

A Research on Aggregate and Structure Relationship Between Energy Consumption and Economic Growth of the Northeastern Provinces in CHINA

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Abstract—This paper studies the aggregate and structural relationship between energy consumption and economic growth of three northeastern provinces in CHINA using the grey relational models. And result shows Ji Lin province exists the strongest correlation between energy consumption and economic growth, but its economic growth has the lowest dependence on energy consumption in all three provinces. which means that the energy consumption of Ji Lin province contributes more to the economic growth than that of the other two provinces, Hei Long Jiang province has the highest dependence of economic growth on energy consumption. Finally we put up with some suggestions that the short-term dependence on energy consumption in economic growth should not be ignored. And each province should make full of comparative advantages in energy, strengthening exploitation and cooperation in energies .

Keywords-economic growth;energy consumption; grey relational model

1. Introduction

The role of energy in economic growth has long been a controversial topic in economic literature. From traditional neo-classical growth model to contemporary economic growth model, energy is seen as intermediate inputs in production whereas land, labor and capital as basic factors., But there are other energy economists who regard energy as a crucial factor of production, because it can directly be used to produce a final product. Therefore, according to this point of view, the economies heavily dependent on energy use will be significantly affected by changes in energy consumption (Cleveland et al., 1984, among others). Beaudreau (1995) criticizes the traditional growth model for treating energy as a secondary factor and points out that production is not possible without energy use.

The study on the causal relationship between energy consumption and economic growth has been examined extensively in the literature since the seminal work of Kraft and Kraft (1978), who found evidence of a unidirectional causality running from *GNP* to energy consumption in the US. However, when using the same time series datum and shorter sample period, studies conducted by Akarca and Long (1979, 1980) on the causal relationship between energy consumption and *GNP* for the USA, failed to confirm Kraft and Kraft's (1978) findings, which mean that the empirical results between energy consumption and economic growth may be influenced by different sample period selected. Yu and Jin (1992) did not find long-term equilibrium relationship between energy consumption and economic growth in the *US* using seasonal datum from 1974 to 1990 and *E-G* two-stage procedure proposed by Engle and Granger (1987).Stern (2000) further investigated the *US* case using multivariate co-integration tests, and the long-run co-integrated relationships were observed between energy use and *GDP*. Hondroyannis et al. (2002) included price development as an index for

economic efficiency in Greece, and co-integration was found within a multivariate system. Lee (2005), while examining the relationship between energy consumption and *GDP* in developing countries, found that energy consumption Granger-causes economic growth in the corresponding countries. Soytas and Sari (2007) found unilateral Granger causality running from electricity consumption to output in Turkish manufacturing industry. Lee (2005), while examining the relationship between energy consumption and *GDP* in developing countries, found that energy consumption Granger-causes economic growth in the corresponding countries. Soytas and Sari (2007) also pointed out that different countries have different energy consumption patterns and various sources of energy. Hence, different sources of energy may have varying impacts on the output of an economy.

Many studies have examined the causal relationship between the two variables in China by applying time-series analysis and other methods. However, the empirical evidence from these studies lacks consensus. Lin Boqiang (2003a,2003b) examined the relationship between electricity consumption and economic growth, which reveals a long-term co-integration equilibrium between *GDP*, capital, human capital and electricity consumption. Han Zhiyong (2004) analyzed the *GDP* time series data from 1978 to 2000 and the gross data on energy consumption, which concluded that there is no long-term equilibrium between energy consumption and *GDP*, but there is bilateral causality between them. Using *E-G* two-stage model, Ma Chaoqun (2004) analyzed the annual data from 1954 to 2003, which concluded that there is a long-term equilibrium between *GDP* and total energy consumption and coal consumption, but there is no co-integration between petroleum, gas and hydropower. And he also concluded that there is a bilateral causality between *GDP* and total energy consumption with Granger test but without stability test. From the perspective of the relationship between economic growth, the fixed asset investment in energy sector and energy consumption, Liu Xiaoli & Lu Fengjun (2007) examined the relationship between energy consumption and economic growth with Granger causality test and vector error correction model on the basis of the data on China's *GDP*, energy consumption and the fixed asset investment. They concluded that in the short run the fixed asset investment in energy sector has positive impact on economic growth, but there is no long-term equilibrium between them. And there is not only a co-integration between energy consumption and *GDP* but also a unidirectional Granger causality from *GDP* to energy consumption. In terms of long-term equilibrium, if *GDP* increases by 1%, energy consumption will increase by 1.458%. Therefore, under the condition of energy scarcity, industrial structure should be optimized in order to conserve energy and promote sustainable economic development.

In terms of test methods, most researches are based on *E-G* two-stage method or Johansen co-integration test to examine the short-term and long-term correlation between energy consumption and economic growth, which is followed by a unilateral or bilateral causality between them. The problem that should be pointed out is that Johansen co-integration test is maximum likelihood estimation on the basis of regression coefficients and it is more efficient than *E-G* two-stage method but it presupposes $I(0)$ or $I(1)$ and if such condition can't be met Johansen co-integration test can't be used; on the other hand, causality test is sometimes not only sensitive to exogenous variables and lag length but also sensitive to the length of sample period (such as Kraft(1978), Akarca and Long(1980))

Most empirical researches focus on the relationship between national economic growth and energy consumption, and very few researches pay attention to the provincial level and analyses on the difference in energy demand between different provinces. While this paper pay attention to the provincial level and analyses on the difference in energy demand between different provinces.

The paper is organized as follows. Section II provides the preliminary analysis of the economic growth and energy consumption of the three northeastern provinces. Section III provides the Gray relational analysis on the economic growth and total energy consumption in three northeastern provinces. Section IV provides Conclusion.

2. The preliminary analysis of the economic growth and energy consumption of the three northeastern provinces

The three northeastern provinces are very important bases for heavy industry, machinery and equipment manufacturing and grain production in China. All three provinces are rich in coal, and in particular

Heilongjiang is very rich in coal and petroleum and is an exporter of energy. But the economic structure and supply and demand of energy in all three provinces are very different.

TABLE I. THE CONTRIBUTION OF THE THREE INDUSTRIES TO ECONOMIC GROWTH IN THE THREE NORTHEASTERN PROVINCES, 1991-2009

	Primary Industry	Secondary Industry	Tertiary Industry
Heilongjiang	14.88	52.86	32.27
Jilin	12.29	48.42	39.94
Liaoning	7.04	51.06	37.35

Source: the Statistical Yearbook of the three provinces 1980-2010.

From the table, it can be seen that in all three provinces the primary and secondary industries in Heilongjiang province makes the greatest contributions to economic growth, which shows that the agricultural and industrial development is relatively advanced but its tertiary industry contributes the least to economic growth; the tertiary industry in Ji Lin province makes the greatest contributions to economic growth, which shows that its service industry is very strong, but the secondary industry contributes the least to economic growth; in Liao Ning province's agriculture contributes the least to economic growth, and the secondary industry and the service industry make less contributions to economic growth than those of Heilongjiang and Jilin provinces respectively.

The differences in industrial structure and resource endowment result in the differences in the mode and path of economic growth in the three provinces. We can see the differences in economic growth and energy consumption in the three provinces from the following two charts.

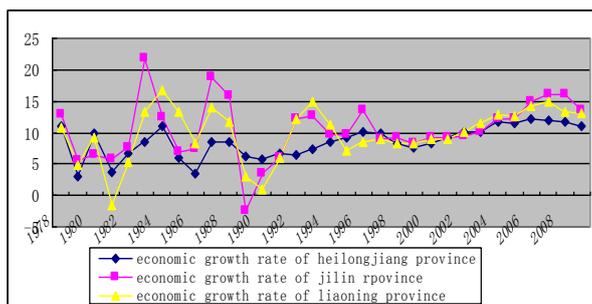


Fig 1.the economic growth rate of the three northeastern provinces;source: the statistical yearbook of the three provinces,1980-2010.

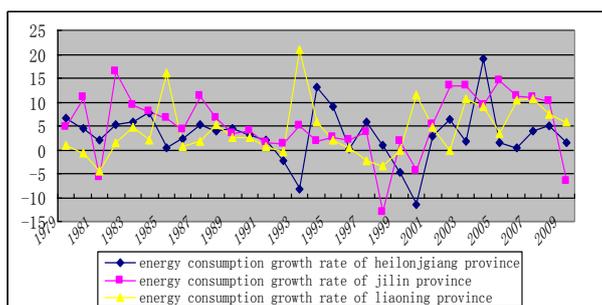


Fig 2.the growth rate of energy consumption in the three northeastern provinces.

In terms of economic growth rate, Heilongjiang province is relatively stable, while Jilin and Liaoning provinces fluctuated drastically before 1993. With regard to the contribution of different industries to economic growth, the fluctuation of the secondary industry in Ji Lin and Liao Ning provinces resulted in the corresponding fluctuation in economic growth before 1993, which also showed that in Ji Lin and Liao Ning provinces , particularly in Liao Ning province there was a serious imbalance between light industries and heavy industries. The lesser fluctuation in Hei Long Jiang province mainly resulted from the leveling effect of the agriculture sector and the rich energy endowment.

From the perspective of energy consumption, although the economy of Liao Ning and Ji Lin provinces fluctuated dramatically before 1993, the energy consumption remained relatively stable, which shows that

after opening up to the world the economy in both provinces grew rapidly from a low starting point, on the other hand energy consumption would easily affect the economic fluctuation of the two provinces. However, from 1994 to 2009, the economic growth is relatively stable compared with the previous period, but energy consumption fluctuated drastically, which shows that the economic growth in this period is largely driven by large amount of energy consumption. Next a thorough analysis on the relationship between energy consumption and economic growth will be done with the Gray relational model.

3. The gray relational analysis on the economic growth and total energy consumption in three northeastern provinces

3.1. Data source

The econometric analysis in this paper draws upon the annual data from 1978 to 2009 and includes two variables: regional *GDP* and regional total energy consumption. In order to eliminate the effects of inflation, this paper uses 1978 as the base year, and energy consumption is calculated according to the method in the Chinese Statistical Yearbook. Energy source includes coal, crude oil and refined oil, electricity, but not includes low-calorie fuel, bio-energy and solar energy.

In this paper, *HE* and *HY* is the logarithmic value of energy and *GDP* of Hei Long Jiang province; *JE* and *JY* is the logarithmic value of energy and *GDP* of Ji Lin province; *LE* and *LY* is the logarithmic value of energy and *GDP* of Liao Ning province. The letter *d* or Δ before variables means the first-order difference of these variables.

3.2. Unit root test and causality analysis

this paper uses *PP* unit root test to test all variables and their first-order difference in order to test their stability. The test results are listed in table II.

TABLE II. THE TEST RESULTS OF THE FIRST-ORDER DIFFERENCE OF ALL VARIABLES

	ΔHE	ΔHY	ΔJE	ΔJY	ΔLE	ΔLY
PP test	-4.526 ^a	-1.98	-4.284 ^a	-2.61	-6.265 ^a	-2.708

Note: a, b, c shows that these variables are statistically significant under the significance level of 10%, 5%, and 1%.

The results in table II show that the logarithmic difference sequences of energy consumption are stable, but the logarithmic difference sequences of economic growth in all three provinces are not stable. Therefore the sequences of energy consumption and economic growth are not in the same order, namely they are not the same integration in order. there is no need to perform further analysis, such as co-integration analysis and Granger causality analysis

From the analysis above, it can be seen that there do not exist causality relationship from economic growth to energy consumption in all three provinces. This means that energy resource is not an obvious bottleneck for economic growth in these provinces. In particular, from Figure 1 and Figure 2, it is clear that the economic growth in the three provinces is achieved at the expense of energy consumption after 1993. However, from the following chart(Figure 3) we can see that Ji Lin and Liao Ning provinces suffer energy shortage, because the ratio of energy consumption to production is over 1, and Ji Lin province suffers relatively greater energy shortage; the ratio of energy consumption to production in Hei Long Jiang province is below 1, which means Hei Long Jiang province is an important energy exporter.

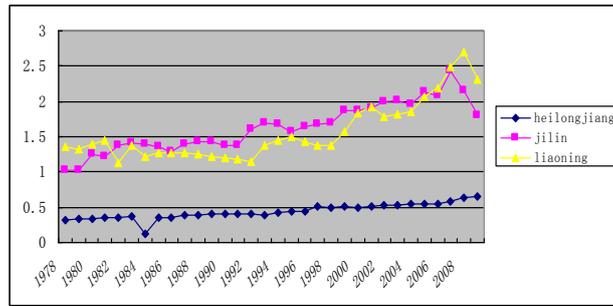


Fig 3. the ratio of energy consumption to production from 1978 to 2009.

According to the comprehensive analysis above, we argue that the three neighboring provinces are different in economic structure but there is complementation between energy consumption and economic growth. For example, Liao Ning province has a comparative advantage in coal, while Ji Lin and Hei Long Jiang provinces have comparative advantages in electricity and petroleum respectively; Liao Ning and Hei Long Jiang provinces have comparative advantages in steel production and machinery manufacturing, while Ji Lin province has comparative advantage in automobile manufacturing. Therefore, we regard the three provinces as an entirety to examine the relationship between energy consumption and economic growth with a grey relational model.

3.3. Introduction to grey relational model

Grey correlation analysis deals with the quantitative comparison of the developmental tendency of a dynamic system, which is a comparison of the geometric relationship of all time series. According to the space theory in mathematics and together with the four principles of normativity, double asymmetry, entirety, and proximity, grey system theory establishes the correlation coefficient between reference series x_0 and series of comparison x_i :

$$\zeta_i(k) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|} \quad (1)$$

Collect the scattered information in the correlation coefficient and average it, then calculate the correlation between x_i and x_0 :

$$r_i = \frac{1}{N} \sum_{k=1}^N \zeta_i(k) \quad (2)$$

In complex systems, if there are many reference series, there will be many series of comparison. In grey system theory, reference series are called parent series or parent factors and series of comparison are called subsidiary series or subsidiary factors. An analysis on a certain parent factor and all subsidiary factors will result in the correlation coefficient. And then the correlation matrix can be established to conduct factor analysis on the system.

3.4. Results of grey correlaiton analysis

Next the correlation matrix of the grey system theory is applied to analyze the correlation between energy consumption and economic growth from 1978 to 2009 in the three northeastern provinces. The logarithmic value of GDP of the three provinces is used as the parent factor; the energy consumption of the three provinces is used as the subsidiary factor; the analysis results is listed in the following Table :

TABLE III. THE RESULTS OF GREY CORRELATON ANALYSIS

GDP energy	Heilongjiang province	Ji Lin province	Liaoning province	horizontal sum
Heilongjiang	0.778	0.48	0.6	1.858
Jilin	0.86	0.51	0.65	2.02
Liaoning	0.71	0.46	0.56	1.73
Vertical sum	2.35	1.45	1.81	

The horizontal sum in matrix R shows the correlation between the energy consumption of a province and the economic growth of all three provinces. $R_i (i=1,2,3)$ stands for the correlation of energy consumption of Hei Long Jiang province, Ji Lin and Liao Ning provinces to the economic growth of all three provinces; Larger value means more significant impact on the economic development. According to the value of R_i , the energy consumption of Ji Lin province has the highest correlation to the economic growth of all three provinces, which means that the energy consumption of Ji Lin province contributes more to the economic growth than that of the other two provinces, followed by Hei Long Jiang and Liao Ning provinces.

The vertical sum in matrix R means the dependence of economic growth on energy resource in all provinces; $R_j (j=1,2,3)$ stands for the dependence of economic growth of Heilongjiang, Ji Lin and Liao Ning provinces on energy consumption; Larger value means higher dependence on energy consumption (i.e. economic growth depends on extensive expansion). In terms of these values, Ji Lin province has the lowest dependence of economic growth on energy consumption of all provinces. Hei Long Jiang provinces has the highest dependence of economic growth on energy consumption.

4. Conclusion

This paper firstly analyse the fundamental condition of three industries and the relationship between energy consumption and economic growth in the three northeastern provinces. We find that Ji Lin and Liao Ning provinces are shortage in energy relative to their energy production, while Hei Long Jiang province is fertile in energy, especially fossil oil and coal. Secondly through unit root test, we do not find long term co-integration relationship between energy consumption and economy growth in these three provinces .and then we builds a grey relational model to examine the general and structural relationship between economic growth and energy consumption in the three northeastern provinces. The findings are as follows: Hei Long Jiang and Liao Ning provinces should develop the tertiary industry quickly, in particular, productive services and modern services industry because this could not only reduce energy consumption, but also improve the value and competitiveness of products.

In a word, economic growth driven by high energy consumption is not sustainable, and the conservation of energy will not have a significant impact on the economy. And each province should make full of comparative advantages in energy, strengthening exploitation and cooperation in energies. Therefore, energy-saving economic development is the optimum choice for the three northeastern provinces.

5. References

- [1] Akarca,A.T.,Long,T, On the Relationship between Energy and GNP: A Reexamination. Journal of Energy and Development 1980. 12(5), pp.326-331.
- [2] Beaudreau, B.C., The impact of electric power on productivity: the case of U.S. manufacturing 1958 - 1984. Energy Economics 1995. 17,pp.231 - 236.
- [3] Chen Yanwu, Wu Chenye., The analysis on the long-term equilibrium of GDP and energy consumption in Taiwan. Journal of Huaqiao University (social sciences edition) 2003, 3,pp.26-31.
- [4] Cleveland, C.J., Costanza, R., Hall, C.A.S., Kaufmann, R.K., Energy and the US economy: a biophysical perspective. Science 225, 1984, pp.890 - 897.
- [5] Engle, R.F., Granger, C.W.J.,. Cointegration and error correction: representation, estimation, and testing. Econometrica 1987. 55, pp.251 - 276.
- [6] Gao Tiemei., Advanced Econometrics. Beijing: Tsinghua University Press .2006,1,pp.234-247.
- [7] Han Zhiyong, Wei Yiming, Jiao Jianling, Fan Ying, Zhang Jiutian., Co-integration and causality analysis on China's energy consumption and economic growth. System engineering 2004,12,pp.19-23.
- [8] Hondroyannis, G., Lolos, S., Papapetrou, E., . Energy consumption and economic growth: assessing the evidence from Greece. Energy Economics 2002, 24, pp.319 - 336.
- [9] Kraft,J.,Kraft,A., . On the Relationship Between Energy and GNP. Journal of Energy and Development 1978,41(3),pp.401-403.

- [10] Lee, C.C., . Energy consumption and GDP in developing countries: a co-integrated panel analysis. *Energy Economics* 2005,27,pp. 415 - 427.
- [11] Lin Boqiang, .*Modern Energy Economics*, Beijing: China Finance and Economics Press 1,2007,pp.15-23.
- [12] Lin Boqiang,.Structural changes, efficiency improvement and predictions on energy demand-the case of Chinese power industry, *Economic Research* 2003(a),5,pp.57-66.
- [13] Lin Boqiang, Power consumption and Chinese economic growth: Research on production function. *Management World* 2003(b)11,pp.18-27.
- [14] Liu Xiaoli, Lu Fengjun,. On China's energy consumption and national economic growth. *Industrial & Technical Economics*2007 9,pp.55-58.
- [15] Ma Chaoqun, Chuhuabin, Li Ke..Co-integration and ECM analysis on China's energy consumption and economic growth. *System engineering* 2004,10,pp.22-27.
- [16] Stern, D.I.,. A multivariate cointegration analysis of the role of energy in the US macroeconomy. *Energy Economics* 2000,22, pp.267 - 283.
- [17] Soytas, U., Sari, R., Ewing, B.T., . Energy consumption, income, and carbon emissions in the United States. *Ecological Economics* 2007,62, pp.482 - 489.
- [18] Yu, Eden S.H. and Been-Kwei Hwang, . The Relationship between Energy and GNP:Further Results. *Energy Economics* 1980, 67(6),pp.186-190.
- [19] Zhao Yu..Statistical analysis on fixed assets investment and economic growth on the basis of ARDL model. *Journal of Lanzhou Business College* 2009, 2,pp.106-110.
- [20] Zhu Tianxing, Gao Lifeng. . Empirical study on industrial investment and economic growth in Liaoning. *Journal of Shenyang University of Technology (social science edition)* 2010, 3,pp.240-243.