Pathways to a Low-carbon Economy for Inner Mongolia, China

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Abstract.

The aim of this paper is to study pathways to a low-carbon economy for Inner Mongolia whose economy highly depends on fossil energy. The paper analyzed the industrial and energy structure of the economy and further demonstrated the necessity of developing the low-carbon economy in Inner Mongolia, a typical province in the western China. In addition, the LMDI Decomposition Method is used to analyze the factors that affect the growth in carbon emission and the Grey Relational Analysis (GRA) is applied to examine the relation between the carbon emission and GDP growth. At last, the paper further studied the advantages of developing the low carbon economy in Inner Mongolia and suggested different modes and pathways for Inner Mongolia to achieve the low carbon economy.

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Keywords: LMDI; Gray Relational Analysis; Carbon Emission; Low carbon economy;

1. Introduction

The concept of “Low Carbon Economy” was first introduced in “Our Energy Future: Creating a Low Carbon Economy”, the Energy White Paper of the UK Government [1].

Scholars in this field generally believe that the low carbon economy is a development mode with low energy consumption, low pollution, low emission and high effectiveness, high efficiency and high performance [2]. Some hold slightly different views. Zhu (2009) thinks that low carbon economy is the transitional economic developing mode from high carbon energy to low carbon one, and the key is to reduce the consumption of high carbon energy and to develop the electric power with clean coal power [3]. Others like Zhuang (2008) carried out research on implementing the low carbon economic mode in China by suggesting that, with no impact on social economic development goal, the possible approaches of realizing low carbon mode are to optimize and adjust the energy structure, to improve energy efficiency,
to optimize industrial structure, to tap carbon sink potential, and to deepen international cooperation etc [4], whereas, Yong Jin (2008) pays more attention on science and technology innovation, consumption process optimization and support of state policies and regulations in the field [5].

2. Necessity of developing low carbon economy

Inner Mongolia, a province with abundant natural resources, is suffering from deterioration of ecological environment, caused by high carbon economic development mode characterized by energy-intensive economy, low energy efficiency, and unsustainable industrial structure.

2.1 High Energy Consumption and High Carbon-based Energy Structures

Inner Mongolia has the coal reserve of 7,016 ton, which ranks first in China and 85% of Inner Mongolia’s energy consumption heavily depends on coal. In 2009, the total energy production was 401,858,500 tons of SCE (Standard Coal Equivalent) and the total energy consumption was 174,736,800 tons of SCE [6].

2.2 High Growth and Energy-intensive Industrial Structure

Recently, the fast growth of Inner Mongolia’s economy mainly depends on the secondary industry while the energy-friendly tertiary industry ranks last. In 2009, the proportion of primary/secondary/tertiary industry of Inner Mongolia is 9.5:52.5:38, but the average proportion of tertiary industry in the developed countries could surpass 70%.

2.3 Deterioration of Ecological Environment

Inner Mongolia is among the regions of the lowest amount of precipitation and the highest amount of evaporation in China. The large quantity emission of greenhouse gases strengthens the greenhouse effect and aggravates the grassland desertification which severely affects the carbon sink ability of grassland.

3. Factors affecting increase in Carbon Emissions in Inner Mongolia

3.1 Decomposing Factors of Carbon Emissions based on LMDI method

1) Research Method

Based on the basic framework of Johan etc. (2002), we get the following equation of carbon emission factored by scale of economy, industrial structure, technological advance and energy consumption [8]:

\[ C = \sum_i C_i = \sum_i F_i \times V_i \times T_i \times G_i \times Y \]  

(1)

Where \( F_i = \frac{C_i}{E} \) represent Carbon emission intensity of each energy; \( V_i = \frac{E_i}{E} \) represent the proportion of one kind of energy in the total energy; \( T_i = \frac{E_i}{E} \) represents the energy efficiency of each industry; Therefore, the carbon emission \( C_i \) of each year is relative to the carbon emission \( C_0 \) in the base year, which is shown in the equation (2):

\[ \Delta C = C_i - C_0 = \Delta C_F + \Delta C_V + \Delta C_T + \Delta C_G + \Delta C_Y \]  

(2)

Where \( \Delta C_F \) represents the carbon emission intensity factor; \( \Delta C_V \) is the energy structure factor; \( \Delta C_T \) represents energy efficiency factor which equals to the technological advance factor; \( \Delta C_G \) is the industrial structure factor; \( \Delta C_Y \) is the scale of economy factor. Due to the carbon emission intensity of each individual
energy is fixed and constant, $\Delta C_f = 0$. Based on the method of LMDI, each factor can be decomposed into the following equations:

\[
\begin{align*}
\Delta C_V &= \sum_i W_i \ln \frac{T_i'}{T_i} \\
\Delta C_T &= \sum_i W_i \ln \frac{V_i'}{V_i} \\
\Delta C_G &= \sum_i W_i \ln \frac{G_i'}{G_i} \\
\Delta C_Y &= \sum_i W_i \ln \frac{Y_i'}{Y_i}
\end{align*}
\]

(3) (4) (5) (6)

Where $W_i$ is:

\[
W_i = \frac{C_i' - C_i^0}{\ln C_i' - \ln C_i^0}
\]

(7)

2) Research Results and Analysis

The data used in this paper comes from the 2000-2010 Inner Mongolia Statistical Yearbooks while the carbon emission is computed by the above equation. The base year is 1990. The result is shown in Table 1. It is known from the Table 1 that the energy structure factor has a positive influence on carbon emissions. Technological advance factor has a negative influence on the carbon emission. This factor contributes to the energy efficiency in each industry, which leads to the reduction of carbon emissions; Industrial structure also has the Negative correlation with the carbon emission.

Through LMDI analysis it is clear that the energy structure and the economic scale have a positive correlation with the quantity of carbon emission.

Table 1 2000-2008 Four Factors’ Influence on The Carbon Emission In Inner Mongolia

| Year | $\Delta C_V$  | $\Delta C_T$  | $\Delta C_G$  | $\Delta C_Y$  |
|------|---------------|---------------|---------------|---------------|
| 2000 | 5678.456      | -5.932        | -0.005        | 0.872         |
| 2001 | 6239.336      | 3.100         | -0.027        | 2.007         |
| 2002 | 6815.704      | 16.361        | -0.054        | 3.462         |
| 2003 | 14385.32      | 32.985        | -0.437        | 6.207         |
| 2004 | 4707.499      | 30.567        | -0.120        | 11.001        |
| 2005 | 19844.053     | 43.201        | -1.739        | 17.414        |
| 2006 | 22823.591     | 41.710        | -4.890        | 19.780        |
| 2007 | 31974.594     | 15.960        | -9.407        | 48.970        |
| 2008 | 14979.825     | -25.087       | -12.602       | 7.228         |

3.2 Factor Relativity Analysis based on Gray Relational Analysis

The Gray Relational Analysis is a method used to find out trends of changes in various factors in a system. When the change trend of two factors is same, those factors are in high relation; Conversely, they are in low relation. Therefore, Gray Relational Analysis provides a quantitative measurement to the system development trend[9].
is initial value of the characteristic sequence and \( Y_i \) is the value of the system behavior sequence. Gray relational coefficient between \( Y_0 \) and \( Y_i \) is

\[
\xi(k) = \frac{\min_{i \in [k]} \{Y_i(k) - Y_0(k)\} + \zeta \max_{i \in [k]} \{Y_i(k) - Y_0(k)\}}{[Y_0(k) - Y_i(k)] + \zeta \max_{i \in [k]} \{Y_i(k) - Y_0(k)\}}
\]

(8)

\( \zeta \) is the recognition coefficient and \( \zeta \in [0,1] \), generally \( \zeta = 0.5 \) (k=1, 2, 3, ..., n: i=1, 2, 3, ..., m). To find out the gray relational grade between the initial characteristic sequence and the system behavior sequence \( m \) of \( Y_0 \), we start to sort gray relational grade on the basis of the magnitude of \( \xi(k) \), when relational grade close to 1, it is stated that the relational grade is bigger. As the rule of thumb, \( \zeta = 0.5 \) when relational grade is larger than 0.6, we believe the relevance is marked [9-10]. Making the variable sequence to non dimensional, which not only keep the primary data united, but also keep the comparative standard united to each variables. We make the non dimensional to the variable sequence, it is formed non dimensional sequence. Non dimensional use initial value operator, as:

\[
Y_j(k) = \frac{Y_j(k) - Y_{j,0}}{Y_{j,\text{max}} - Y_{j,\text{min}}}
\]

\( j \) and \( i \) in the formula is \( j = 0, 1, 2, ..., m; \) \( i = 1, 2, 3, ..., n \). The data comes from 2010 Inner Mongolia statistic yearbook, we get the table 2 through the excel analysis and computation.

The paper studied six trades among three industries considering each trade has certain affect on GDP and carbon emission. The primary industry contains farming, forestry and animal husbandry. The secondary industry includes manufacturing and construction business, and the tertiary industry contains transportation, post and telecommunication, wholesales and retails, and others. Now we set the energy consumption of each trade as the system behavior sequence: X1 (Agriculture, forestry, animal husbandry), X2 (Manufacturing), X3 (Construction), X4 (Transport posts and telecommunications), X5 (Wholesale and retail trade), X6 (Others tertiary industry). The carbon emission and regional GDP are set as the system characteristic sequence: \( Y_0 \) and \( Y_i \). All data is processed in Excel and the result is shown the Table 2.

|       | X1     | X2     | X3     | X4     | X5     | X6     |
|-------|--------|--------|--------|--------|--------|--------|
| \( Y_0 \) | 0.9479 | 0.9613 | 0.8729 | 0.9453 | 0.7972 | 0.8882 |
| \( Y_1 \) | 0.9423 | 0.9667 | 0.8774 | 0.951  | 0.7946 | 0.8663 |

It is clear that when carbon emission is the system characteristic sequence \( Y_0 \), there is the result of \( Y_{01}, Y_{02}, Y_{03}, Y_{04} \); when the regional GDP is the system characteristic sequence, there is \( Y_{01}, Y_{02}, Y_{03}, Y_{04}, Y_{05} \).

Through the above sorting result of the gray relational grade, it is clear that manufacturing ranking first in the secondary industry have close relation to GDP and carbon emission. It means GDP increase depend on the secondary industry which leads to the most carbon emission. Conversely, the primary industry and the tertiary industry have less contribution to GDP growth than the secondary industry, and less contribution to the carbon emission as well.
4. The Pathways To Low Carbon Economy in Inner Mongolia

Through studying the factors affecting the carbon emission, the paper found the reason of high carbon and further analyzed the advantages of Inner Mongolia to develop low carbon economy. On the basis of the above study, the paper put forward the pathways to develop low carbon economy in Inner Mongolia.

1) To develop renewable energy production base. Inner Mongolia is rich in wind energy and solar energy, which the cost of developing green energy resource is inexpensive.

2) To build coal derived clean fuel base. Inner Mongolia current has two of clean fuel production lines. With development of the low carbon technology, the clean fuel has the great potential to replace the high carbon fuel in future.

3) To develop the market base for carbon emissions exchange. Inner Mongolia ought to develop carbon sink under the superior condition of the big size of forest and grasses so as to the high storage of carbon sink, the vast area of land which could plant trees and grasses to increase carbon sink.

4) To tap carbon sink potential and develop the base of carbon sink of forests and grasslands. Inner Mongolia should carry out ecological construction projects, improve management level of forest, and further build the base of forests and grasslands carbon sink.

5) To build low carbon consciousness through constructing educational base for low carbon development. Inner Mongolia should improve the society energy saving and environmental protection awareness, advocate a change in the concept of consuming through a systematic and popular education and establish a rational low carbon consumption structure and various way of low carbon consuming in whole society.

5. Conclusion

The paper has given full consideration of the necessity and advantages of Inner Mongolia in developing the low carbon economy confirming that Inner Mongolia is rich in fossil energy and renewable energy and huge reserves of carbon sink. Through LMDI decomposition, the factors affecting the carbon emission in Inner Mongolia are identified and sorted. The study found that energy structure and the scale of economy has positive effect on the carbon emission while the technology factor and the changing industrial structure has adverse effect on it. The Grey Relational Analysis result proved that carbon emission has strong relations with GDP and the secondary industry development. Based on the above analysis, the paper suggested several pathways for Inner Mongolia to develop the low carbon economy.

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