Carbon Emissions Reductions Trend Analysis and Research in Yangtze River Delta

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Abstract: Through constructing GM (1,1) and markov structure model, we predict total energy consumption and energy consumption structure in Yangtze River Delta. Using the relationship between the energy consumption quantity, structure and the carbon emissions (Units of energy consumption coefficient of carbon emissions), the total carbon emissions of Yangtze River Delta in 2009-2015 are calculated. Then we propose the concrete measures about decreasing the carbon emissions of Yangtze River Delta.

Keywords: carbon emission; energy consumption; energy structure; emission factors; GM(1,1)

1 Introduction
The global climate change is the most significant environment question which the humanity faced until now, is also one of the most complex challenges which the 21st century humanity faces. Regarding slows down the climate warming international negotiations is not only to relate humanity’s living environment, but also directly affect the process of modernization and sustainable development of developing countries. At present the international scientific circles believed that the climatic change is at least causes by the human activity. One of the fundamental measure to solve climate change is to reduce anthropogenic emissions of greenhouse gases. The research carbon dioxide carbon emissions question has the very vital significance.

Shaofeng Chen in [1] discussed technological progress and the relationship between carbon emissions. Proved that science and technology drive the evolution of carbon emissions under the order to follow the three inverted U curve laws. Yanling Chen in [2] established the impact of China’s carbon dioxide emissions factor models, system analysis these factors to our country average per person carbon dioxide withdrawal influence. Qin Zhu in [3] carried on the factor using the LMDI decomposition method to the energy use carbon emissions to decompose, obtained the economic output effect to be biggest to our country this stage energy use carbon emissions technical progress factor. Zheng Wang in [4] accounted for the major source of carbon emissions - carbon emissions caused by energy consumption, and carried on the contrastive analysis in the provincial level criterion to China’s carbon emissions. The face of international demands for the voice of China’s rising emissions, and in 2012 the Kyoto Protocol expires, the arrival of a new round of negotiations, China faces great pressure to reduce emissions. China has recognized that energy consumption, carbon emissions and the relationship between economic growth. National Development and Reform Commission made it clear that the reduction of carbon emissions targets to write 12-5. Therefore, understanding the status of the Yangtze River Delta region and the search for carbon emissions reductions in routes and measures to realize the objectives of the overall control is important. This article will study the Yangtze River Delta carbon emission behavior and future change tendency, and will give pointed strong reduces a row of measure.

2 Carbon emissions relationship
The carbon emissions are mainly the carbon dioxide which the fossil fuel consumption discharges, namely consumption coal, petroleum, natural gas emissions, therefore as follows carbon emissions relations in the formula only lists the energy

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carbon emissions relationship. Formula for calculating carbon emissions, through carbon dioxide emission factor, the amount of carbon dioxide emissions in the process of fossil fuel can be calculated directly.

Since the differences among the fuel combustion rate, carbon oxidation rates and other indicators, the carbon emissions conversion ratio provided by different organization are slightly different. It is more credible to use the averaging values to determine the energy consumption for the carbon emission factor. Therefore, in accordance with the measured physical quantity of carbon emissions relationship is:

\[ Q_t = 0.7329 * E_c + 0.5574 * E_o + 0.4226 * E_n. \]  (1)

Where, \( Q_t \) is the Yangtze River Delta carbon emissions total quantity, \( E_c \) is the coal consumption quantity of goods produced (ton), \( E_o \) is the petroleum consumption quantity of goods produced (ton), \( E_n \) is the natural gas consumption (ton). However, fossil fuels are not all for the consumption, there are some raw materials for chemical production. At this time, some carbon in the fuel production process will fix to the product, and will not emit carbon dioxide. According to the National Energy Research Institute, China’s solid-fuel carbon sequestration rate is 0.2\% , the liquid fuels is 14.7\% , gas fuels is 1.7\% . Therefore (1) transforms to

\[ Q_t = 0.998 * 0.7329 * E_c + 0.853 * 0.5574 * E_o + 0.983 * 0.4226 * E_n. \]  (2)

In order to study the energy structure change on the Yangtze River Delta the impact of carbon emissions, to predict the future carbon emission reduction targets Yangtze River Delta and the effect of the amount required in the physical relation between carbon emissions and further derived based on the total energy consumption and carbon emissions relationship, National Development and Reform Commission published reference range of the coefficient of energy converted into coal equivalent: 1 ton coal = 0.7143 tons of standard coal, 1 ton of oil = 1.4286 tons of standard coal, 1 ton = 1.7 tons of standard coal gas.

Assumed Yangtze River Delta total annual energy consumption is tons of standard coal. Including coal, oil, natural gas share of total energy consumption respectively, \( \alpha, \beta, \gamma \), then the physical quantity corresponding to three types of fuel are: \( E_c = \alpha * E_t / 0.7143 \), \( E_o = \beta * E_t / 1.4286 \), \( E_n = \gamma * E_t / 1.4286 \). Above three type generation of person formula in (2), the calculation of the energy structure can be drawn in accordance with the relationship of carbon emissions

\[ Q_t = E_t (\alpha * 1.025 + \beta * 0.3328 + \gamma * 0.2443). \]  (3)

By (3) style can be seen: each ton standard coal’s emission factor is \( K = \alpha * 1.025 + \beta * 0.3328 + \gamma * 0.2243 \). Under the different energy structure the \( K \) value is also different, the coal proportion is higher, the \( K \) value is higher, but the petroleum, the natural gas proportion is higher, the \( K \) value is lower.

3 Carbon emissions forecast

3.1 GM (1,1) model

Grey forecasting mode called the GM model, GM (1,1) expresses first-order, single-variable linear dynamic model. For a variable: If \( \chi^{(0)} \) has \( m \) mutually corresponding data, it can form a number of columns \( \chi^{(0)}(1), \chi^{(0)}(2), \cdots , \chi^{(0)}(m) \). Makes an accumulation to \( \chi^{(0)} \), produces new sequence \( \chi^{(1)} \), we have

\[ \chi^{(1)}(j) = \sum_{m=1}^{j} \chi^{(0)}(m). \]  (4)

Then it may produce new sequence \( \chi^{(1)}(1), \chi^{(1)}(2), \cdots , \chi^{(1)}(m) \). We can establish the differential equation of the albinism form to the new sequence ,

\[ \frac{d \chi^{(1)}}{dt} + a \chi^{(1)} = u. \]  (5)

The type (5) may be represented as \( \hat{a} = (a, u)^T \). And \( a \) is called the development ash number, \( u \) is the endogenous control ash number. According to least squares method estimate parameter \( \hat{a} \), then we get

\[ \hat{a} = (B^T B)^{-1} B^T y_n. \]  (6)
In the formula: \( B = \begin{pmatrix} \frac{-1}{2} (\chi^{(1)}(1) + \chi^{(1)}(2)) & 1 \\ \frac{-1}{2} (\chi^{(1)}(2) + \chi^{(1)}(3)) & 1 \\ \vdots \\ \frac{-1}{2} (\chi^{(1)}(m-1) + \chi^{(1)}(m)) & 1 \end{pmatrix}, \quad y_n = (\chi^{(0)}(2), \chi^{(0)}(3), \ldots, \chi^{(0)}(m))^T. \) By (5), GM(1,1) model is

\[
(\hat{x}^{(1)})(j + 1) = \left| \chi^{(0)}(1) - \frac{u}{a} \right| e^{-aj} + \frac{u}{a}.
\]

Then we have

\[
(\hat{\chi}^{(0)})(j + 1) = (\chi^{(1)})(j + 1) - (\chi^{(1)})(j) \quad (j = 1, 2, \ldots, m).
\]

From this may calculate \( j + 1 \) year predicted value \( (\hat{\chi}^{(0)})(j + 1) \).

### 3.2 Yangtze River Delta region’s total energy consumption forecast

As the Yangtze River Delta region’s total energy consumption and the growth of economic development, energy structure, industrial structure, and many other factors, some of which factors are identified, and some factors are uncertain, so it can be seen as a gray system.

According to the Yangtze River Delta region’s total energy consumption data (Tab 1). Establishes GM(1,1) model, obtains \( \hat{a} = \begin{bmatrix} a \\ u \end{bmatrix} = \begin{bmatrix} -2.470694 \\ 20261.32422 \end{bmatrix}. \) According to \( (\hat{x}^{(1)})(j + 1) = \left| \chi^{(0)}(1) - \frac{u}{a} \right| e^{-aj} + \frac{u}{a} \), calculates \( (\hat{\chi}^{(0)})(j + 1) \), and \( \chi^{(0)}(1) = 24137.54, \) Therefore \( (\hat{x}^{(1)})(j + 1) = 24137.54 - \frac{20261.32422}{e^{0.149436}} + \frac{20261.32422}{e^{0.149436}}. \) Obtains the forecast data series by \( (\hat{x}^{(0)})(j + 1) = (\hat{x}^{(1)})(j + 1) - (\hat{x}^{(1)})(j). \)

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy consumption</td>
<td>24137.54</td>
<td>27379.56</td>
<td>31881.99</td>
<td>37230.86</td>
<td>40932.13</td>
<td>44865.94</td>
<td>47206.26</td>
</tr>
</tbody>
</table>

According to the results of the model, total energy consumption average relative error is 2.65% in Yangtze River Delta. Simulation results better. Use this as a prediction, total energy consumption in the Yangtze River Delta region continue to maintain high growth between 2002-2008 (Tab 2).

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy consumption</td>
<td>49246.12</td>
<td>53719.22</td>
<td>55981.76</td>
<td>58113.37</td>
<td>61751.95</td>
<td>63692.49</td>
<td>65892.46</td>
</tr>
</tbody>
</table>

### 3.3 Predict the energy consumption structure in Yangtze River Delta

Here we use energy consumption structure in the Yangtze River Delta region of coal, crude oil, natural gas, other energy sources based on structural data for the study (Tab 3).

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>62.25</td>
<td>61.43</td>
<td>61.35</td>
<td>60.66</td>
</tr>
<tr>
<td>Crude oil</td>
<td>25.85</td>
<td>24.64</td>
<td>23.88</td>
<td>22.86</td>
</tr>
<tr>
<td>Natural gas</td>
<td>1.21</td>
<td>2.12</td>
<td>2.62</td>
<td>3.08</td>
</tr>
<tr>
<td>Others</td>
<td>10.69</td>
<td>11.81</td>
<td>12.15</td>
<td>13.40</td>
</tr>
</tbody>
</table>

IJNS homepage: http://www.nonlinear science.org.uk/
Structural shift in the system established by the homogeneous Markov chain model based on quadratic programming to further discuss the Yangtze River Delta region of the evolutionary trend of energy consumption structure. As future phases of the situation only with the current situation, whereas the situation has nothing to do with the past, so that the transfer process of a homogeneous Markov. X is the total energy consumption in Yangtze River Delta. $X_i(t)$ is the energy consumption of the Yangtze River Delta region accounts for the proportion of total energy consumption in year t, namely $X_i(t)/X$. $W_i(t) = \sum_{j=1}^{4} W_j(t-1)P_{ij} + \varepsilon_j(t)$, Let the $\sum_{j=1}^{n-1} \sum_{i=1}^{4} \varepsilon_j(t)$ error to be smallest and establish two planning models:

$$
\min \sum_{i} \sum_{j} (W_j(t) - \sum_{i=1}^{4} W_i(t-1)P_{ij})^2 \text{s.t.} \begin{cases}
0 \leq P_{ij} \leq 1 \\
\sum_{i=1}^{4} P_{ij} = 1
\end{cases}
$$

We obtains 2005-2008 year transition probability matrix $P = \begin{bmatrix}
0.9814 & 0.0103 & 0.0083 \\
0.9798 & 0.0202 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{bmatrix}$, from this we get various energy structure prediction (Tab 4).

### Table 4: Prediction of energy consumption structure between 2009-2015 in Yangtze River Delta (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>59.53</td>
<td>58.42</td>
<td>57.34</td>
<td>56.27</td>
<td>55.22</td>
<td>54.19</td>
<td>53.18</td>
</tr>
<tr>
<td>Crude oil</td>
<td>22.38</td>
<td>21.95</td>
<td>21.50</td>
<td>21.06</td>
<td>20.64</td>
<td>20.22</td>
<td>19.81</td>
</tr>
<tr>
<td>Natural gas</td>
<td>4.19</td>
<td>5.24</td>
<td>6.29</td>
<td>7.32</td>
<td>8.32</td>
<td>9.32</td>
<td>10.29</td>
</tr>
<tr>
<td>Others</td>
<td>13.90</td>
<td>14.39</td>
<td>14.87</td>
<td>15.35</td>
<td>15.82</td>
<td>16.27</td>
<td>16.72</td>
</tr>
</tbody>
</table>

As can be seen from Tab 4, as natural gas, new energy development, the Yangtze River Delta region transfers from a coal-based energy structure to the natural gas and other energy.

Using formula (3), standard coal per ton of carbon emission factor K (Tab 5), As the coal in total energy consumption structure has been continuously decreasing, significantly improving the energy structure in Yangtze River Delta, the standard coal per ton of carbon emission coefficient K decreasing. Using the calculated K, we obtain the predictive value of carbon emissions of the Yangtze River Delta region (Tab 6).

### Table 5: Variable K coefficient

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>0.6705</td>
<td>0.6607</td>
<td>0.6512</td>
<td>0.6419</td>
<td>0.6325</td>
<td>54.19</td>
<td>0.6234</td>
</tr>
</tbody>
</table>

### Table 6: Predictive value of carbon emissions of Yangtze River Delta (Unit: million tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of carbon emissions</td>
<td>33019.78</td>
<td>35493.92</td>
<td>36456.36</td>
<td>37296.14</td>
<td>39059.53</td>
<td>39710.27</td>
<td>40495.41</td>
</tr>
</tbody>
</table>

### 4 Conclusions

From Tab 6, with the economic development of Yangtze River Delta, carbon emissions of Yangtze River Delta region has been an upward trend, despite the downward trend of emission intensity, but the arduous task of carbon emissions. Therefore, the Yangtze River Delta need to achieve reduction of carbon emissions. Here we give the following specific measures:

Reduce the proportion of coal-fired power generation. Increase the share of oil, natural gas, hydropower, nuclear power, improve energy production and consumption structure. If through alternative energy, oil, natural gas, hydropower, nuclear power share, change the coal-dominated energy structure and carbon emissions from the Yangtze River Delta region will greatly ease.

Improve energy efficiency, energy conservation. In the case of difficulties in the energy restructure, improving energy efficiency, energy conservation should be a long-term economic development as a policy. Not only this conforms to the
economic growth way from the extension to the intensive radical transformation need, moreover is advantageous in reduces the economic growth to the energy the dependence, causes it to become the most effective carbon to reduce a row of way.

Enhance research in emission reduction technologies, and international cooperation. Due to technical and economic reasons, the current coal-dominated energy structure and speed of adjustment are difficult breakthrough. Carbon dioxide emissions from burning coal is a major source of carbon emissions. Therefore, we must increase the coal-fired emissions through capturing and sequestration of carbon dioxide emission reduction technologies such as energy research and development efforts and international cooperation in order to reduce the environmental impact of coal.

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