CHEMICAL ENGINEERING TRANSACTIONS
VOL. 51, 2016
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Tichun Wang, Hongyang Zhang, Lei Tian

ISBN 978-88-95608-43-3; **ISSN** 2283-9216
DOI: 10.3303/CET1651197

Study on the Effects of the Industrial Structure Evolution on Carbon Emissions—A Case Study

Yunwei Du*[a,b], Taozhen Huang[c], Shengbang Song[a], Cehua Li[d]

[a]School of Business，Hohai University，Nanjing，211100，China
[b]Graduate School，Nanjing University of posts and Telecommunications，Nanjng，210003，China
[c]School of Public Administration，Hohai University，Nanjing 211100，China
[d]School of Economy，Nankai University，Tianjin，300071，China.
duyw@njupt.edu.cn

Based on relevant data in Jiangsu from 1995 to 2014, this article uses the measurement model to analyze the influence on carbon emissions of the industrial structure evolution. The research shows that the structure of the industrial carbon emission in Jiangsu province presents" two-three-one" mode. The secondary industry is the chief component of carbon emissions. The second industry as the leading industrial structure has an obvious driving effect on carbon emissions, but its carbon emission intensity is decreasing and its proportion of GDP is positive relevant with per capita carbon emission. The relationship between per capita GDP and per capita carbon emission presents the inverted N-shape. With the Per capita GDP increasing, the personal average carbon emission at the beginning increases at an increasing rate and then at the decreasing rate. Owing to the proportion of secondary industry decreasing and proportion of tertiary industry increasing, the momentum of rapid growth of carbon emissions has been suppressed.

1. Introduction

Carbon emission reduction is more an economic problem than an environmental problem of the mitigation of climate change because carbon emissions is an external economic problem, and any carbon emission reduction policy or action will ultimately refer to the economic development and the industrial structure. The process of industrialization indicated that the optimized promotion of industrial structure is the most effective approach to slow down the rapid growth of carbon emissions. The researches of foreign scholars (Grossman and Krueger, 1991; Minihan-Erin S and Wu, 2011; Galeotti, 2005, Craig, 2001) showed that the evolution of industrial structure is the main factor of carbon emission reduction. Domestic researcher's (Ji and Zhu, 2009; Xu, 2006; Li and Zhou, 2012)who adopted different ways generally assumed that the industrial structure dominated by the second industry was the main reason of the increasing of carbon emissions, and optimization and upgrading of the industrial structure could remarkably help make a lower carbon level.

The existing literature mostly focused on the relationship between the industry structure and carbon emissions on national scale while the research achievements in the provincial regional scale are correspondingly deficient (Yang and Lv, 2011; Zhao and Long, 2010). It's worth to investigate the process and the mechanism t between the industrial structure and carbon emissions on a regional scale.

In the national "13th Five-Year Plan" outline, as binding targets, reduction of carbon dioxide emissions per unit of GDP by 18% must be achieved by 2020. As a major economic province, Jiangsu province promised that the whole province would reduce energy consumption per unit of GDP to finish its part of national plan during the 13th Five-Year Plan. To achieve this goal, the most effective means to cut down carbon emission is to optimize industrial structure. The paper selects Jiangsu province as a case to study the relation between industry structure and carbon emissions, and gives some feasible suggestions about structural adjustment and transformation to reduce regional carbon emissions.

Please cite this article as: Du Y.W., Huang T.Z., Song S.B., Li C.H., 2016, Study on the effects of the industrial structure evolution on carbon emissions—a case study, Chemical Engineering Transactions, 51, 1177-1182 DOI:10.3303/CET1651197

2. Profile of industrial structure and carbon emissions in Jiangsu province

With the development of economy, industrial structure in Jiangsu province has been further adjusted and optimized. Calculated in accordance with the same price in 1995, the growth of first industrial output is slow, with an average annual growth rate of 8.4%, and the proportion of GDP continues to decline, from 16.8% in 1995 to 5.6% in 2014.The second industry output growth faster, with an average annual growth rate of 14.5%, and the second industry has always occupied a dominant position. The output growth of the third industry is the fastest, with an average annual growth rate of 17.2%, the proportion rising from 30.5% in 1995 to 47% in 2014. The type of industrial structure gradually has changed from the original “Second–First-Third" into “Second-Third-First" mode.

As can be seen in Figure 1, the characteristic of industrial carbon emissions structure in Jiangsu is consistent with the characteristics of industrial structure, in a “Second-Third -First” pattern as well. The weight of the second industrial carbon emissions has an overall downward trend, but still above 80%, which is the major part of the total carbon emissions. The weight of the second industrial carbon emissions is about six or eight times the total weight of the first and third industry, far more than the weight of the first or third industry. The weight of the first industrial carbon emissions is relatively stable while the weight of third industry’s increases fast, rising by annual 5.16% from 1995 to 2014.

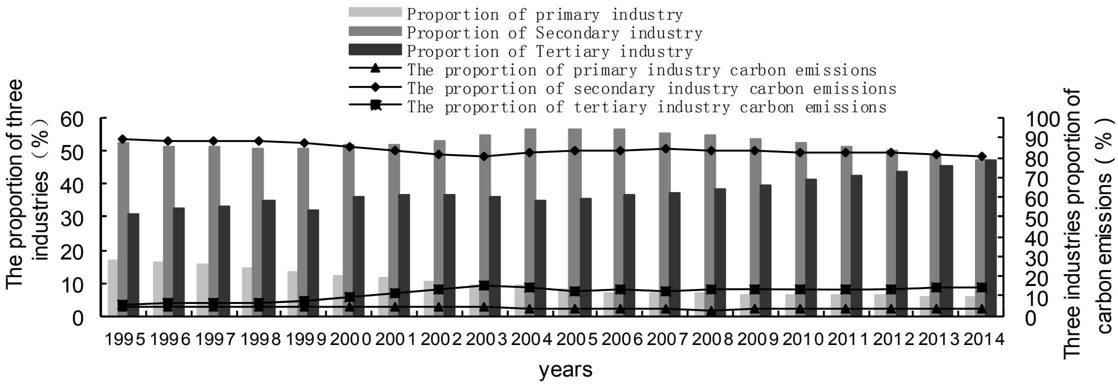

Figure1: The ratio of three industries in GDP and carbon emission of three industries of Jiangsu province from 1995 to 2014

In terms of the industrial carbon emission intensity, three industries carbon emission intensities all have a dropping trend between1995-2014. Among them, the annual rate of dropping the drop of the second industrial carbon emission intensity was the highest, Respectively reaching 82% and 10.65%.The first industrial carbon intensity annually decreased by 6.32% and had a drop by 64.7%. The third industrial carbon intensity annually decreased by 7.34%.

The relationship has stage characteristics between the per capita carbon emission and the proportion of secondary industry. Specifically, from 1995 to 2005, the proportion of the second industry first slightly decreased, and then continued to raise from 1998, finally reached the maximum in 2005, however, the proportion of the second industry declined significantly, from 56.59% in 2006 to 47.4% in 2014. Meanwhile, the per capita carbon emissions continued to rise, rising significantly faster after 2002. Per capita carbon emission increased to 14,600 tons in 2005, but the growth rate of per capita carbon emission slow significantly from the beginning of 2006.

3. Analysis of carbon emission effect of Jiangsu industrial structure evolution

3.1 Models

With reference to empirical research of the domestic and foreign scholars on EKC curve, joining the index changes of industrial structure beside per capita carbon emissions and per capita GDP The author set model to study the relationship between the adjustment of industrial structure and carbon emissions. In addition, the model will be used on the logarithmic form, it can not only reduce heteroscedasticity, but also directly obtain the elasticity of the dependent variable to the independent variable.

The model is set as follow:

$$LnC = \alpha + \beta_1 LnY + \beta_2 Ln^2Y + \beta_3 Ln^3Y + \beta_4 LnS + \beta_5 D*S + \varepsilon \quad (1)$$

Formula: C for per capita carbon emissions, Y for per capita GDP, S for the industrial structural index. In view of the influence of stage characteristics of second industry on carbon emissions, this paper researches on the impact of the second industry on carbon emissions introducing the virtual variable to divide the process of second industry into two stages, so it can get better results. D is virtual variable, a value of 0 for year from 1995 to 2005 and a value of 1 from 2006 to 2014. α is for intercept, and β_1……β_4 represent the coefficients of each explanatory variables, ε as random error term.

3.2 Index selection and data sources

In order to highlight the main influence of the second industry on carbon emissions, the change of industrial structure index mainly adopts three kinds. The first kind of index is at present the majority of scholars adopted second industry output value accounted for the proportion of GDP (S2), and second kinds of index is from reference of Talukdar (2001) with first and second industry output accounted for the proportion of GDP (S1, S2), and the third category is the output of the second and third industry accounted for the proportion of GDP (S2, S3). According to the three categories of indicators, three models are established, and the three models compared according to the significant test. In the study of relationship between regional output level and carbon emissions, learning from the practice of most scholars, the per capita GDP is adopted to measure the level of regional economic development.

The data of total GDP and population come from "Jiangsu Statistical Yearbook"(1996-2015). Annual GDP is calculated based on price of 1995. The author multiplied the corresponding energy consumption coefficient from "Chinese Energy Statistics Yearbook" 2008 by the consumption of common energy unit transformed the data of various kinds of energy consumption from "Chinese energy statistical yearbook" (1996-2015) into, then We obtained the carbon emissions.

3.3 Results and analysis

According to econometric model, Using Eviews7.0 software for processing and analysis, this article obtains the corresponding regression coefficients (table1).

In general, the R square of model 1 is closer to 1, and the value of F is larger and the value of DW displays that the random error term is not autocorrelation, which illustrates that the models is fitted better. The final result for the model estimation is:

$$LnC = 5.503 - 28.209LnY + 3.463Ln^2Y - 0.113Ln^3Y + 2.238LnS - 1.749D*S \quad (2)$$

The estimation result of Model 1-3 shows that the first item, quadratic and three items coefficients of per capita GDP at the 5% level statistics are significant, and the first item and three items coefficients of per capita GDP is negative, and the quadratic coefficient of per capita GDP is positive, which indicates that the relationship between per capita GDP and carbon emissions is neither linear nor nonlinear of traditional inverted U-shape, but like inverted N-shape curve, and this relationship lies in the middle section of the inverted N-shape Specifically, with the continuous development of GDP, per capita carbon emission at the beginning increases at an increasing rate and then at a decreasing rate, and the inflection point is when lnY is equals to 10.215.At this time, GDP is equals to 27,309.78 yuan, and per capita GDP of Jiangsu province is 28,526 yuan in 2006. Namely, in the inflection point, per capita carbon emissions rises fastest, and then shows a slow growth trend. It means that with the economy growth, carbon emissions will repeatedly decrease or increase, and implies such a phenomenon that with the further development of economy, no matter what change carbon emissions do in the intermediate process, it will go down eventually and environmental quality will improve. The conclusion of this paper is similar to the study results of previous scholars in Zhejiang, Guangdong and other coastal developed provinces.

For the industrial structure, the estimation of the1-3 model shows that the second industry proportion coefficient is statistically significant at the 5% level, and the coefficient is positive, all above 2, which is close to the expectation before this study. Thus, it shows that the model is effective, and it is Positive correlation between the second industry and carbon emissions. While maintaining per capita GDP, the higher the proportion of the second industry is, the higher the carbon emission is. Model2 shows that the coefficient of the proportion of the first industry is 0.336, but not statistically significant, which indicates that the impact on carbon emission of the first industrial development is less. Although agricultural mechanization increased carbon emissions, the carbon sequestration effect of agricultural production is far greater than the effect of the carbon source produced by agricultural machinery.

Table1: the regression results of measurement

Variable for explanation	Model 1	Model 2	Model 3
LnY	-28.209*** (4.12)	-42.569* (4.68)	-39.038** (4.96)
(LnY)2	3.463** (3.81)	3.604** (4.77)	4.039* (4.26)
(LnY)3	-0.113** (3.26)	-0.135** (4.16)	-0.126** (4.62)
S1	–	0.536(0.65)	–
S2	2.238** (2.31)	2.179** (2.46)	2.194** (1.98)
S3	–	–	0.815(0.77)
D*S	-1.749(-7.924)	-1.231(-4.874)	-0.221(-5.926)
R-squared	0.9961	0.8766	0.7822
Adjusted R-squared	0.9948	0.8518	0.7541
Sum squared resid	0.0112	0.0191	0.0146
S.E of regression	0.0293	0.0213	0.0325
F-statistic	810.723(0.00)	780.362(0.00)	776.671(0.00)
DW	2.131	2.385	1.783

Note: the table brackets values for the coefficient value of the T; * ,* * and* * * respectively in 10%, 5% and 1% level of significant level by t test.

Model 3 shows that the coefficient of the proportion of the third industry is 0.815, but statistically significant, showing that the development of the third industry leads to carbon emissions rising, but it isn't significant, and the impact on carbon emissions of the third industry is more than those of the first industry. In the long term, the industrial structure dominated by the second industry compressed the development space of the third industry, thus causing carbon emissions a sharp increasing. With the further development of the third industry, it is entirely possible to reduce the dependence on the second industry so as to achieve the effect of carbon emissions reduction in future, but obtaining the same level of GDP.

Model tests found that D*S coefficients were significantly different from zero, which further verified that the second industry had an effect of phases on carbon emissions. In 1995-2005, as the proportion of the first industry declining, the proportion of the second industry increases, the third industry growing slowly, the average annual growth rate of Per capita e carbon emissions reached by 7.6%, so the second industry was the main factor driving the rapid growth of carbon emissions. Though in the period from 2006 to 2014, the proportion of secondary industry accounted for more than 50%, the proportion of the second industry began to decrease from 2006, at the average annual decline rate of 1.7%, and per capita emissions growth has slowed at the average annual rise by 4.8%.At the same time, the third industry was growing fast. Thus, without taking into account the technical effect and scale effect to improve the situation, growth rate of decline of per capita carbon emissions was caused by the structure effect. Meanwhile, the rapid growth of per capita carbon emissions was held back and tended to be slow.

4. Conclusions and discussion

Through the analysis of econometric test statistics on carbon emissions, industrial structure and per capita GDP data in Jiangsu Province, it can be drawn the following conclusions:

Firstly, the intensity of carbon emissions in Jiangsu province in 1995-2014 has been declining. It shows that energy consumption structure has been optimized further, and industrial restructuring to reduce carbon emission intensity also played a certain role, and energy dependence of the economic development changed from high to low.

Secondly, there is an inverted N-shape relationship between Per capita GDP and Per capita carbon emissions, and it lies in the middle section of inverted N-shape in Jiangsu province. This indicates that with the Per capita GDP increasing, the personal average carbon emission at the beginning increases at an increasing rate and then at the decreasing rate. Currently, Per capita carbon emissions in Jiangsu province has already passed through the inflection, showing a slow growth trend, but having not yet reached its peak.

Thirdly, the proportion of the second industry is positively correlated with personal average carbon emissions, and industrial structure leaded by the second industry of Jiangsu province made carbon emissions rising. Meanwhile, the decline in the proportion of the second industry and the proportion of the third industry rising delayed the process of Per capita carbon emissions, slowing growth trend appearance. Thus, the environmental effect of industrial structure optimization has already appeared.

The wave curve inverted N-shape between carbon emissions and economic growth in Jiangsu province is different from inverted U-shape characteristics of the past developed countries in the stage of industrialization. Government departments cannot blindly apply the inverted U-shape, and believe that it is an inevitable trend that carbon emissions with GDP growth will eventually decline, but this trend should not be the reason that a lot of people choose the policy "treatment after pollution". While maintaining sustained and healthy economic development, we need to insist the environment protection idea that we need both gold and silver, more beautiful scenery.

Acknowledgment

This work was financially supported by Youth Fund Project of Humanities and social sciences research of the Ministry of education of in 2014 (14YJC840005).

References

Galeotti M., Lanza A., 2005, Desperately Seeking Environmental Kuznets. Environmental Modelling& Software, 20(11).1379-1388, DOI: http://dx.doi.org/10.1016/j.envsoft.2004.09.018。

Grossman-Gene M., Krueger-Alan B., 1991, Environmental Impact of North American Free Trade Agreement .NBER Working Paper No. 3914, DOI: 10.3386/w3914.

Ji Y.L., Gao Y.X., 2011, An empirical study of carbon dioxide emission intensity, Statistical research, 28 (7): 37 – 44,DOI:10.3969/j.issn.1002-4565.2011.07.005

Li J., Zhou H., 2012, The associated carbon emission intensity and the industrial structure analysis of China. China population, resources and environment22 (1), 7–14, DOI: 10.3969/j.issn.1002-2104.2012.01.003.

Minihan-Erin S., Wu Z.P., 2011, Economic structure and strategies for greenhouse gas mitigation. Energy Economic, 5 (11):1016-102, DOI: http://dx.doi.org/10.1016/j.eneco.2011.05.011.

Talukdar D., Meisner-Craig M., 2001, Does the Private Sector Help or Hurt the Environment? Evidence from Carbon Dioxide Pollution in Developing Country, World Development, 29, 827-840, DOI: http ://dx.doi.org/10.1016/S0305-750X(01)00008-0

Xu G.Q., Liu Z.Y., Jiang Z.H., 2006, The decomposition model and Empirical Study of China’s carbon emissions: 1995 - 2004.China population, resources and environment, 6,158-161,DOI:10.3969/j.issn.1002-2104.2006.06.030.

Yang L., Lv T., 2011, The Factor Decomposition and Comparative Analysis of Carbon Emissions in Jiangsu, Zhejiang and Shanghai, Contemporary economic management, 5,56-61,DOI:10.3969/j.issn.1673-0461.2011.05.013

Zhao X., Long Y.R., 2011, Decomposition and empirical analysis. China population, resources and Environment status and factors of carbon emissions in Jiangsu Province dragon as silver,(5):21-30,DOI:10.3969/j.issn.1002-2104.2010.07.004.

Zhu Y.B., Wang Z., Pang L., 2009, Economic simulation of China's energy consumption and carbon emission peak based prediction. Geographic Learned Journal 64 (8), 935-944, DOI: 10.3321/j.issn: 0375-5444.2009.08.004.