The Relationship between Carbon Dioxide Emissions and Industrial Structure Adjustment for Shandong Province

Zhang Xiaoqing, Ren Jianlan
School of Population, Resources and Environment in Shandong Normal University

Abstract
From 2005, the industrial added value and carbon dioxide emissions in Shandong Province have been all ranked first in China. The article focuses on quantifying the relationship between CO₂ emissions and industrial structure adjustment. Cointegration tests indicate that there exist the long-term stable equilibrium relationship between industrial structure and the emissions in Shandong Province. Granger causality tests show that the industrial structure is the reason for the change of the emissions, but the latter is not a reason for the former. By building the decomposition model of CO₂ emissions, the contribution of economic growth, industrial structure and technical efficiency to the growth of CO₂ emissions are measured and three important conclusions are drawn: (1) the change in the total economy is the most important factor to promote the emissions; (2) the change in industrial structure has the different contribution to the emissions in different stages, in 1994-99 and 2006-09, the contribution rate is negative, which indicates that changes in industrial structure curb the emissions; (3) technical efficiency is the main factor to reduce emissions, but compared with the role of economic growth, the effect of technical efficiency is very limited.

Key words: carbon dioxide emission; industrial structure; relationship; measures; Shandong Province

1. Introduction
In recent 200 years, with continuing population growth and accelerating industrialization and urbanization process, world energy consumption have been sharply increased and ecological environment is gradually worsening, climate warming has been seriously threat to sustainable human development. It becomes a major global challenge to adapt climate change. Greenhouse gases are the culprit of global warming. According to the 2007 IPCC Fourth Assessment Report, the main source of greenhouse gases is the burning of fossil fuels, which release the 95.3% of the total CO₂ in 2004 (which didn’t include the increment of CO₂ caused by deforestation and the reduction of biomass). The total CO₂ emissions in China has surpassed the United States since 2008 and ranks the first in the world. From 2005, the
industrial added value and CO₂ emissions in Shandong Province have been simultaneously ranked first in China. For a long time the coal-dominated energy structure has made the province’s social and economic development give tremendous pressure on the environment. Therefore, in Shandong Province, how to control and reduce CO₂ emissions, how to change the economic development way and adjust the economic structure will be one of the most urgent issues in the future.

Many domestic scholars discuss the relationship between economic growth and energy consumption as well as CO₂ emissions from the perspective of qualitative and quantitative study. However, fewer scholars analyze the relationship between low carbon economy and industrial restructuring, and the studies often focus on the qualitative analysis. Scholars generally suggest that energy consumption of industrial production accounts for 70% of the total in China. It is far more difficult to reduce the emissions in China than in the developed countries where is the consumer-dominated CO₂ emissions. Energy saving and emission reduction by industrial restructuring should be preferred. If the industrial structure is optimized and the quality of economic growth is promoted as well as the technical progress keep the average annual rate of 3% in the next 10 years, it maybe offset the negative impacts on the economy which is led by the CO₂ emission[1]. Therefore, the article focuses on quantifying the relationship between the CO₂ emissions and industrial structure adjustment by taking the Shandong as a case study, which includes causality test and factors contribution analysis.

2. Causality Test between Industrial Structure and Carbon dioxide Emissions in Shandong Province

2.1 Stationarity test

Referencing to the calculation method of CO₂ emissions made by many scholars[2] (XU Guo quan, 2006), we estimate CO₂ emissions from 1994 to 2009 on energy consumption in Shandong Province by using formula:

\[ C = \sum_j C_j = \sum_j m_j \cdot \delta_j \]  (1)

In equation (1), C indicated for the CO₂ emissions, in units of tons; C_j for the j-species final energy consumption of CO₂ emissions; m_j for the j-species final energy consumption, calculated by standard coal; \( \delta_j \) for the CO₂ emission coefficient of the j-species final energy, in units of tons / tons; j for the types of energy, taking 17 types. There are 15 categories of energy CO₂ emission coefficient which are published by IPCC. The emission coefficient of remaining two types of energy (other coal washing and coal products) are equal to the coefficient of raw coal. Furthermore, because the original consumptions of all kinds of energy before 2003 are physical statistics, according to the "China Energy Statistical Yearbook in 2008[3]," all kinds of energy are converted into standard coal by energy converted standard coal coefficients. The basic datum for various types of energy come from the Shandong Statistical Yearbook[4].

Granger causality test as a measurement method had been generally accepted and widely used by economists. The relationship between industrial structure and CO₂ emissions in Shandong Province is quantitatively analyzed through the method. Firstly, to test the Stationarity of the series, unit test is preformed. The CO₂ emissions is represented for CAR. The SEC indicates the proportion of second industrial output value in total GDP. Test results show that SEC and CAR are non-stationary time series. But ΔCAR and ΔSEC which are their forms of the first difference are stationary time series. Test results are shown in Table 1.

<table>
<thead>
<tr>
<th>variable</th>
<th>test form</th>
<th>ADF statistics</th>
<th>5% critical value</th>
<th>test result</th>
</tr>
</thead>
</table>

Table 1. Stationarity test with CO₂ emissions and the proportion of second industrial output value in total GDP
Note: c was interpreted as the intercept, t as the trend term, m as the lag order. In the test form, if it contained a constant term and time trend term, so it was written as the form (c, t, m). Lag order were selected automatically by AIC and SC criteria.

2.2 Cointegration test

Engle-Granger test is often used to test the cointegration relationship between two variables and includes two-step. The first step is cointegration regression. The equation between the CAR and the SEC is estimated by using ordinary least squares (OLS) estimates and non-equilibrium error is calculated. The estimated equation is expressed as formula (2).

\[
\text{CAR} = -32647.35 + 740.59* \text{SEC} \quad (2)
\]

\[\begin{align*}
(\text{-5.97}) & \quad (7.08)
\end{align*}\]

Adjusted R²=0.78; D.W=0.68

We can see that the variables are significant. R statistic are 0.78, which indicates the fitting well.

The second step is to examine the residual unit root test and identify whether the residual series is stationary. The mean of residuals is 0, so ADF test with no intercept and no trend term and lag order is performed. ADF value (-3.74) is significantly greater than the critical value (-2.74) in significance of 1%. It indicates that residual series is stationary and cointegration relationship between CO₂ emissions and the industrial structure exist. They have the relationship of long-term stable equilibrium. However, the specific direction of causality remain unclear.

2.3 Granger causality test

Granger causality tests is further used to verify the relationship between industrial structure and the total amount of CO₂ emissions in Shandong Province. Because the selection of lag order with Granger test is sometimes very sensitive, completely different results may be obtained under different lag order. When the random error term in the model has no have serial correlation (based on LM value) and AIC criteria selection value is least, the optimal lag is 3. Test results are shown in Table 2.

<table>
<thead>
<tr>
<th>lag order</th>
<th>obs</th>
<th>original hypothesis</th>
<th>F value</th>
<th>P value</th>
<th>LM value</th>
<th>AIC value</th>
<th>conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>14</td>
<td>SEC does not Granger Cause CAR</td>
<td>13.67</td>
<td>0.00</td>
<td>1.70</td>
<td>16.07</td>
<td>refused</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAR does not Granger Cause SEC</td>
<td>0.23</td>
<td>0.78</td>
<td>2.93</td>
<td>4.32</td>
<td>accepted</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>SEC does not Granger Cause CAR</td>
<td>6.70</td>
<td>0.02</td>
<td>3.35</td>
<td>15.94</td>
<td>refused</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAR does not Granger Cause SEC</td>
<td>0.84</td>
<td>0.51</td>
<td>5.86</td>
<td>4.31</td>
<td>accepted</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>SEC does not Granger Cause CAR</td>
<td>3.72</td>
<td>0.15</td>
<td>3.22</td>
<td>15.96</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAR does not Granger Cause SEC</td>
<td>0.46</td>
<td>0.78</td>
<td>7.79</td>
<td>4.88</td>
<td>accepted</td>
</tr>
</tbody>
</table>

Table 2 shows that it has to refuse the hypothesis of "SEC does not Granger Cause CAR" and accept the "CAR does not Granger Cause SEC". The relationship between industrial structure and CO₂ emissions is one way Granger causality. That is, industrial structure is the reason for the change of the emissions, and the emissions is not a reason for the change of industrial structure.
3. Factors Contribution to Carbon Dioxide Emissions in Shandong Province

3.1 Decomposition model of carbon dioxide emissions

Decomposition model of carbon dioxide emissions can break down the factors’s impacts and their impacts can be measured through the contribution value and contribution rate. CO₂ emissions, C, are expressed as formula (3):

\[ C^t = \sum_{i=1}^{n} Y^t_i \cdot Y^t_i \cdot \frac{C^t_i}{Y^t_i} = \sum_{i=1}^{n} Y^t_i \cdot S^t_i \cdot I^t_i \]  (3)

\( C^t \) is the amount of CO₂ emissions throughout the economic system at t times; \( Y^t \) is the GDP at t period; \( Y^t_i \) is i-industrial added value at t period; \( C^t_i \) is i-industrial CO₂ emissions at t period; \( S^t_i = Y^t_i / Y^t \), is the proportion of i-industrial value added in GDP and the industrial structure at t period; \( I^t_i = C^t_i / Y^t_i \), is the emission intensity or the efficiency of i-industrial at t times.

SUN (1998) as an international energy expert proposed the principle named "co-produced, in equal shares" to deal with the residual term in the structure decomposition process [5]. According to it, formula (4) of the decomposition process is obtained.

\[ \Delta C = C^t - C^0 = \sum_{i=1}^{n} Y^t_i \cdot S^t_i \cdot I^t_i - \sum_{i=1}^{n} Y^0_i \cdot S^0_i \cdot I^0_i = EY_{\text{effect}} + ES_{\text{effect}} + EI_{\text{effect}} \]  (4)

\( EY_{\text{effect}}, ES_{\text{effect}} \) and \( EI_{\text{effect}} \) are the contribution values of GDP, industrial structure and industrial emissions intensity, respectively.

3.2 The factors contribution to carbon dioxide emissions in Shandong Province

The CO₂ emissions and CO₂ intensity in Shandong Province during 1994-2009 can be divided into three stages according to the trend of them, that is, 1994-99, 2000-05, 2006-09. The economy is divided into six industry sectors: primary industry, manufacturing, construction, transportation, storage and postal industry, wholesale and retail, and hotel and restaurant industry, the other tertiary sector. In addition, the GDP, the industrial added value and CO₂ intensity are calculated by 1990 constant price. \( EY_{\text{effect}}, ES_{\text{effect}} \) and \( EI_{\text{effect}} \) are calculated and the results are shown in Table 3.

<table>
<thead>
<tr>
<th>factors</th>
<th>contribution value(million tons)</th>
<th>contribution rate(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>changes in GDP</td>
<td>6.2378</td>
<td>16.2315</td>
</tr>
<tr>
<td>changes in industrial</td>
<td>-0.3735</td>
<td>3.1131</td>
</tr>
<tr>
<td>structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>changes in technical</td>
<td>-104.70</td>
<td>4.9603</td>
</tr>
<tr>
<td>efficiency</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Firstly, change in economic output is the most important factor to promote CO₂ emissions. During the period of 1994-99, 2000-05, and 2006-09, the contributions of changes in economic output are always the highest. In 1994-99, if other factors remained unchanged, overall economic growth would lead to average annual growth of 6.23 million tons of CO₂ emissions; In 2000-05, if other factors remained unchanged, overall economic growth would lead to average annual growth of 16.23 million tons; In 2006-09, if other factors remained unchanged, overall economic growth would lead to average annual growth of 13.71 million tons.
Secondly, the contribution value of the industrial structure to changes of the emissions in 2000-05 is positive. It shows that the change in industrial structure can promote CO₂ emissions. But in 1994-99 and 2006-09, the contribution value are negative, which indicate that the change of the industrial structure in two stages can curb CO₂ emissions; however, compared with the contribution of the total economy, the effect of industrial structure is relatively small. In 2000-05, the contribution rate of the industrial structure rapidly increases and this is closely related with the fast industrialization in Shandong Province (the proportion of industrial output from 2000 to 44% to 51.3% in 2005).

Thirdly, the technical efficiency is the main reason to curb the CO₂ emissions. In 1994-99 and 2006-09, the contribution rates of changes in the efficiency factor are -23.71% and -51.03%. It shows that if other factors remained unchanged, the changes of technical efficiency would lead to the emissions reduction, which would cut back by 1.04 and 4.06 million tons. However, the contribution value of the efficiency in Shandong Province is very limited by comparisons of economic growth. Especially in the "Eleventh -Five-Year" period, the total economy leads to a significant increase in CO₂ emissions, which influences the effect of efficiency factor weak and changes into negative value.

Therefore, economic growth in Shandong Province must be accompanied by a substantial increase in the total emissions in the foreseeable future. The main ways to emission reduction are to adjust the industrial structure, reduce the emissions intensity of the each sector and improve energy structure.

4. Conclusion

There exist the long-term stable equilibrium relationship between industrial structure and the CO₂ emissions in Shandong Province. The industrial structure is the reason for the change of the emissions, but the latter is not a reason for the former. The change in the total economy is the most important factor to promote the emissions. The change in industrial structure has the different contribution to the emissions in different stages, in 1994-99 and 2006-09, the contribution rate is negative, which indicates that changes in industrial structure curb the emissions. Technical efficiency is the main factor to reduce emissions, but compared with the role of economic growth, the effect of technical efficiency is very limited. So the main ways to emission reduction are to adjust the industrial structure, reduce the emissions intensity of the each sector and improve energy structure.

References:


