Research on China's Carbon Reduction Efficiency—Based on Foreign Trade and Foreign Direct Investment Perspective

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ABSTRACT: This paper, standing on the perspective of foreign trade and foreign investment, taking export dependency, foreign trade competitiveness, FDI/GDP, R&D input intensity as the input indicators of carbon emissions, taking carbon emissions intensity and carbon emissions increase or decrease proportion as the output indicators of carbon emissions, calculates the carbon emissions efficiency by using DEA model. The empirical results indicate that carbon efficiency governance in recent years of China is not efficient enough but at the same time of economy development, the carbon dioxide emissions that brought by per unit of GNP falls which implies the startup of low carbon economy developing mode. To realize the synchronous follow up of economic growth and carbon emission reduction, the key points of our adjustments will be the import-export commodity structure, the introducing direction of foreign investment and the inner innovation and outer introduction of technology, supplemented by pollution abatement and policy guidance, the efficiency of carbon reduction will be satisfying higher.

1 PREFACE

In recent years, low carbon concept has been widely responded and gradually become a consensus in the tide of global warming, accordingly low-carbon economy has joined in the strategic planning of countries. According to the Britain Petroleum Energy Statistics Yearbook, in the year of 2013 human generated carbon emissions reached 36 billion tons, especially China and the United States, the top two biggest emitters of greenhouse gases, their emissions accounted for 42% of total global emissions, which highlighted China's carbon emission reduction pressure. Therefore China is hammer at carbon reduction commitment. China confirms the its carbon emission reduction goal: by 2020, striving to achieve the maximum target ,which is the carbon dioxide emissions intensity40% - 45% lower than in 2005. By 2030, carbon dioxide emissions brought by per unit of GDP lower to 60% - 65% than in 2005.

Under the background of economic globalization, the rapid development of China's foreign trade brings huge traction to its economy, also boosts output, which means an increase of carbon dioxide because of more output, more energy. In terms of the foreign trade structure of our country, high energy-consuming and high carbon-emission products dominates, so reducing carbon emissions while keeping the sustainable development of foreign trade must rely on advanced technology and equipment. Utilizing foreign capital can ideally solve the problem of lacking funds and technology. So it is the core Point that based on the perspective of foreign direct investment and foreign trade commodity structure in the study of carbon emission reduction efficiency when formulating national carbon emission reduction policies, direction and methods, and will promote the quality of whole economy growth and energy reservation and emission reduction.

At present, scholars devoting to literature researches under the foreign trade and carbon emission perspective mainly involves Ye Qi, Hui-Min Li, Ming Xu (2008). Study found that, 1997-2006, our country discharged huge amounts of carbon emissions into other countries in the form of product export. Especially, 1997-2004, implicit carbon net exports accounted for the proportion of the total carbon emissions between 0.5% and 2.7%. After 2004 it increased rapidly, reached around 10% in 2006. Wang and Watson (2007), Weber et al. (2008), Ye Qi (2008), Yan and Yang (2010), Lin and Sun (2010), You-Guo Zhang (2010), Shu-Zhong Ma and Ying Chen (2010) and others researches show that in recent years, China's foreign trade on the whole has become a net exporter of carbon. Shui and Harriss (2006), Xian-Ping Yin and Ming Cheng (2010), Liu et al. (2010), Li and Hewitt (2008), and other people has also come to the conclusion that China is in the state of implicit carbon net export after investigating the bilateral trade of Sino-US, Sino-Japan and Sino-UK.
In the study of foreign direct investment, carbon emissions, carbon emissions efficiency, mainly focus on FDI, through various channels, produced significant influence to the host country on the source of energy, resource consumption and emissions (Grimes and Kentor, 2003; Fisher - Vanden et al., 2006; Yasmine Mercanetal., 2007; Jorgenson, 2007; Perkins and Neumayer, 2008; Cole et al., 2008; Acharkyya, 2009). Take the current FDI scale and its role in China’s economy into consideration, FDI has a great influence on China’s CO2 emission. Furthermore, FDI’s capital effect and technology effect of high-carbon-emission industry and low-carbon-emission industry appear different.

Researches on the carbon reduction efficiency evaluation model mainly involves factor decomposition model of CO2 emission reduction efficiency based on the production theory by Wei Zhang, Qi-Gui Zhu, Han-Wen Li (2013), this model decomposes the factors that influence efficiency of CO2 emission reduction within China, analyzes the impact that the energy use and CO2 emissions technology progress and efficiency will have on the CO2 emission reduction efficiency of 30 provinces in our country, furthermore build the DEA model respectively input and output oriented with constant returns to scale, which applies environmental directional distance function, regards capital, labor and energy as input factors, regards GDP and CO2 emissions as output factors, separately measure the total factor CO2 emission reduction efficiency of 30 provinces domestically. Portela, etc. (2004) put forward a RDM (Range Directional Model) which considering undesirable output to measure environmental technology efficiency, this method ensures the measure result is steady even though sample units and variable transformations changes, thereby they can better adapt to the introduction of the negative form of the undesirable output. Based on the RDM model, Sharp etc. (2007), presented a modified SBM model (MSBM), it inherits the advantages of the RDM model, in the meantime took slack output and slack input into consideration in efficiency measurement, therefore acquire more valid measure results. Based on the production theory, Zhou & Ang (2008) presented a CO2 emission reduction efficiency factor decomposition model. Kao (2009) presented a parallel DEA model that had allowed endowing different weight to each subsystem in the same DMU (Decision Making Units), which offered a strong support for decision maker to indentify invalid sources. Kerstens and Woestyne (2011) presented a more general Farrell Generalized Proportional Distance Function (GPDF), therefore introduced negative input or output into the efficiency measuring progress. Based on the GPDFM producing structure, combining SBM model, Sahoo etc.(2011) presented a new efficiency measuring method, under the condition of assuming the undesirable output can be strongly tractable.

Researches from other aspects study carbon emission involve Liu-Hao Hong, Yi Zheng, Jian-Hui Yu (2013), which thinks energy reservation and carbon emission task is mainly aim at waste water, waste gas and solid waste. And choose China’s industrial wastewater emissions discharge rate, solid waste emission discharge rate, industrial SO2 removal ratio of total production, industrial smoke removal ratio of total production, industrial dust removal of total production, these five measured variable to assess China’s energy reservation and carbon emission reduction efficiency.

With a review of the literature we found that most of recent existing researches use DEA model to measure interprovincial, industrial energy conservation and carbon emission reduction efficiency. Carbon emission generates from output, and an increase of export and foreign investment will increase output, so it will be more reasonable to measure carbon emission reduction efficiency basing on the foreign trade structure and foreign direct investment. Thus, this paper will introduce relevant indicators about foreign trade structure and foreign investment, use DEA model to measure carbon emission reduction efficiency.

2 MEASURING METHOD, INDEX SELECTED AND DATA SOURCES

2.1 Measuring method

DEA method is a Data Envelopment Analysis method, founded by Charnes etc. in 1978. It is based on the concept of relative efficiency, evaluate the validity of the same kind multi-index input, multi-index output economy system.

DEA model is:

\[
\begin{align*}
\min_{\lambda, \theta, \varepsilon} & \quad -C = \sum_{j=1}^{m} \lambda_j - \sum_{i=1}^{n} \varepsilon_i + \sum_{i=1}^{n} s^-_i \\
& \quad \sum_{j=1}^{m} \lambda_j x_{ji} + s^-_i = \theta x_{oi} \\
& \quad \sum_{i=1}^{n} \lambda_j x_{ji} = y_{oi} + \varepsilon \\
& \quad s^+_i \geq 0, s^-_i \geq 0 \\
& \quad \lambda_j \geq 0, \quad j = 1, 2, \ldots, n
\end{align*}
\]  

(1)

\(J\) is called DMU (Decision Making Unit), assessing indicator system is consisted by \(m\) input and \(t\) output. They respectively mean “resources consumed” and “work result”. Set \(x_{ji}\) as the input that No. \(j\) DMU devotes to No. \(i\) kind of input, set as the output that No. \(j\) DMU devotes to No. \(r\) kind of output, set \(s^+_j\) and \(s^-_j\) as slack variables, set \(\varepsilon\) a Archimedes dimensionless, and \((\varepsilon = 1, 0)^t\) when counting. Set \(\lambda_j, s^+_j, s^-_j, \theta\) as estimating
parameters. The above model is $C^2 R$ model, it means to find $n$ DMU’s some sort of linear combination, minimize input as much as possible under the condition of making its output no less than No. $j_0$ DMU.

Using this model, we can evaluate every DMU’s relevant efficiency. Set Year 2010-2014 as DMU, define relevant efficiency as the of carbon emission reduction rate, it shows in the accelerating period of globalization the carbon emission intensity and export carbon emission amount as domestic industries are constantly integrated with foreign investment and foreign trade structure gradually improve. If in this environment, the carbon intensity and export of carbon emissions is larger, shows lower carbon reduction efficiency. When $\theta = 1$, it indicates a low efficiency of carbon emission reduction; when $\theta = 0$, it indicates a high efficiency of carbon emission reduction; the more $\theta$ reaches to 1, the lower efficiency of carbon emission reduction; the further $\theta$ gets away from 1, the higher efficiency of carbon emission reduction. Due to data limitations, this article selects each department export dependency, trade competitiveness, FDI/GDP, R&D input intensity these four indicators, using each departments’ data in 2010-2014 for empirical analysis of carbon reduction efficiency.

2.2 The data source and index calculation formula
Data in 2010-2014 are from 2014 China Statistical Yearbook, Industrial Statistical Yearbook and China Statistical Yearbook of Science and Technology. The export dependency = exports/gross national product (GNP); Flat international competitiveness index = (E - I) / (E + I); In this paper, we use industrial enterprises’ research and experimental development activity funds to represent R&D, these enterprises possess designated size. Output indicators have carbon emissions intensity and carbon emissions increase or decrease proportion. Carbon emission intensity= carbon emission amount / added value of total output. This article adopts the method puts forward by ORNL to calculate the emission amount of carbon dioxide of the industrial burning of fossil fuels:

The carbon emission of coal = coal consumption * 0.982 * 0.73257
The carbon emission of fuel = standard coal equivalent * 0.982 * 0.73257 * 0.813
The Carbon emission of gas = standard coal equivalent * 0.982 * 0.73257 * 0.561

In the formula, 0.982 is valid oxidation percentage; 0.73257 is carbon content of per ton of standard coal; 0.813 is obtaining the same heat, the multiples of oil releases CO$_2$ to coal release CO$_2$; the above results are carbon dioxide emissions from all walks of life.

By the above data and formula, input and output parameter values are set out below:

<table>
<thead>
<tr>
<th>Table 1. Input and output index value in 2010-2014 (%)</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export Dependency</td>
<td>26.2</td>
<td>25.5</td>
<td>24.2</td>
<td>23.3</td>
<td>22.6</td>
</tr>
<tr>
<td>Trade Competitiveness</td>
<td>6.1</td>
<td>4.3</td>
<td>6</td>
<td>6.2</td>
<td>8.9</td>
</tr>
<tr>
<td>FDI/GDP</td>
<td>1.8</td>
<td>1.6</td>
<td>1.3</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>R&amp;D Input Intensity</td>
<td>0.98</td>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Carbon Emission Amount</td>
<td>2595</td>
<td>03.27</td>
<td>28944</td>
<td>30990</td>
<td>3169</td>
</tr>
<tr>
<td>Carbon Emission Increase or Decrease Proportion</td>
<td>7.9</td>
<td>11.5</td>
<td>7.1</td>
<td>2.3</td>
<td>-16.7</td>
</tr>
<tr>
<td>Carbon Emission intensity</td>
<td>4.1</td>
<td>3.85</td>
<td>6.2</td>
<td>5.88</td>
<td>5.5</td>
</tr>
</tbody>
</table>

3 THE EMPIRICAL ANALYSIS

According to DEA model, the DMU 2010 input-output equation is as follows:

$$m \leq n \theta - 10 \left( \sum s_j + \sum s_i + \sum s_s + \sum s_s' + \sum s_s' \right)$$
$$26.2 \lambda_j + 25.5 \lambda_i + 24.2 \lambda_s + 23.3 \lambda_s' + 22.6 \lambda_s'' + s_s' - 26.2 \theta = 0$$
$$6.1 \lambda_j + 4.3 \lambda_i + 6 \lambda_s + 6.2 \lambda_s' + 8.9 \lambda_s'' + s_s' - 6.3 \theta = 0$$
$$1.8 \lambda_j + 1.6 \lambda_i + 1.3 \lambda_s + 1.3 \lambda_s' + 1.2 \lambda_s'' + s_s' - 1.8 \theta = 0$$
$$0.98 \lambda_j + 1.2 \lambda_i + 1.3 \lambda_s + 1.4 \lambda_s' + 1.5 \lambda_s'' + s_s' - 0.98 \theta = 0$$
$$7.9 \lambda_j + 11.5 \lambda_i + 7.1 \lambda_s + 2.3 \lambda_s' - 16.7 \lambda_s'' - s_s'' = 7.9$$
$$4.1 \lambda_j + 3.85 \lambda_i + 6.2 \lambda_s + 5.88 \lambda_s' + 5.5 \lambda_s'' - s_s'' = 4.1$$
$$\lambda_j \geq 0, j = 1, 2, 3, 4, 5$$
$$s_j, s_i, s_s, s_s', s_s'' \geq 0$$

Other years omitted, by using LINDO software, we can obtain carbon reduction efficiency, see table below

<table>
<thead>
<tr>
<th>Table 2. Estimated Results of Carbon Reduction Rate $\theta$ in 2010-2014.</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$</td>
<td>0.88</td>
<td>0.86</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Data shows that in 2010-2014, China’s carbon reduction efficiency is not high. 2010 and 2011 $\theta$ were 0.88 and 0.86 and being 1 from 2012 to 2014, means lower efficiency.

4 THE CONCLUSIONS AND POLICY RECOMMENDATIONS

Based on the DEA model, from the perspective of foreign trade and foreign direct investment, this
article makes an empirical analysis of the efficiency of China's carbon emissions. We selected the export dependency, trade competitiveness, FDI/GDP, R&D input intensity as input indicators of carbon emissions, carbon emissions intensity and carbon emissions increase or decrease proportion as carbon output indicators. The empirical conclusion shows carbon efficiency is not high in China. Carbon emissions rose year by year, in 2013 reached a maximum; there was a slight decline while holding a steady export dependency. Trade competitiveness plummeted in 2011, in other years increased year by year, but the overall competitiveness is not high; Industrial enterprise research and experiment development funds increased year by year, but compared with other countries, the investment is relatively small. Carbon intensity declines in 2010, 2011, in 2012, emerged an increase, after a few years gradually declined; means at the same time of economy development, the carbon dioxide emissions that brought by per unit of GNP falls which implies the startup of low carbon economy developing mode. By analysis, although in recent years our country carbon efficiency is not high, no high efficiency, but our country has started the development of low carbon economy mode. To realize the synchronous follow up of economic growth and carbon emission reduction, the key points of our adjustments will be the import-export commodity structure, the introducing direction of foreign investment and the inner innovation and outer introduction of technology, supplemented by pollution abatement and policy guidance, the efficiency of carbon reduction will be satisfying higher.

Above all, export trade and foreign investment really had a great influence to carbon emissions in our country, the government should comprehensively consider the export trade and foreign investment's contribution to the economic growth in China and their impact on the environment, coordinating the relationship among export trade, foreign investment and environmental protection, more effective and reasonable environmental regulation measures come out while using foreign capital, encouraging export trade to expand exports scale, hammer at improving energy saving and emission reduction technology, government should focus on improving the efficiency of energy utilization of rapidly increase export department, reduce pollution emission intensity. Adjust the structure of export commodities, control part of the pollution-intensive products' exports, and improve the proportion in exports of low pollution, low energy consumption, high-tech products, endeavor the transformation of the export commodity structure in the direction of clean, avoid becoming a "pollution haven" of developed countries for their pollution transfer.

REFERENCES