statistical yearbook 2004. The other data are form China energy statistical yearbook 2008.

Missing values: Price indices of investment in fixed assets in many regions are missing. Many researchers substitute it with retail price index, and many others substitute it with data of neighborhood region with similar economic performance. In this paper price indices of investment in fixed assets of Hainan province from 1995 to 1999 are substituted by retail price index. Data of Guangdong province from 1995 to 1999 are substituted by data of Fujian province. The number of employed persons at year-end by three strata of industry in 2006 is substituted by the number of employed persons at year-end in urban and rural areas. Energy consumption data of

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Hainan province in 2002 and Ningxia hui nationality autonomous region from 2001 to 2002 are the moving average of previous years.

3.3 Empirical Analysis

3.3.1 Stationary tests

To avoid the spurious regression problem in panel data model and make sure the effectiveness of estimation, it must test the stationary of panel series. So before conducting the cointegration analysis of the panel data, we conduct a panel unit root test. We adopt four different tests, namely LLC test, IPS test, Fisher-ADF test and Fisher-PP test. In addition to these, we adopt the procedures of Maddala and Wu (1999) who propose a more straightforward, nonparametric unit root test and suggest using the Fisher-ADF and Fisher-PP statistics [24]. Table 1 to 4 shows the panel unit root test results of the north region, the south region and the west region respectively at the 1% or 5% significance level.

The panel unit root test results show that at the 1% or 5% significance level labor series are $I(0)$ process, others are $I(1)$ process. As a general rule, if series are integration in the same order, cointegration test can be conducted. When the number of variable is more than two, that is to say when the number of independent variables is more than one, this term can be relaxed. When the integration order of dependent variable is not higher than any independent variables, or when the order of independent variables is higher than the dependent variables, there must be at least two independent variables the integration order of which is higher than the integration order of dependent variables, cointegration test can be conducted.

3.3.2 Cointegration test

Cointegration test is to investigate the long-term equilibrium relations between variables. In this paper we conduct cointegration test using the heterogeneous panel cointegration test developed by Pedroni (1999) which allows for cross-sectional interdependence with different individual effects [25]. According to Pedroni there are two types of residual-based tests. As for the first type, four tests which are distributed as being standard normal asymptotically and are based on pooling the residuals of the regression for the within-group; they are the panel v -statistic, panel ρ statistic, panel PP-statistic and the panel ADF-statistic. With the second type, three tests are also distributed as being standard normal asymptotically but are based on pooling the residuals for the between-group; they are the group ρ -statistic, group PP-statistic and the group ADF-statistic [20]. Test results are showed in table 4.

Table 1 Panel Unit Root Test Results Of The North Region

	△LN(GDP) (C,T,0)	△LN(K) (C,T,0)	LN(L) (C,0,0)	△LN(E) (C,T,0)
LLC test	-7.85*** (0.00)	-4.89*** (0.00)	-9.41*** (0.00)	-9.50*** (0.00)
IPS test	-2.89*** (0.00)	1.07 (0.86)	-5.61*** (0.00)	-3.54*** (0.00)
Fisher-ADF test	43.27*** (0.00)	15.44 (0.84)	72.37*** (0.00)	47.23*** (0.00)
Fisher-PP test	133.34*** (0.00)	49.18*** (0.00)	75.27*** (0.00)	109.25*** (0.00)

Notes: *** indicates statistical significance at the 1% level. Probabilities for Fisher-type tests were computed by using an asymptotic χ^2 distribution.

Table2 Panel Unit Root Test Results Of The South Region

	△LN(GDP) (C,T,0)	△LN(K) (C,T,0)	LN(L) (C,0,0)	△LN(E) (C,T,0)
LLC test	-5.70*** (0.00)	-4.36*** (0.00)	-8.36*** (0.00)	-6.65*** (0.00)
IPS test	-1.98** (0.02)	0.63 (0.74)	-5.10*** (0.00)	-2.57** (0.01)
Fisher-ADF test	33.10** (0.03)	18.02 (0.59)	62.41*** (0.00)	37.89** (0.01)
Fisher-PP test	79.85*** (0.00)	75.06*** (0.00)	101.00*** (0.00)	114.79*** (0.00)

Notes: *** and ** indicate statistical significance at the 1% and 5% level, respectively.

Table 3 Panel Unit Root Test Results Of The West Region

	△LN(GDP) (C,T,0)	△LN(K) (C,T,0)	LN(L) (C,0,0)	△LN(E) (C,T,0)
LLC test	-5.08*** (0.00)	-146.99*** (0.00)	-4.95*** (0.00)	-8.34*** (0.00)
IPS test	-2.13** (0.02)	-52.45*** (0.00)	-2.94*** (0.00)	-3.64*** (0.00)
Fisher-ADF test	28.75*** (0.03)	29.33*** (0.02)	35.18*** (0.00)	39.22*** (0.00)
Fisher-PP test	112.96*** (0.00)	48.09*** (0.00)	73.21*** (0.00)	73.22*** (0.00)

Table 4 Panel Cointegration Test Results

	The north region	The south region	The west region
Pedroni Panel v- Statistic	-4.43*** (0.00)	2.10** (0.02)	0.66 (0.25)
Pedroni Panel rho- Statistic	2.095 (0.98)	-2.26** (0.99)	1.66 (0.95)

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Pedroni Panel PP- Statistic	-1.61** (0.05)	-1.79** (0.04)	-2.49** (0.01)
Pedroni Panel ADF- Statistic	-4.89*** (0.00)	-2.88*** (0.00)	-2.50** (0.01)
Pedroni Group rho- Statistic	3.24 (0.99)	3.71 (0.99)	2.76 (1.00)
Pedroni Group PP- Statistic	-3.81*** (0.00)	-1.65** (0.05)	-4.50** (0.01)
Pedroni Group ADF- Statistic	-4.32*** (0.00)	-4.18*** (0.00)	-2.98*** (0.00)

Notes: The italic standards for weighted static.

Pedroni（1999）points out that compared with other statistics, Panel ADF statistic and Group ADF statistic have a comparative advantage in terms of small sample size. So for small sample size, mainly judge by these two statistics to draw conclusions. According to table Ⅳ, panel data of the three regions all pass the test at the 1% or 5% significance level. The null hypothesis that there is no cointegration is rejected. Generally speaking, GDP, stock of physical capital, labor and energy consumption move together in the long-run. That is to say, there is a long-run steady state relationship between energy consumption and GDP for a cross-section of three region economies after allowing for the region-specific effects. The nest step is to estimate this relationship.

3.3.3 Regression

Utilize Hausman test to determine cross-section random effects. From table 5 we can see the null hypothesis that there is cross-section random effect is rejected at the 1% or 5% significance level. So we construct a fix effect model.

Use the OLS technique for heterogeneous cointegrated panels to determine the long-run relationship. GDP is the dependent variable. Table 6 provides the test results of the three regions.

Table 5 Hausman Test Results

cross-section random effect	The north region	The south region	The west region
Chi-Sq statistic	62.89	146.15	36.82
Chi-Sq. d.f.	3	3	3
Probability	0.00	0.00	0.00

Table 6 OLS Estimate Results

Variables	The north region		The south region		The west region	
	coef.	T stat.	coef.	T stat.	coef.	T stat.
Ln(K)	0.58	7.83	0.36	6.41	0.02	1.54
Ln(L)	0.11	2.53	0.21	3.84	0.06	1.16
Ln(E)	0.25	3.73	0.20	2.81	0.18	3.72
C	0.60	0.87	2.40	2.70	5.62	10.96
R^2	0.995		0.997		0.96	

3.3.4 Analysis of the results

From Table 6 we can find that in the north region and the south region all of the coefficients of EC, K and LB are statistically significant at the 5% level, and the effect is positive. Although in the west region, the coefficients of K and LB are not significant at the 5% level, but the impact of K and LB on economic growth is an acknowledged fact. Energy consumption has had a significant impact on change in GDP in the three regions. The elastic coefficient of EC is 0.25%, 0.20% and 0.18% respectively. Implicit here is that a 1% increase in energy consumption leads to a 0.25%, 0.20% and 0.18% increase in real GDP. Energy consumption has the greatest contribution to economic growth in the north region. This is consisting with the actual circumstance in the north region. The north region is abundant in energy resources, such as coal, oil and gas. Shanxin, Shaanxi, Inner Mongolia and Heilongjiang are important coal supply bases of China. Songliao, Erdos and Daqing are important oil supply bases. High energy-consuming industries are important impetus to push economic development in the north region. The west region is also abundant in energy resources, but the contribution of energy consumption to economic growth is smallest. Because the industrialization level is comparatively low and is shortage of capital and technology, abundant energy resources have not play a big role in the economic development. By estimation, energy consumption elastic coefficient of EC is 0.20 in the overall level of China, which is basically consistent with 0.19 estimated by Lee (2010) for OECD countries. The elastic coefficient of K is 0.58, 0.36 and 0.02 and the elastic coefficient of LB is 0.11, 0.21 and 0.06 respectively. The contribution of capital to economic growth in the north region is bigger than in other regions. The contribution of labor to economic growth in the south region is bigger than in other regions. This is because capital-intensive heavy industries are mainly located in the north region, such as the northeast old industrial base and labor-intensive industries are mainly located in the south region, important exports industries such as

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textile industry and toy industry mainly located in this region.

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