Research Article
Based on the Grey Relational Analysis of Energy Consumption Structure of Shandong Province

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Abstract: Due to the unreasonable industrial structure and energy structure, the development of provincial economy of Shandong province is slowing in decade years. In order to found the root cause of the problem, improve the energy development and the economic structure in Shandong province, achieve economic development bottleneck breakthrough, this study made a comprehensive analysis on the situation of energy consumption of Shandong Province and then introduces the method of grey correlation on the energy structure of Shandong Province, analyzes the problems. This study has certain theory significance and practical application value, the coordinated development of economy and energy development in Shandong province and has certain guiding innovation significance of relevant field.

Keywords: Shandong province, the energy structure, the gray correlation analysis

INTRODUCTION

Shandong province is rich in natural resources, is China's important energy base, with the original advantage of industry and agriculture, from 2004 to 2008, GDP of Shandong province has been in the second place in the country. However, since 2009, it has fallen to the third place. This is to some extent related to the unscientific way of economic development in Shandong province. As economic province, the economic growth is too much relying on the high energy consumption and high-polluting industries in the second industry, such as: paper, woven square, chemical industry, metallurgy, building materials, oil refining coking and so on. These industries are mainly dependent on the scale expansion of development, compared with the input, the output is less, not only consumes a lot of energy, but also causes serious destruction to the ecological environment. Because of the existence of high energy consumption industries, resulting in high energy consumption in recent years in Shandong Province, the industrial structure optimization has been slow.

Not only that, the extensive mode of economic development in Shandong province is also seriously affected the local ecological environment, the respirable particulate matter in the province accounted for about 40% of the pollution load, sulfur dioxide emissions remained at the national first place, which contains oil, ammonia nitrogen, organic oxygen consumption industrial waste water substances also caused irreversible damage to the local water environment. At the same time, the decline in air quality and the pollution of water resources is to the health of local residents, as well as the normal production and life caused great harm. Therefore, in order to achieve sustainable and rapid economic development, we must change the unscientific way of economic development in Shandong province, reconsidering the layout of the present industrial structure, take the low carbon, high efficient and environmentally friendly new industrialization path of development.

Many scholars have made a lot of work and achieved remarkable results: (Wang *et al.*, 2012) using the method of grey correlation degree analysis of electric power enterprises in Jilin Province, the economic behavior and energy consumption were analyzed and got great achievements. Ren and Ai (2007) through the actual data, the economic growth of Shandong province and the actual energy consumption was analyzed and obtain the result that positive relationship between economic growth and energy consumption. Oxiaowan (2008) from theoretical view, the relationship between economic growth and energy consumption is analyzed in theory and has good theoretical value. Yang (2006) economic growth and energy consumption theory is applied to the practice of Shandong Province and obtains the research results from the actual situation of Shandong Province, which has the very good practical significance. Xi *et al*. (2009) analyzed and evaluated various methods of enterprise performance evaluation based on the method

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of induction, comparison and inference and they provided ideas and methods to improve performance management and evaluation for state-owned enterprises. Li (2008) in the background of china electric power market, evaluate electric power market performance from different point of view. Zou and Shao (2011) in the background of resources depletion have the research on how to improve the energy structure and operation mechanism and got great achievements.

In this text, we based on the analysis of energy production and consumption status quo, using gray relational theory to analyze the structure of the energy production in Shandong Province and then look for reducing energy consumption, accelerate economic development in the new development ideas.

THE ENERGY PRODUCTION AND CONSUMPTION PRESENT SITUATION ANALYSIS IN SHANDONG PROVINCE

Shandong province has always been a big energy producing province, not only to meet energy required in this province for production and life, but can supply outward. Since 1994, this advantage will no longer exist. Figure 1 shows the total energy production and consumption in Shandong Province in 1994-2011.From 1994 to 2001, in addition to the low amount of energy production in 2000, energy production and consumption in Shandong province is basically the same, that is basic to guarantee its energy demand, however, since 2002 in Shandong province, energy consumption is higher than production, to make ends meet, especially to rise significantly in 2005, compared with the less volatile movements of energy production, from 2005 to 2011, energy consumption continued to rise. Difference between energy consumption and production of 2010 up to 196.262 million tons of standard coal, the province's energy production has far cannot satisfy the needs of their own, energy 54.55% external dependency. The total energy production and consumption in Shandong Province in 1994-2011.

Starting in 1994, vigorously industrial development and gradually tilted in heavy industry of Shandong province, Shandong heavy industry proportion in the gross value of industrial is 49:51 in 2002, while the total energy consumption is 1.1 times of the total energy production and total energy consumption has doubled compared with 1992, the first number of the national rankings. During this period, heavy industries such as manufacturing, metallurgy, chemical industry, building materials and other equipment manufacturing industry accounts for the significant increase the proportion of production. From industrial energy consumption structure in 2002, we can find the second industry in the industrial proportion accounted for 79.5%, energy consumption rose by 1.6%. Coal
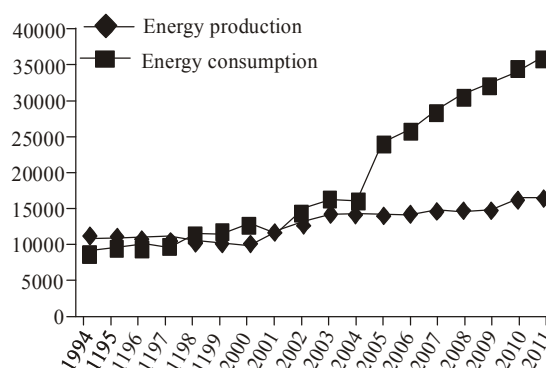

Fig. 1: The total energy production and consumption in Shandong Province in 1994-2011

products accounted for 76% in total energy consumption, oil 22%, energy consumption of Shandong province heavy dependence on coal, due to the sustained increase of energy consumption, its Foreign-trade Dependence is also relatively increase.

From 2003 to 2008, Shandong province enters a new period of comprehensive and rapid development of the society, the economy achieved development by leaps and bounds. But the rapid economy development of Shandong province is mainly relying on heavy industry, heavy industry proportion in the gross value of industrial is 34.8:65.1 in this period. There is an obvious feature of heavy industrialization and rapid increase energy consumption, more than double six years energy consumption, external dependency also exceeded 50%, has been the highest in the national energy consumption. Industrial energy consumption in 2007 reached two hundred million tons of standard coal, rising 98.7% compared with 2002, accounting for 80.8% of the total energy consumption in the province, accounting for 11.7% of the total national industrial energy consumption. In recent years, Shandong province has gradually aware of the disadvantages of present industrial structure, but energy consumption still shows a rising trend from 2009 to 2011 and the form is not optimistic.

Five years industrial energy consumption in Shandong province through the calculation can be concluded by calculating, industrial coal consumption accounts for a proportion of the total coal consumption is about 95%, oil consumption accounts for about 36% of the total oil consumption, industrial energy consumption accounts for about 75% of the total energy consumption. Thus, high energy consumption, high pollution of the heavy industry in Shandong province is too high, which to some extent, restricted the rapid economy towards intensive growth way transformation, the unreasonable energy consumption structure to the strategic adjustment of industrial structure also brought certain obstacles. It is a stumbling block to achieve sustainable economic development in Shandong province.

According to the statistics in Shandong statistical yearbook 2012, the total energy consumption in Shandong province is 359.78 million tons of standard coal, ranking first in the national energy consumption. Shandong Province has abundant coal resources, raw coal production accounted for 74.95% of total disposable energy production in 2011 and new types energy such as solar energy, wind energy, tidal energy development and utilization is obviously low, hydropower and wind power production in the energy production accounts for only 0.33%. This single coal-based energy structure of Shandong Province has caused the extensive mode of economic growth and the high energy consumption.

Resources in Shandong province are very scarce and coal resources reserves per capita is less than half the national average, per capita reserves of petroleum and natural gas are far less than the national average. According to research statistics, in accordance with existing mining speed, the Shandong province traditional energy such as coal, crude oil lasted only for about 30 years and with the gradually reduction of global energy reserves, the purchase cost rising, the possibility of outsourcing resource is getting smaller and smaller. Therefore, Shandong province need to increase efforts to the development and popularization of new energy, new energy sources such as solar energy, wind energy can not only save natural resources like coal, oil, provide a steady stream of green energy for production and living, but also can improve the local ecological environment, improve people's quality of life, which is fully staffed strategic decisions.

THE BASIC PRINCIPLE OF GREY CORRELATION ANALYSIS

The so-called gray correlation analysis of gray system theory, put forward in 1982 by Professor Deng Julong. This is a quantitative description of a system development situation and comparative methods, the basic idea is determined by reference data series and several comparative data series of geometric shape similarity degree to judge whether the contact closely, which reflects the correlation degree between the curve. Curve approximates to the greater the correlation between the corresponding sequence, whereas the less. Grey correlation degree is relative correlation with absolute correlation degree Relative incidence degree and absolute correlation degree is in its curve of proximity and similarity between two relative for the system behavior is only one factor and the factor affected by many factors, the relative correlation is more appropriate, more convenient. Therefore, the research takes the relative incidence degree:

- **Standardized treatment:** This text selects the mean of the treatment method to standardize the raw data, standardization of formula is as follows:

$$X_{ij}^{\ 0} = \frac{X_{ij}}{X_{i1}} \ (i = 1, 2, \cdots, m; \ j = 1, 2, \cdots, n)$$

Among them, X_{ij}^{0} is the data after the standardization, X_{ij} is the original data X_{i1} is the first data for the variable I.

- **Calculate the correlation coefficient:** Correlation degree refers to similarity of the curve shape between reference sequence and compare sequence, when the shape of two series of curve is close, the correlation degree of both is bigger; and when the shape of two series of curve is different, the connection degree is smaller. Correlation coefficient calculation formula is as follows:

$$\varepsilon_{ij}(k) =$$

$$\frac{\min\limits_{j}\min\limits_{k}\left|x_i(k) - x_j(k)\right|}{\left|x_i(k) - x_j(k)\right| + \rho\max\limits_{j}\max\limits_{k}\left|x_i(k) - x_j(k)\right|} +$$

$$\frac{+\rho\max\limits_{j}\max\limits_{k}\left|x_i(k) - x_j(k)\right|}{\left|x_i(k) - x_j(k)\right| + \rho\max\limits_{j}\max\limits_{k}\left|x_i(k) - x_j(k)\right|}$$

Among them, $\left|x_i(k) - x_j(k)\right|$ is as the absolute difference between the point k items I; $\frac{min}{j}\frac{min}{k}\left|x_i(k) - x_j k\right|$ is for the minimum difference between the two; $\frac{max}{j}\frac{max}{k}\left|x_i(k) - x_j(k)\right|$ is the biggest difference between the two; ρ is to distinguish coefficient, values, generally between 0 ~ 1, the smaller the differences between the correlation coefficient, the greater the distinction between the stronger the force, this study ρ is 0.5.

- **Calculate the associated degrees:** Summary of the correlation coefficient, get the whole correlation degree of compare series $x_j(k)$ and reference series $x_i(k)$. That is $\gamma_{ij} = \frac{1}{m}\sum\limits_{k=1}^{m}\varepsilon_{ij}(k)$.

THE ENERGY PRODUCTION STRUCTURE ANALYSIS OF SHANDONG PROVINCE

In order to more in-depth analysis was carried out on the structure of energy production in Shandong province, this study selects Shandong province between 2001 and 2010, total energy production, raw coal, crude oil, natural gas and wind power and hydropower production as the foundation data, starting from the theory of grey correlation degree, reflect the status quo of the overall proportion of energy structure in Shandong province, as the data shown in Table 1.

Table 1: Total primary energy production in Shandong Province from 2001 to 2011 (ten thousand tons)

Year	Total energy production	Coal	Oil	Nature gas	Hydroelectricity
2001	11550.26	7634.32	3811.52	103.34	1.08
2002	13241.75	9333.02	3816.52	91.07	1.14
2003	14384.08	10476.85	3808.65	98.36	0.22
2004	14394.61	10461.78	3820.50	111.84	0.49
2005	13995.62	10021.63	3849.36	123.03	1.60
2006	14083.40	10042.24	3935.89	103.46	1.82
2007	14616.67	10526.28	3990.22	99.22	0.95
2008	14615.32	10500.62	3998.91	113.05	2.74
2009	14600.08	10424.07	4040.38	119.97	2.14
2010	16055.71	11913.14	3980.08	129.01	2.63
2011	16351.80	12255.64	3973.65	69.16	53.35 (Total of hydropower and wind power)

Table 2: Standardized data in Shandong province from 2001 to 2010

Year	Total energy production	Coal	Oil	Nature gas	Hydroelectricity
2001	1	1	1	1	1
2002	1.146446	1.222508357	1.001312	0.881266	1.055556
2003	1.245347	1.372335716	0.999247	0.95181	0.203704
2004	1.246259	1.370361735	1.002356	1.082253	0.453704
2005	1.211715	1.312707615	1.009928	1.190536	1.481481
2006	1.219315	1.315407266	1.03263	1.001161	1.685185
2007	1.265484	1.378810425	1.046884	0.960132	0.87963
2008	1.265367	1.375449287	1.049164	1.093962	2.537037
2009	1.264048	1.365422199	1.060044	1.160925	1.981481
2010	1.390073	1.56047166	1.044224	1.248403	2.435185

Table 3: Correlation coefficient between total primary energy productions from 2001 to 2010

Year	Coal	Oil	Nature gas	Hydroelectricity
2001	1	1	1	1
2002	0.893155512	0.814161386	0.705687217	0.874931
2003	0.833527942	0.720954624	0.684155318	0.379042
2004	0.836693026	0.722755359	0.794951977	0.445141
2005	0.862935564	0.759095467	0.967765325	0.702113
2006	0.868712826	0.773033329	0.744547647	0.577137
2007	0.84872904	0.744158521	0.675566798	0.622337
2008	0.852420463	0.746251863	0.787664884	0.333333
2009	0.862488929	0.757092035	0.860448516	0.469851
2010	0.788649002	0.647697816	0.817788804	0.37826

In the study of "Shandong statistical yearbook 2012", total primary energy production data does not include the wind power output by 2009, therefore, in this study, based on the statistical results of China's energy statistics yearbook 2011, 2009 and 2010, the wind power is respectively 1.74 and 214 million KWH, equivalent to a standard unit of output is respectively 2.14 and 26300 tons of standard coal. Because we can't find it in 2011 in Shandong province hydropower production, the back of the study involved 2010 only.

According to relevant formula in the above analysis, we can get a total energy production of standardized data in Shandong province from 2001 to 2010, in the following Table 2.

We may obtained the minimum difference between is 0 by calculating, the biggest difference between is 1.27167, according to the correlation coefficient formula obtained, the energy and the correlation coefficient between total primary energy production from 2001 to 2010 can be calculated and shown in Table 3.

According to the correlation formula, we can respectively calculate the correlation degree between the total energy production and the raw coal, crude oil, natural gas and hydropower. $\gamma_{coal} = 0.865$, $\gamma_{oil} = 0.769$, $\gamma_{gas} = 0.804$, $\gamma_{electricity} = 0.578$.

In the structure of energy production, raw coal with grey correlation of total primary energy production is the largest, however, as the traditional energy; combustion efficiency is very low combustion efficiency and will release a large amount of pollution in the process of combustion gas. With coal as the subject of the energy structure is the important reason for the Shandong province ten thousand yuan GDP energy consumption continues to rise. Not only do this led to the growth of energy consumption, but also bring serious harm to the local ecological environment and people's health, which is the main obstacle in achieving sustainable economic growth in Shandong province.

In four kinds of energy, the connection degree of hydropower production and total energy output is minimal, which showed that in terms of new energy development and utilization is still relatively backward in Shandong province. Jiao dong peninsula in Shandong province has superior geographic advantages, new energy sources such as wind power, tidal power, solar energy is very rich. With full use of new energy in Shandong province can we improve the current single,

uncoordinated energy structure and effective governance the existing environmental problems.

DEVELOPMENT SUGGESTIONS

In conclusion, according to the analysis above, changing the existing energy structure and industry layout, to realize the rapid development of economy in Shandong province, can we start from the following four points?

First, optimize the energy structure. On the basis of guarantee the sustainable economic growth and gradually reduce the proportion of coal in the existing energy structure increased the use of natural gas and oil proportion. Actively expand the popularity of green energy such as wind, hydro and solar energy. Gradually improve the single, uncoordinated energy structure, so that the shift in the direction toward the low energy consumption and high efficiency and realize sustainable development.

Second, improve energy efficiency. We should promote the utilization efficiency of the traditional energy such as coal, oil At the same time of changing the existing energy structure Introduce some perfect energy conservation and emission reduction technology, enhance the traditional energy output rate, maintain the local ecological environment as well as residents' normal production and life and to speed up the concrete realization of energy conservation and emissions reduction work.

Third, develop new energy. Increase investment in research and education. Give the new energy development and use of certain policy support and encouragement. Local governments and the responsible department should focus on supporting the green energy power projects in the province and in view of the geographical advantage all over the world and then develop new energy sources, such as solar energy, wind energy, tidal energy, ocean energy and others. Gradually reduce ten thousand yuan GDP energy consumption, promote the sustainable development of economy in Shandong province.

Fourth, adjust the industrial structure. Appropriate to reduce the proportion of secondary industry in GDP and gradually tilted to the third industry. Resolutely ban high pollution, high energy consumption industries, vigorously develop high-tech technology with independent intellectual property rights, encourage the sense of innovative consciousness of the enterprise and constantly enhance the added value of products, so as to realize low carbon economy.

CONCLUSION

The energy industry is pillar industries in the 21st century global market and it plays a significant role to improve the lives of humanity. Today, the power industries in the People's Republic of China are in a critical period of transformation to meet modern managerial standards for effective delivery.

This study expounds the present situation of Shandong province energy production and consumption structure and the latest research progress in related fields at home and abroad and then introduces the basic theory of the grey relational grade analysis, development and practical application of the method. Have the detailed quantitative analysis of the energy structure of Shandong Province with the method of grey correlation analysis and the actual, practical data from 2001-2011 in Shandong Province based on the analysis of energy production in Shandong Province, the actual and the consumption structure, the regulation of energy consumption, improve the Shandong province actual economic methods and suggestions on the development of structure. Helps to reduce energy consumption in the actual operation process, adjusting energy structure, improving energy efficiency and ultimately promote economic development. By analyzing the real data of Shandong Province, put forward the coordinated development of energy and economic development suggestions and promote the sustainable development of energy industry in Shandong province. This study is of theoretical significance and practical application value, has a certain reference to the related industry and analysis.

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