Energy Consumption, Environmental Pollution and Economic Growth Correlation--- Shandong Province

DAI Jinhui
Shandong Institute of Business and technology Statistics, Yantai, Shandong, 264005
jinhuidai@sohu.com

Abstract: Energy consumption, environmental protection and economic growth belong to an organic whole. In this paper, according to Shandong Province, gray correlation analysis is used to analyze the industrial structure, energy consumption and environmental pollution respectively in analysis by synthesis. Consequence is that the secondary industry is the support of national economy. The development of industry plays an important part in the development of the national economy. Meanwhile, the development of industry spends lots of energy and makes serious pollution. At the end of this paper, there are several decision-making mechanisms of development adapt to the basic state of Shandong province.

Keywords: Grey relational analysis, economic growth, energy consumption, environmental pollution

1. Introduction

Development of economy is not indicated by the increase of national economy gross, also the improvement and majorization of the economic structure and economic quality. Energy is an important material basis of human survival, economic development and social progress. It is also the lifeline of national economy, the important strategic basis of national security and the material basic of modern civilization. Since the reform and opening up, China is promoting energy production and sustainable economic growth. As a result, the economic strength grows vigorously. However, the problem of environmental pollution caused by consumption of energy becomes obviously gradually at the same time. We know that the environment should not be the cost of economic development. Research shows that, in the developed countries and newly industrialized countries (regions), the relationship between variation trend of environmental pollution and economic development are shown as the inverted "U". The development situation don’t allow China to go the route: treatment after pollution. Thus, exploring the numerical relationship and evolution among economic growth, energy consumption and environmental pollution in-depth has a great practical significance for guiding the healthy development of China's economy.

So far, there are a lot of literatures exploring the relationship among energy consumption, environmental protection and economic growth. But many of them just show a relationship between two of the three, such as the relationship between environmental protection and economic growth. Few of them show the relationship among the three factors, although these literatures are useful to design the policy of the local environment.

Grey relational analysis is simple in calculating, clearly sorting and it has no special requirements for data distribution types and variable correlation types, etc. So it has high practical value to use the grey relational analysis to research the influence of energy consumption and environmental pollution in China on its economic growth.

2. Grey Relational Analyses

Grey system theory makes research on "small sample size, poor information" uncertainty system with some of the information known, partial information unknown. Through exploring the formation and development of the known information, we can extract valuable information to achieve the goal that make correct understanding and accurate description of the rules of the system. Grey system theory is that all the gray sequence can weaken its randomness and reveal the regularity by some kind of process.
The correlation analysis proposed by Grey system theory is mainly a quantitative analysis focusing on the process of dynamic development. It measures the degree of correlation of factors based on the similarity or dissimilarity degree of development trend of factors. Since the development is the start point, it is all equally applicable for any size of sample and no matter whether the sample is typical distribution or not. What’s more, the results of quantitative and qualitative analysis are impossible to be different with each. The basic idea of Grey relational analysis is basing on the similarity of the geometry of sequences curve to determine whether they are closely linked. The correlation between the corresponding sequences gets greater when curve approaches more whereas the smaller. Associated sequence relevant the approximate order of the factors to the characteristic behavior of the system in which the maximum correlation factor is optimal. Associated sequence can be used to compare and sort the various related factors. The modeling steps of grey relational dynamic analysis are as follows:

2.1 Establish the original series of the dependent variable reference sequence and independent variable comparison series:
Dependent variable, also known as master sequence reference sequence, denoted $X_0 = [x^{(1)}_0, x^{(2)}_0, x^{(3)}_0, \ldots, x^{(k)}_0]$
Independent variable reference sequence called sub-sequence, denoted $X_i = [x^{(1)}_i, x^{(2)}_i, x^{(3)}_i, \ldots, x^{(k)}_i]$ (Where, $i = 1, 2, 3... n$)

2.2 The original sequence is initialized, that is, deal with dimensionless
Eliminating the influence of magnitude of different sizes in order to facilitate the calculation and comparative analysis, generally use the initialization method to address, namely, $x_i^{(k)} = x_i^{(k)} / \bar{X}_i$, also can do processing means, $x_i^{(k)} = x_i^{(k)} / \bar{X}_i$

2.3 Calculate the absolute value of remainder between the master sequence and the sub-sequence at each time point, and find the maximum and minimum:
Remainder sequence: $\Delta_i = x^{(k)}_i - x^{(k)}_i$ (where $i = 1, 2, 3, \ldots, n$)
Max remainder: $\Delta_{\text{max}} = \max_i \max_i \left| x^{(k)}_i - x^{(k)}_i \right|
Min remainder: $\Delta_{\text{min}} = \min_i \min_i \left| x^{(k)}_i - x^{(k)}_i \right|

2.4 Calculate the grey relational coefficient
$L_{oi}^{(k)} = \frac{\Delta_{\text{min}} + \lambda \Delta_{\text{max}}}{\Delta + \lambda \Delta_{\text{max}}}$
Among them, $L_{oi}^{(k)}$ is the relative remainder determined by the sub-factors and the master of the k point, the larger absolute remainder, the smaller $\Delta \cdot L_{oi}^{(k)}$, and vice versa. So the size of $L_{oi}^{(k)}$ describes the impact and department correlation $X_i$ to $X_0$ in the k point, the formula $\lambda$ is resolution ratio, generally between 0.5 and 1 selection, often taking $\lambda = 0.5$.

2.5 Calculate the grey correlation $R_{oi}$

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In order to get the overall correlation, the importance of the different observation points in the overall observations should to be considered and the method need to calculate the weight of each point. This based on the arithmetic mean method to calculate the grey correlation $R_{ij}$:

$$R_{ij} = \frac{1}{n} \sum_{k=1}^{n} L_{0i}(k)$$

2.6 Correlation sort
Date order according to the size of $R_{ij}$ sequence of correlation. The correlation closed to 1 shows that the greater the association is. Experience shows that when $\lambda = 0.5$, the correlation of the two factors is greater than 0.6. We believe that the association is significant.

The paper take Shandong as an example and use the data from *Statistical Yearbook of Shandong Province*, 2002-2008, to establish the grey dynamic models in accordance with the above steps, correlation results in Table 1, Table 2 and Table 3.

3. Grey Relational Analyses of Three Industries and the National Economy Development in Shandong

In order to measure and compare the size of correlation between three industries and the national economic development in Shandong, the paper takes gross national product (GDP) for the parent sequence and take the primary and secondary industry, industry, tertiary industry for the sub-sequence, 2002-2008, in Shandong to establish models, correlation shown in Table 1.

<table>
<thead>
<tr>
<th>Years</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>10275.50</td>
<td>12078.15</td>
<td>15021.84</td>
<td>18516.87</td>
<td>22077.36</td>
<td>25965.91</td>
<td>31072.06</td>
<td>1.0000</td>
</tr>
<tr>
<td>Primary Industry</td>
<td>1390.00</td>
<td>1480.67</td>
<td>1778.45</td>
<td>1963.51</td>
<td>2138.90</td>
<td>2509.14</td>
<td>3002.65</td>
<td>0.7287</td>
</tr>
<tr>
<td>Secondary industry</td>
<td>5184.98</td>
<td>6485.05</td>
<td>8478.69</td>
<td>10628.62</td>
<td>12751.20</td>
<td>14776.53</td>
<td>17702.17</td>
<td>0.8197</td>
</tr>
<tr>
<td>Industry</td>
<td>4518.87</td>
<td>5706.71</td>
<td>7576.12</td>
<td>9568.58</td>
<td>11555.99</td>
<td>13412.72</td>
<td>16102.19</td>
<td>0.7802</td>
</tr>
<tr>
<td>Tertiary industry</td>
<td>3700.52</td>
<td>4112.43</td>
<td>4764.70</td>
<td>5924.74</td>
<td>7187.26</td>
<td>8680.24</td>
<td>10367.25</td>
<td>0.6491</td>
</tr>
</tbody>
</table>

The results show that: the correlation (0.8197) between the second industry and GDP ranks the first. Indicating the second industry has the most important impact on national economy in Shandong. The industry (0.7802), indicating that industrial development in Shandong play an important role in national economies. The primary industry (0.7278) ranks second and the tertiary industry (0.6491) is the min. Thus, primary industry, secondary industry is still the lifeblood of the national economy in Shandong. Along with the rapid development of the national economy, especially industrial development, energy consumption will continue to increase. Either the energy supply or demand contradictions can be well solved will be the key of sustainable and healthy development of the national economy in Shandong.

4. Grey Relational Analyses of Energy Consumption and Industrial Development in Shandong

Energy is the most important material basis of economic growth in a region. Coal, oil, electricity are the main components of the energy. However, the industry is a major energy-consuming industry. So we select the three types of energy on the analysis of industrial output in Shandong. In order to measure and compare the size of correlation between industrial development and these three types of energy, the
paper takes industrial output value for the master sequence and the coal, oil, electricity consumption for sub-sequence, 2002-2008, of Shandong to establish models, correlation shown in Table 2.

<table>
<thead>
<tr>
<th>Category</th>
<th>2002</th>
<th>2003</th>
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<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Correlation</th>
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</thead>
<tbody>
<tr>
<td>Industry</td>
<td>4518.87</td>
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<td>7576.12</td>
<td>9568.58</td>
<td>11555.99</td>
<td>13412.72</td>
<td>16102.19</td>
<td>1.0000</td>
</tr>
<tr>
<td>Coal</td>
<td>3121.28</td>
<td>3504.25</td>
<td>3652.11</td>
<td>6423.10</td>
<td>6970.49</td>
<td>6813.70</td>
<td>7949.75</td>
<td>0.6931</td>
</tr>
<tr>
<td>Oil</td>
<td>1567.65</td>
<td>1833.40</td>
<td>2700.81</td>
<td>4242.44</td>
<td>6423.10</td>
<td>4820.33</td>
<td>4329.45</td>
<td>0.7716</td>
</tr>
<tr>
<td>Electricity</td>
<td>1511.52</td>
<td>1715.35</td>
<td>2081.92</td>
<td>2464.28</td>
<td>2841.48</td>
<td>3190.55</td>
<td>3351.46</td>
<td>0.6263</td>
</tr>
</tbody>
</table>

Table 2 Gray correlations between energy consumption and industrial development of Shandong, 2002-2008.

The results showed that: the correlation (0.7716) between oil and industrial output value ranks the first, indicating oil has the most important impact on the national economy in Shandong; industrial output of coal (0.6931) in the second place, indicating the current national in Shandong economic development is still mainly dependent on coal. Electricity (0.6263) ranks the third, exposing the irrational energy structure in Shandong. The consumption of electricity power in the economic development in Shandong is low and large amount of consumption of electricity of which main energy is coal and oil leads to the rising problems of environmental pollution.

5. Grey Relational Analyses of Environmental Pollution and Industrial Development in Shandong

In environmental pollution aspects, this paper selects waste water, waste residue, waste gas (SO$_2$ and dust) emissions. In order to measure and compare the size of correlation among three types of pollution and industrial development, the paper takes industrial output value for the master sequence and wastewater, SO$_2$, dust, waste emissions for the sub-sequence, 2002-2008, of Shandong to establish models, correlation shown in Table 3.

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>4518.87</td>
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<td>7576.12</td>
<td>9568.58</td>
<td>11555.99</td>
<td>13412.72</td>
<td>16102.19</td>
<td>1.0000</td>
</tr>
<tr>
<td>Wastewater</td>
<td>230.709</td>
<td>245.782</td>
<td>264.014</td>
<td>280.377</td>
<td>302.637</td>
<td>334.255</td>
<td>358.910</td>
<td>0.6647</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>169.00</td>
<td>184.00</td>
<td>182.00</td>
<td>200.00</td>
<td>196.00</td>
<td>182.20</td>
<td>169.20</td>
<td>0.6418</td>
</tr>
<tr>
<td>Dust</td>
<td>62.00</td>
<td>62.00</td>
<td>52.00</td>
<td>62.00</td>
<td>58.00</td>
<td>46.30</td>
<td>44.00</td>
<td>0.6040</td>
</tr>
<tr>
<td>Residue</td>
<td>6559.00</td>
<td>6786.00</td>
<td>7922.00</td>
<td>9175.00</td>
<td>11011.00</td>
<td>11934.70</td>
<td>12988.00</td>
<td>0.7038</td>
</tr>
</tbody>
</table>

Table 3 Gray correlations between industrial development and environment of Shandong, 2002-2008.

The results showed that: the correlation (0.7803) between residue and industrial output value ranks the first, the waste water (0.6647) in the second place, the so (0.6418) ranks the third, while the dust (0.6040) is the min. This is the cost of making the coal, oil as the primary energy. Along with rapidly economic development, people's living standards improve and awareness of environmental protection enhance, the proportion of electricity, natural gas and high-quality energy consumption will increase.

6. Basic Conclusions

Energy consumption, environmental protection and economic growth belong to an organic whole. Since reform and opening, Shandong is promoting energy production vigorously and the energy industry is growing fast. Meanwhile, the national economy grows rapidly. However, serious environmental pollutions have been made at the same time. Environmental pollutions will have a negative impact on the economic development eventually. This is a disharmony mode of economic growth. It is the basic requirements for the development of society to achieve energy consumption, economic growth and environmental protection constitute a dynamic balance. Recommend to control actively as the following
aspects and establish an effective, integrated, decision-making mechanism.

1. Optimize the industrial structure of Shandong, promote industrial upgrading, and promote energy, environment and economy to make a coordinated development. Improve the primary industry, secondary industry and the professional socialization of production levels, make industrial structure adjustment, and save energy further; give priority to the development of tertiary industry. The tertiary industry owns the characteristics: high technology content, good economic returns, low energy consumption, pollution less, full use of human resources, and it is an important way to improve the overall effectiveness and efficiency of the national economy.

2. Improve the energy consumption structure in Shandong, improve energy use efficiency and reduce environmental pollution. First of all, speed up establishing power grid in Shandong, make lower thermal power ratio, increase electricity generation, reduce coal terminal consumption; follow to implement high efficiency cleaning combustion technology and improve the technical equipment level, promote energy use to the direction of high efficiency and clean; finally develop new energy and renewable energy, broaden the applied range of wind power, nuclear power, tidal power and other new energy projects in Shandong.

3. Develop the circular economy vigorously through scientific and technological progress meanwhile protect the environment; promote the transform of economic structure. The circular economy put the clean production, energy utilization and integration of ecological design together. Make the environmental protection performance to be "low emission" or even "zero discharge" in which the development of circular economy consistent with the situation in Shandong and achieve continues support from environmental and energy to economy construction.

4. Establish relevant policies and regulations, legislation to regulate environment pollution soon. Shandong provincial committee and government should implement the decisions on the environmental protection. Start it from the main pollutants emission, then effectively promote water and air pollution prevention, strengthen law enforcement about environmental protection, and accelerate the construction of ecological province. Meanwhile keep the development of economy sustained and rapidly, make the environment becomes much better than now. More importantly, along with the people’s environmental protection consciousness improves, the understanding of environmental issues deepens and the concerned range expands unceasingly. So environmental protection will accelerate the pace of advance to the depth. Environmental information disclosure, public participation in environmental, planning and valuation, hearing of witnesses, green national economic accounting, cadres examinational, pollution-discharge right trade etc, also will gradually entered the comprehensive decision-making.

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