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The Sustainable Energy and Economy Development in Northeast China

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With the rapid economic development, the conflicts between energy and economy development gradually emerge. The economic development in Northeast China heavily rely on energy consumption for a long time, to find a more sustainable way for energy and economy development of northeast china, this paper establishes a economic analysis model, this model has a certain evaluation system, use the grey correlation analysis and matrix analysis method. Then, this paper uses the model to analyze the relationship between the energy consumption and industrial structure, and the relationship between energy consumption and economy development, also the influence of energy consumption intensity on economy sustainable development. Finally, through the analysis above, this paper come to the conclusion that the secondary industry is still the main industry in northeast china, and the coal consumption still play a major role in energy consumption, this paper also put forwards some corresponding policy suggestions in the end.

1. Introduction

Energy has been the great factor to promote the economy development in human society through the history, though with the rapid economy development, the conflict between energy consumption and economy development began to emerge. Energy resources shortage, energy price fluctuations, the energy transportation channel competition and the environmental pollution brings by great amount of energy consumption, this problems to a great extent restricts the economy development. Northeast area is the cradle of China's industry, since the reform and opening up, China's economic development heavily depends on large amounts of energy consumption, taking a great price on natural resources and environment, Hao et al (2013) reported. Due to various reasons such as policy and political situation, the economic development in Northeast China heavily rely on high energy consumption, high pollution and low benefit of extensive production model, meanwhile, lacking of long-term perspective of sustainable development, the enterprise managers blindly pursue to increase the production output, make many enterprises increasing the overall energy consumption and utilizing the backup energy resource, to face an energy resource depletion, Hu (2013) reported. Therefore, based on the study of the sustainable development theory, by studying the northeast regional industrial structure change and mutual relationship between energy consumption and the impact on the sustainable economic development, the study has a realistic meaning and significance to the northeast regional energy and economic sustainable development.

2. Indicators and methods of energy and economy analysis

2.1 Indicators of energy and economy analysis

This article is mainly analyzing the relationship of energy consumption and industrial structure, and the influence of both these factors to economic development. This paper selects the industrial structure, total energy consumption, energy consumption structure and energy consumption density as the main analyze indicators. Industrial structure mainly refers to the various industry between and within the industry. From the point of national economy department, this paper mainly studies the agricultural, manufacturing, service industry and so on, and the relationship among them. The total energy consumption is the sum of various energy consumption of a country (a region) during a certain period for manufacturing departments, non-manufacturing departments and the service. It reflects the national (regional) energy consumption level,

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growth rate and the overall quantity index. The amount of energy consumption usually increases along with the development of the economy. The energy consumption structure refers to the different type of energy consumption accounts for the total energy consumption. Its computation formula is: energy consumption structure = one kind of energy consumption/ total energy consumption. Energy consumption intensity refers to the amount of energy use by a unit of gross domestic product (GDP), thus the energy consumption per unit of output. Its computation formula is: energy consumption intensity = the total energy consumption/gross domestic product (GDP).

2.2 Methods of Energy and Economy Analysis

Because of various factors in the system have different physical meanings, this will lead to different data dimensions, which is not convenient to compare or is difficult to get the correct conclusion. Thus the analysis is typically processed to be non-dimensional. Commonly used processing method are the initial value method, average and range relative method. The initial value method is commonly used in economics. Initialization refers to all the data divide the first value, to generate a new sequence, which is the percentage of every value to the first one:

$$X_i' = \frac{X_i}{X_i(l)} = (x_i(1), x_i(2), \cdots, x_i(n)) \quad i = 0,1,2,\cdots,m$$

The correlation degree is actually the geometry of the differences between two sequence curves, so the link degree can be represented by the range of the difference between curves. For a reference X_0 and multiple compare sequences $X_1, X_2, \cdots, X_m$, the correlation degree of reference sequence and compare sequence at different time point is:

$$\gamma_{0i} = \frac{\Delta(\min) + \varepsilon\Delta(\max)}{\Delta_{0i}(k) + \varepsilon\Delta(\max)} = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \varepsilon \min_i \min_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \varepsilon \min_i \min_k |x_0(k) - x_i(k)|}$$

Among the equation above, $k=0,1,2,\ldots,n$; $i=0,1,2,\ldots,m$, ε stands for distinguish coefficient, $0<\sum<1$, generally it will take 0.5. The overall energy intensity is decided jointly by two parts, one is the industrial energy intensity reflecting the industrial energy efficiency, and the other is the industrial structure reflecting the portion of the industry output value in national overall economy. So the energy intensity analysis can be divided into the change of industrial structure and industrial energy efficiency analysis:

The compact of industrial structure change:

$$\frac{\sum_{i=1}^{3} e_i^{n-1}(g_i^n - g_i^{n-1})}{\sum_{i=1}^{3} e_i^n g_i^n - \sum_{i=1}^{3} e_i^{n-1} g_i^{n-1}} \quad i = 1,2,3; n = 1,2,\cdots,N$$

The compact of energy utilization efficiency:

$$\frac{\sum_{i=1}^{3} (e_i^n - e_i^{n-1}) g_i^n}{\sum_{i=1}^{3} e_i^n g_i^n - \sum_{i=1}^{3} e_i^{n-1} g_i^{n-1}} \quad i = 1,2,3; n = 1,2,\cdots,N$$

In the equation above, n-1 represents the base period, e_{ni} and $e_{n-1,i}$ represents the energy consumption density of year n and n-1 of the i industry, g_{ni} and $g_{n-1,i}$ represents the i industry output's proportion in the region's overallproduction in the year n and n-1.3. Northeast China industry structure and energy consumption

3.1 Energy consumption analysis

With the development of Northeastern regional economy, the overall energy consumption, closely related to manufacturing and people's living, is also increasing, especially with the revitalization of the Northeast regional as a country policy, industrial structure and energy consumption also differs from before, this paper selects the industrial structure and energy consumption data of three provinces in Northeast China from 1997 to 2010 (Table 1 and Figure 1). Data of Liaoning, Jilin, Heilongjiang provinces come from their provincial statistical yearbook. This paper uses the grey correlation analysis method to analysis total energy consumption. The total energy consumption as the reference sequence X_0, the output value of the industry structure changes as a comparative sequence:

$$X = \{X(k)_i\}, k = 1997,\cdots,2010, i = 1,2,3.$$

First process the data to be dimensionless, this paper adopts the method of preliminary processing, the new sequence is as follows:

$X_0' = (1,1,006,1,021,\cdots,1.703)$, $X_1' = (1,1,073,1,054,\cdots,1.453)$,
$X_2' = (1,1,052,1,071,\cdots,1.126)$, $X_3' = (1,1,054,1,123,\cdots,1.362)$.

By formula of correlation coefficient (distinguish coefficient 0.5), the calculated results is shown in Table 2 and Figure 2.The calculated correlation degree of X_1, X_2, X_3 and X_0 : $\gamma_1 = 0.720, \gamma_2 = 0.792, \gamma_3 = 0.750$, and this result shows: $r_2 > r_3 > r_1$. Thus the energy consumption most closely related to secondary industry, with lesser correlation of tertiary industry and the minimum correlation of Primary industry. Through the above analysis of industrial structure change and energy consumption with the grey correlation analysis method, the results show the relationship between output of different industry and its energy consumption, the relationship between energy consumption of different industry and total energy consumption. The conclusion is that in the current situation, the Northeast regional secondary industry's impact on energy consumption is still in a primary position, but its influence is gradually diminishing, and the tertiary industry's influence on energy consumption is as same as the secondary industry.

Table 1: Northeast China industrial structure and total energy consumption

Year	Industrial Structure			Total Energy Consumption
	Primary(%)	Secondary (%)	Tertiary (%)	
1999	29.29	53.23	16.84	19574.3
2000	29.32	54.24	16.01	19597.2
2001	29.77	53.97	15.97	19720.8
2002	28.47	53.54	16.58	20004.3
2003	26.50	52.57	16.94	19202.6
2004	25.83	53.07	17.24	18953.1
2005	26.77	52.61	17.25	19068.0
2006	27.52	50.91	17.81	19900.4
2007	27.81	49.75	18.15	20746.7
2008	30.25	49.64	18.18	22508.2
2009	29.69	49.25	18.34	25176.1
2010	29.69	49.12	17.86	28460.5
2011	33.23	47.97	17.90	31065.9
2012	33.97	48.72	17.40	33368.2

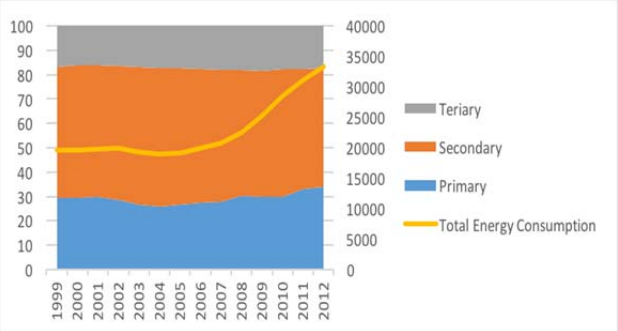

Figure 1: Northeast China industrial structure and total energy consumption

Table 2: Correlation coefficient of different industry and energy consumption

Year	r1	r2	r3
1999	1	1	1
2000	0.8678	0.9233	0.9173
2001	0.9594	0.9094	0.7882
2002	0.9010	0.9020	0.7069
2003	0.9867	0.9004	0.6934
2004	0.9770	0.8637	0.6532
2005	0.9184	1	0.6812
2006	0.8401	0.7920	0.7456
2007	0.6954	0.6450	0.9360
2008	0.6552	0.4900	0.8840
2009	0.6161	0.4990	0.8840
2010	0.5214	0.4324	0.6536
2011	0.5767	0.3719	0.5504
2012	0.5725	0.3563	0.4901

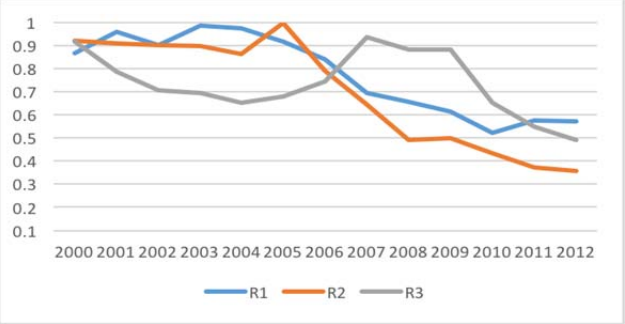

Figure 2: Outputs of five industries in 2000 and 2011

3.2 Industry structure changes

In order to adapt to the requirement of social and economic development, after the reform and opening-up, the industrial structure is in constant changes, along with the change of energy consumption. Various industries have different energy consumption related to their own characteristic, therefore changes in industry structure result the change in energy consumption structure. For changes in industry structure, this paper use matrix analysis method to study its influence on energy consumption structure. This paper selects data of 2000 and 2011 to analyze. The outputs of five different industry of three Northeastern provinces in 2000 and 2011 are shown in Table 3 and Figure 3.

Table 3: Outputs of five industries in 2000 and 2011

Year	Genetic Industry	Manufacturing	Construction	Transportation	Wholesale and Retail
2000	1424.06	3500.17	459.14	541.43	910.55
2011	2569.2	10338.53	1488.21	1220.66	2990.07

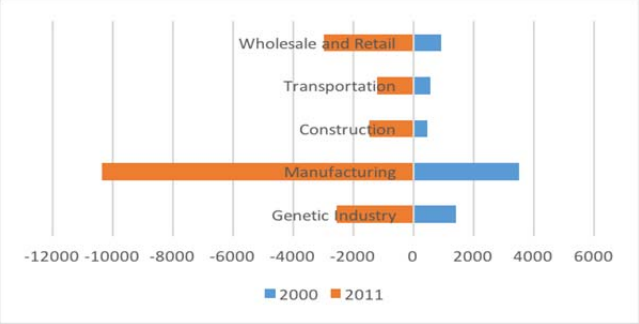

Figure 3: Outputs of five industries in 2000 and 2011

The energy consumption of five different industry of three Northeastern provinces in 2000 and 2011 are shown as below:

Table 4: Energy consumption of five industries in 2000 and 2011

Year		Genetic Industry	Manufacturing	Construction	Transportation	Wholesale and Retail
2000	Coal	772.42	12220.36	35.31	553.48	518.57
	Oil	0	3966.27	0.01	3.20	0
	Natural Gas	0	156.88	0	0	0
	Electricity	27.78	660.18	10.97	34.97	21.70
2011	Coal	203.50	18262.57	34.58	205.05	237.74
	Oil	0	7481.57	1.38	315.35	165.26
	Natural Gas	0	45.44	0	3.75	0.77
	Electricity	55.85	1749.14	24.54	47.19	77.66

Calculate with the data from the charts above to get the three provinces' annual industry output rate matrix B from 2000 to 2011:
B= (6.07 22.67 12.48 8.47 12.63)
And the annual energy consumption rate C:

$$C = \begin{bmatrix} -12.50 & 4.10 & -0.20 & -5.80 & 7.50 \\ 0 & 6.55 & 63.4 & 58.26 & 16.50 \\ 0 & 11.65 & 0 & 0.38 & 7.70 \\ 7.23 & 10.23 & 8.38 & 3.04 & 11.22 \end{bmatrix}$$

From the equation E=CB, the energy consumption structure change matrix E is:
E= (60.175 1641.58 364.58 547.84)
By the calculation results, in Northeast China from 2000 to 2011, the oil consumption changes a lot in energy consumption structure, followed by electricity consumption and coal consumption. It shows that from 2000, the refined oil products is the fastest increasing energy among overall energy consumption, and the genetic industry has the lowest energy demands among all the industries.

3.3 Energy intensity effect

Production process of each industry differs as their energy consumption vary, and this difference will change their energy intensity, this paper use factorization method to analyze the relationship between the change of industrial structure and energy intensity.

By the formula of energy intensity $e = \frac{E}{G}$ inference:

$$e = \frac{E}{G} = \frac{\sum_{i=1}^{3} E_i}{\sum_{i=1}^{3} G_i} = \frac{\sum_{i=1}^{3} e_i G_i}{\sum_{i=1}^{3} G_i} = \sum_{i=1}^{3} e_i g_i \quad i = 1, 2, 3$$

Based on this formula, the overall energy intensity e is determined by two aspects, one is the efficiency of each industry e_i , the other is g_i the proportion of each industry' output in gross national product (GNP).

The result of three provinces' energy intensity effect is shown in Table 5.

Table 5: Energy intensity effect of three provinces

Year	Energy intensity effect					
	Liaoning		Jilin		Heilongjiang	
	structure proportion	efficiency proportion	structure proportion	efficiency proportion	structure proportion	efficiency proportion
2008	0.20	0.80	0.20	0.80	0.18	0.82
2009	0.19	0.80	0.15	0.85	0.13	0.87
2010	0.23	0.77	0.26	0.74	0.25	0.75
2011	0.24	0.76	0.27	0.73	0.26	0.74

By the data in the chart above, the structure proportion and efficiency proportion of three provinces all increase among those years, meaning the changes in industrial structure and increasing efficiency in energy consumption play a positive effect in total energy consumption. From 2006, the structure proportion is smaller than efficiency proportion, and structure proportion is increasing every year, conclusion is that the changes in industrial structure has a more and more strong effect in decreasing the energy consumption year by year.

4. Conclusions and policy recommendations

Through the analysis of energy consumption, changes in industrial structure and energy efficiency effect above, the conclusions are as follows:
The secondary industry is still the main energy consumption industry in Northeast China. Although the proportion of the energy consumption of secondary industry is decline, but the decline range wouldn't change its position of energy consumption among all the three industries. The secondary industry output and energy consumption have the highest degree of correlation. Coal is the main energy source in energy consumption structure. So far, the Northeast region's primary energy consumption is coal, followed by refined oil.The influence of the industrial structure change on energy consumption is increasing every year. Industrial structure change and energy intensity effect relationship analysis shows that since 2005, the structure and efficiency of energy intensity jointly promote the decrease of energy intensity, and the efficiency proportion is bigger than structure proportion, thus among the factors bring down the Northeast China energy consumption, the efficiency of energy usage play a bigger role compare to structure change in industries.

Base on the conclusion above, in order to guarantee the sustainable development of the Northeast regional economy, combined with the study of domestic and foreign energy policies, suggestions are put forward as follows:

Develop clean energy such as electric power, natural gas. Speed up the reform in production process, with modern and scientific electricity usage, eliminate old production technique, will improve the efficiency of industrial power use greatly. Control the total consumption of the coal. Improvements in the coal utilization structure, reform in the industrial structure related to coal, cutting down the overall coal usage in manufacturing and other industries, are the crucial methods to build a sustainable development economy in Northeast China, Zhao and Shi (2013) confirmed. Acceleration of the development and utilization of new energy and renewable energy. Government policy support, such as encouraging scientific research institutes and enterprises cooperation, researching new energy and renewable energy technologies, are important in the process of replacing renewable energy of conventional energy. The technical improvement throughout the industrial structure adjustment and optimization of energy structure in Northeast China industrial has a major effect in energy consumption efficiency improvements. Rely on technological progress to promote industrial structure upgrade, to adjust and optimize the structure of energy consumption. The impact on energy of technological progress, realized through the development of energy-saving products and energy-saving technology applied to reduce energy consumption. Develop alternative resources. Vigorously develop new energy and reduce one-time energy consumption, also a important way to reduce the pressure of existing energy source, Zhang et al (2013) confirmed. Therefore, taking technical innovation as the fundamental method, speeding up technology upgrading, are important in the process of industrial structure adjustment.

Out of data technology and equipment must eliminate as soon as possible, advanced technology and equipment should be put into use immediately, both of this method are the very best and economic way to improve the contribution rate of science and technology, to reduce the energy consumption intensity, in order to achieve the sustainable energy and economic development.

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