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Grey correlation analysis of relationship between economic growth and industrial structure and energy consumption in Shandong province

Hong Meixiang
Heze College, Heze, Shandong Province, 274015, (CHINA)
E-mail : mumeiheyue@163.com

ABSTRACT

Dynamic correlation analysis is carried out for the relationship among the industrial structure, energy consumption and economic growth in Shandong Province with grey correlation analysis method by taking the data of Shandong Province from 2006 to 2012. The results show that the proportion of total energy consumption and tertiary industry in economy is the main factor affecting economic growth of Shandong Province; and another factor is the proportion of energy consumption structure and secondary industry in the local economy. Therefore, in order to realize healthy and benign sustainable development of economy in Shandong Province, Shandong Province must first start with improving energy efficiency and adjusting and upgrading industrial structure, vigorously developing green and low carbon economy, forming reasonable energy consumption structure and realizing harmonious development of society and economy.

KEYWORDS

Economic growth; Industrial structure; Energy consumption; Grey correlation analysis.

INTRODUCTION

Since 2012, China's GDP growth has been slowing down and a lot of economic problems are left over by rapid economic development in the past 30 years and more, especially irrational industrial structure and energy consumption structure. Excessive energy consumption causes serious environmental pollution and ecological crisis and makes the per capita share of resources decline rapidly, seriously damaging healthy development of the economy. At the same time, along with the acceleration of industrialization and urbanization, energy shortages will surely become a bottleneck restricting China's economic growth [1]. Thus, under the condition of a limited amount of energy and increasing need of energy in economic growth, it is urgent to clarify the relationship among industrial structure, energy consumption and economic growth and explore the way and method to change energy use mode and improve energy efficiency through adjustment and upgrading of industrial structure in order to promote sustainable economic development.

As an important production factor to realize economic growth, energy has always been one of the strategic focuses of economic development and plays a vital role in the economic development [2]. As a large and strong province in national economic development, Shandong Province is in a period of rapid development of urbanization; in recent years, it maintains a relatively rapid growth in social economy and realized total local output value of 5001.324 billion yuan in 2012. Rapid economic development also results in increasing energy demand, total energy consumption of Shandong Province reached 376.5 million tons of standard coal and energy consumption per unit of output value was 0.75t standard coal/ten thousand yuan in 2012. Large energy consumption thus has resulted in more serious environmental pollution, natural ecosystems have been seriously damaged and people's health is threatened. Given this, current extensive investment-based growth model must be changed as soon as possible and it is bound to take the energy-saving development path. Because energy consumption structure is affected by the industrial structure and they have an effect on economic growth concurrently, the analysis of the relationship among industrial structure, energy consumption and economic growth in Shandong Province has very important economic significance in reducing energy consumption, promoting the adjustment of industrial structure and promoting sustainable economic growth, etc.

Domestic and foreign scholars mainly adopt direct regression analysis and grey correlation analysis and other quantitative models to research industrial structure, energy consumption and economic growth, but the research is mostly limited to the relationship between two factors[3]. For example, Ren Dapeng, Ai Minghua (2007), Li Xingzhou, Xu Quanzhi, Che Xiliang (2009), Gao Yongjuan and Zhang Minghui (2012), et al., have made empirical researches on the relationship between energy consumption and economic growth in our province; Dang Hao (2013), Huang Bingjie and Sun Xunjie (2013) et al., have made empirical researches on the relationship between industrial structure and economic growth in Shandong Province with measurement mode; Li Zhixia and Ren Jianlan (2013), et al., have analyzed the relationship between energy consumption and industrial structure in Shandong Province with grey correlation analysis. In essence, industrial structure, energy consumption and economic growth interact each other in a very close way, the analysis of two of them is not sufficient to fully grasp the problems. Though some scholars have gradually researched industrial structure, energy consumption and economic growth as a system, there are scare materials about analysis of the relationship between energy consumption and economic growth from the adjustment of industrial structure by taking Shandong Province as a research object.

EXPERIMENTAL SECTION

In this paper, grey correlation theory is used to analyze the relationship among industrial structure, energy consumption and economic growth in Shandong Province. Grey correlation is a part of grey system theory and established by domestic well-known scholar Professor Deng Julong. Grey correlation theory is a method to survey the degree of correlation among different factors mainly based on level of similarity or degree of difference of development trend among different factor, namely, "grey correlation" we usually call. This theory is expected to find the numerical relationship among different factors of the system with this kind of quantitative method, for a system, this method can better quantify the change trend of development, very suitable for dynamic analysis [4].

The following basic steps shall be followed in the process of analysis with grey correlation theory: firstly, determine standard data array, namely, the data array affecting behavioral features of the system; collect relevant data corresponding to the factors affecting system behaviors and form comparative sequence; secondly, apply dimensionless method to the selected data array and comparative sequence of each assessment index; thirdly, calculate grey correlation coefficient of the data array and comparative sequence; fourthly, evaluate the grey correlation degree; fifthly, sort the indexes to be assessed according to the degree of correlation.

Selection of Relevant Data Indexes

Considering availability of relevant original data when selecting them, in this paper, gross regional domestic product (GDP) is selected to represent economic growth index, expressed in XO; the proportion of total output of primary industry, secondary industry and tertiary industry in GDP is selected to represent industrial structure, expressed in X1, X2 and X3 respectively; in addition, three indexes including total energy consumption (unit: ten thousand tons of standard coal) and energy efficiency (namely, energy consumption/unit GDP) and energy consumption structure are selected to represent energy consumption, expressed in X4, X5 and X6 respectively, where energy consumption structure will be balanced based on the

proportion of energy mostly consumed in the region in total amount of energy. Considering time continuity of data, in this paper, 2006-2012 data of Shandong Province are selected as the time range of the data corresponding to the above 7 variables; at the same time, because energy consumption in Shandong Province is dominated by coal, the proportion of coal in total amount of energy consumption is taken as an index to measure energy consumption structure.

Data Processing

(a) Determination of Standard Data Array and Comparative Sequence

Combined with the indexes selected above, in this paper, GDP (X0) is taken as a standard data array and six indexes in two classes including the proportion of total output of primary industry, secondary industry and tertiary industry in GDP (X1, X2 and X3) and total amount of energy consumption (X4), energy efficiency (X5) and energy consumption structure (X6) are taken as comparative sequence.

Table 1 : Original Data of GDP, Industrial Structure and Energy Consumption of Shandong Province during 2006-2012

Year	GDP (100 million yuan) X0	Proportion of primary industry (%) X1	Proportion of secondary industry (%) X2	Proportion of tertiary industry (%) X3	Total amount of energy consumption (ten thousand tons of standard coal) X4	Energy efficiency (ten thousand tons of standard coal/100 million yuan) X5	Energy consumption structure (%) X6
2006	22077.36	9.8	57.4	32.8	26759	1.2121	0.7984
2007	25776.91	9.7	56.8	33.5	29177	1.1319	0.8047
2008	30933.28	9.7	56.8	33.5	30570	0.9883	0.7798
2009	33896.65	9.5	55.8	34.7	32420	0.9564	0.7713
2010	39169.92	9.2	54.2	36.6	34266	0.8748	0.7617
2011	45361.85	8.8	52.9	38.3	35978	0.7931	0.7647
2012	50013.24	8.6	51.4	40.0	37650	0.7528	0.7521

(b) Data Standardization

In order to enhance the comparability among various factors, dimension of all factors shall be eliminated, this is data standardization. Specifically, take year 2006 as the benchmark year, divide the data of the other years in the same line in Table 1 by the data of year 2006, apply dimensionless method to all factors, and then a set of standardized data will be obtained, as shown in Table 2.

Table 2 : Dimensionless Data of GDP, Industrial Structure and Energy Consumption of Shandong Province during 2006-2012

Year	X0	X1	X2	X3	X4	X5	X6
2006	0.6251	1.0505	1.0428	0.9206	0.8258	1.2646	1.0287
2007	0.7298	1.0398	1.0319	0.9403	0.9004	1.1809	1.0369
2008	0.8758	1.0398	1.0319	0.9403	0.9434	1.0311	1.0048
2009	0.9597	1.0184	1.0138	0.9739	1.0005	0.9979	0.9938
2010	1.1090	0.9862	0.9847	1.0273	1.0575	0.9127	0.9814
2011	1.2844	0.9433	0.9611	1.0750	1.1103	0.8275	0.9853
2012	1.4161	0.9219	0.9338	1.1227	1.1619	0.7854	0.9691

(c) Difference Sequence Result of Data

Table 3 : Difference Sequence

Year	Δ1	Δ2	Δ3	Δ4	Δ5	Δ6
2006	0.4254	0.4177	0.2955	0.2007	0.6395	0.4036
2007	0.3100	0.3021	0.2104	0.1706	0.4511	0.3070
2008	0.1640	0.1561	0.0644	0.0676	0.1552	0.1289
2009	0.0586	0.0540	0.0142	0.0408	0.0381	0.0341
2010	0.1228	0.1244	0.0818	0.0516	0.1964	0.1276
2011	0.3410	0.3233	0.2094	0.1740	0.4569	0.2991
2012	0.4942	0.4822	0.2934	0.2541	0.6307	0.4470

(d) Calculation of Correlation Coefficient

Based on calculation with grey correlation method, it can be drawn that maximum value of two extremes of comparative sequence and standard sequence$\Delta max=0.6395$ and minimum value of two extremes$\Delta min=0.0142$, by calculating correlation coefficient and correlation degree with$\theta=0.5$, the results are as shown in Table 4.

Table 4 : Calculation Results of Correlation Coefficient and Correlation Degree

Year	γ1	γ2	γ3	γ4	γ5	γ6
2006	0.4481	0.4528	0.5428	0.6416	0.3481	0.4616
2007	0.5303	0.5370	0.6299	0.6810	0.4332	0.5328
2008	0.6903	0.7018	0.8693	0.8621	0.7031	0.7443
2009	0.8825	0.8935	1.0000	0.9262	0.9331	0.9438
2010	0.7545	0.7519	0.8317	0.8994	0.6470	0.7465
2011	0.5054	0.5193	0.6311	0.6763	0.4300	0.5396
2012	0.4103	0.4164	0.5446	0.5819	0.3514	0.4355
关联度 Correlation degree	0.6031	0.6104	0.7213	0.7526	0.5494	0.6292

Calculation of Comprehensive Grey Correlation and Sequence of Correlation Coefficient

According to "grey correlation theory", the calculation results of comprehensive correlation between standard sequence "Economic Growth of Shandong Province" and comparative sequence "six factors" are as shown in Table 5.

Table 5 : Correlation between Variable Sequence and Economic Growth

	Comprehensive correlation	Close degree
Proportion of primary industry	0.60	5
Proportion of secondary industry	0.61	4
Proportion of tertiary industry	0.72	2
Total amount of energy consumption	0.75	1
Energy efficiency	0.55	6
Energy consumption structure	0.63	3

RESULTS AND DISCUSSION

Results

Based on empirical analysis of the relationship among industrial structure, energy consumption and economic growth in Shandong Province with grey correlation model, it is concluded:

Firstly, it can be drawn from Table 1 that the evolution of industrial structure in Shandong Province is in line with "Kuznets theory of three industries", i.e. the proportion of the output of primary industry in economic aggregate decreases gradually; the proportion of the output of secondary industry gradually increases, but tending to become slow; the proportion of tertiary industry tends to rise as a whole. Changing trend of such data shows that industrial structure of Shandong Province is transferring from low value-added primary industry to high value-added tertiary industry, and secondary industry is a leading dominant industry.

Secondly, it can be drawn from correlation sequence in Table 5 that among the six variables affecting economic growth, the greatest one is total amount of energy consumption, with a degree of correlation with economic growth of 0.75, showing that economic growth of Shandong Province is driven by energy consumption and the increase in the total energy consumption amount, compared with other factors, is more effective in promoting economic growth. Energy consumption structure, especially the degree of correlation between energy efficiency and economic growth is behind it at a lower position, reflecting the energy efficiency in Shandong Province is relatively low and can be further improved.

Thirdly, from industrial structure, the tertiary industry is the most closely related to economic growth, showing the tertiary industry has a relatively significant influence on economic growth of Shandong Province. The degree of correlation between the secondary industry and economic growth is next to the degree of correlation between tertiary industry and economic growth, conforming to the industrial structure mode of "tertiary, secondary and primary industries" expressed by Petty- Clark. It can be concluded from the results that industrial structure in Shandong Province is gradually optimized.

Discussion

(a) Develop Green Economy, Improve Energy Efficiency

Based on the above analysis, in order to improve energy efficiency in Shandong Province and promote healthy economic growth, it is required to continue to steadily promote adjustment, optimization and upgrading of industrial structure under existing conditions, which requires continuing to promote the concept of transformation of economic growth mode and reduce the proportion of high energy-consuming industries. Specifically, it is required to promote higher level of industrial development and lead enterprises to upgrade themselves to "creation center" from "manufacturing center"; vigorously develop green economy, develop high-tech industries, accelerate the establishment of energy-saving dominant industry and form rational energy consumption structure. While focusing on the effect of coal consumption on economic growth, more attention shall be paid to sustainability of ecology, environment and resources, etc., to realize coordinated development of economic growth and environment.

(b) Develop Modern Service Industry, Promote Optimization and Upgrading of Tertiary Industry

Service industry has the largest development potential, is also the key to adjust and optimize industrial structure and the main channel to expand social employment. In order to develop service industry in Shandong Province, it is required to accelerate the development of finance, insurance, logistics and other industries with high technical contents and added value, enhance economic efficiency and drive the overall improvement of the service industry. At the same time, we must seize the opportunity to upgrade the resident consumption pattern, vigorously develop tourism, culture, information and other industries with large market potential and make them become a pillar industry to support local economic development. In this process, we must transform and upgrade traditional service industry and develop new areas of service industry according to market demand.

(c) Make Multi-participation and Promote Coordinated Development of Economy and Society

First, play the role of the government in macro-control and establish a legal system for development of low-carbon industry by establishing and improving corresponding legal institutions to enhance energy conservation and emission reduction in Shandong Province and improve energy efficiency; second, improve the performance evaluation system and include energy conservation, environmental protection, quality of life and well-being index and other indicators into the performance evaluation system in order to urge the government to pay attention to protecting and improving livelihood projects; third, enhance environmental protection awareness of people and different enterprises at all levels to make all of them know though economic growth is important, it cannot be compared with healthy body and mind, beautiful natural environment and ecological resources reserved for future generations and it is impossible to stake future happiness.

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