Renewable and Sustainable Energy Reviews 77 (2017) 386–394

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Sustainable development of China's energy intensive industries: From the aspect of carbon dioxide emissions reduction

Boqiang Lin[a,*], Ruipeng Tan[b]

[a] Collaborative Innovation Center for Energy Economics and Energy Policy, China Institute for Studies in Energy Policy, School of Management, Xiamen University, Fujian, 361005, PR China

[b] China Center for Energy Economics Research, School of Economics, Xiamen University, Xiamen, Fujian 361005, PR China

ARTICLE INFO

Keywords:
China's energy intensive industries
Kaya identity
LMDI method
Cointegration method
Carbon dioxide emissions reduction

ABSTRACT

According to *China's Economic and Social Development Statistical Bulletin of 2010*, the energy intensive industries include six highest energy intensive sub-industries. Because China is still in the process of urbanization and industrialization, it requires the products of energy intensive industries. In this study, we review the main method of doing decomposition analysis on CO_2 emissions, investigate the main factors affecting CO_2 emissions in China's energy intensive industries using Kaya identity and Logarithmic Mean Divisia Index (LMDI) method and then adopt cointegration theory to construct the long-term relationship among CO_2 emissions and the main factors. Finally, we estimate the reduction potential of CO_2 emissions in China's energy intensive industries in the future. The results show that industrial scale and labor productivity are the main factors increasing CO_2 emissions while energy intensity is negative to emissions. If moderate measures are taken, the emission reduction potential will be 1.98 billion tons and 9.34 billion tons in 2020 and 2030 respectively. If aggressive measures are taken, the emission reduction potential will be 3.33 billion tons and 14.12 billion tons in 2020 and 2030 respectively. The results indicate that emission reduction potentials are substantial. Some related policy suggestions are proposed to support emissions reduction.

1. Introduction

Data from IEA shows that, global carbon dioxide emissions were 36 billion tons in 2013. China, the USA and the European Union emitted nearly 10 billion, 5.2 billion and 3.5 billion tons of CO_2 respectively. The amount of carbon dioxide emitted in China had already exceeded the total amount of the US and the EU, and it accounted for nearly 29% of global emissions. The emission of greenhouse gases such as carbon dioxide will cause serious greenhouse effect, ruin the planet, and cause catastrophic effect for human. One pretty realistic problem ahead is how to effectively reduce carbon dioxide emissions. To respond to the climate crisis caused by large amount of carbon dioxide emissions, the Chinese government has taken several steps. For example, in November 2009, it promised that by year 2020, the carbon dioxide emission per unit GDP in China would reduce by 40–50% compared to that of 2005. In 2014, China and the USA issued the *U.S.-China Joint Announcement on Climate Change* in which China promised to peak carbon dioxide emissions around 2030.[1]

Most of the CO_2 emissions in China are caused in by industrial production, especially by energy intensive industries. According to *the National Economic and Social Development Statistical Bulletin of 2010*, China's energy intensive industries include six highest energy intensive sub-industries. They are Processing of Petroleum, Coking and Processing of Nuclear Fuel, Manufacture of Raw Chemical Materials and Chemical Products, Manufacture of Non-metallic Mineral Products, Smelting and Pressing of Ferrous Metals, Smelting and Pressing of Non-ferrous Metals, Production and Supply of Electric Power and Heat Power. In 2011, the World Bank issued the World Development Indicators which showed that China's CO_2 emissions had increased from 1.46 billion tons in 1978 to 7.03 billion tons in 2008,[2] indicating a growth rate of about 381.5%. In this study, we calculate the energy-related carbon dioxide emissions at the aggregate, industrial and energy intensive sub-industrial levels in China. We find that from 1985 to 2014, the average growth rates of energy consumption and CO_2 emissions in China's energy intensive industries are 7.23% and 7.20% respectively. In 2014, the total industrial energy consumption of China

* Corresponding author at: Collaborative Innovation Center for Energy Economics and Energy Policy, China Institute for Studies in Energy Policy, School of Management, Xiamen University, Fujian, 361005, PR China.

E-mail addresses: bqlin2004@vip.sina.com, bqlin@xmu.edu.cn (B. Lin).

[1] The information is from http://yjbys.com/jiuyezhidao/news/708484.html, 10:36,2015/11/14.

[2] The data are from World Bank.

http://dx.doi.org/10.1016/j.rser.2017.04.042
Received 14 November 2015; Received in revised form 13 February 2017; Accepted 17 April 2017
1364-0321/

was 2.97 billion tons of standard coal equivalent (SCE), and the total CO_2 emissions were 8.42 billion tons. For the energy intensive industries, the total energy consumption was 2.17 billion tons of SCE and the CO_2 emission was 7.09 billion tons. It can be seen that China's energy intensive industries accounted for most of industrial energy consumption and CO_2 emissions, and the corresponding proportions were 73.1% and 84.2%, respectively.[3] Thus, if the goal of CO_2 emissions reduction is to be achieved, China's energy intensive industries cannot be ignored.

Fig. 1 shows the energy-related carbon dioxide emissions in China's industrial and energy intensive industries. From 1985 to 2014, CO_2 emissions in the industrial sector and energy intensive sectors kept an increasing trend. And these two sectors account for a large proportion of China's total CO_2 emissions. For example, in 2008, total CO_2 emissions were 6.75 billion tons, out of which the industrial and energy intensive sectors accounted for about 5.80 billion tons and 4.95 billion tons respectively.

Fig. 2 depicts CO_2 emissions and energy consumption per unit of industrial value added in China's energy intensive industries. From 1985 to 2014, there is a decreasing trend in both CO_2 emissions and energy consumption per unit of industrial value added. The years 1995 and 1996 marked the peak values of CO_2 emissions and energy consumption per unit of industrial value added respectively, after which they decreased. China is still in the process of urbanization and industrialization, and it requires the supply of raw material and energy from energy intensive industries. For example, the cement manufacturing industry subordinated to non-metallic mineral industry ensures the smooth progress of public infrastructure construction in cities. The processing of petroleum, coking and processing of nuclear fuel industries provide industrial "blood"–oil for modern industries. The smelting and pressing of ferrous metals industry produces steel and it is the mainstay of the national economy. Since 2014, China proposed another development strategy known as the Belt and Road Initiative.[4] The countries involved in the initiative are poor in all sorts of basic infrastructure and transport infrastructure construction. So the requirements of raw materials can promote the development of China's energy intensive industries. Considering China's resource endowment conditions, coal has the advantages of large reserves and low price. Also, technology makes the substitution of coal by clean energy impossible in the short-term. Since 1985, coal has been the major source of energy consumption in China's energy intensive industries, and this phenomenon will continue in the near future. Considering the fact that the coefficient of carbon emission of coal is the largest in all kinds of energy, carbon dioxide emissions will continue to increase in China's energy intensive industries. Based on these facts, it is necessary to study the related factors of CO_2 emissions, investigate the long-term relationship among these factors and emissions and calculate the CO_2 emission reduction potential in China's energy intensive industries. The rest of the review is organized as follows: The second part is the literature review in which we retrospect the methods of decomposition analysis, the method of cointegration, scenario analysis and the corresponding literatures. The third part introduces the methodology and data used in this study. The fourth part is the result of this review and finally some conclusions and policy suggestions are given in the fifth part.

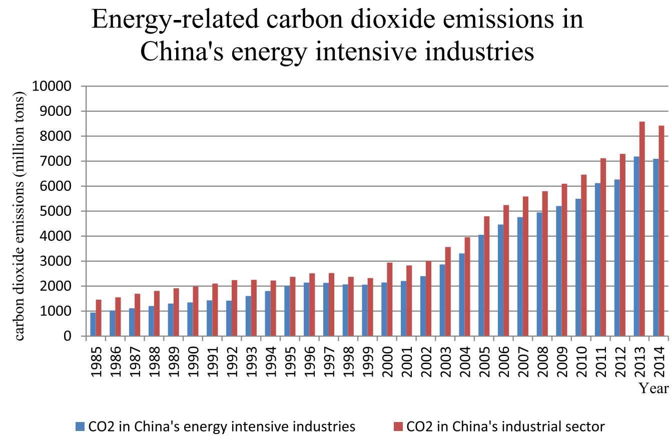

Fig. 1. Energy-related carbon dioxide emissions in China's industry sector and energy intensive sectors.

2. Literature review

The start of academic study on CO_2 emissions and the influencing factors can be dated back to the 1980s, with studies such as Ang and Choi [1], which proposed a modified decomposition method that can overcome the problem of residual existence and difficulty in handling value zero when doing decomposing analysis on CO_2 emissions. Ang and Pandiyan [2] adopted two methods to decompose the CO_2 emissions of the manufacturing industry in mainland China, South Korea and Taiwan.

From a comprehensive review of the literature on carbon emissions, we find that there are mainly two groups of methods: factor decomposition analysis and system optimization method. Factor decomposition analysis is a useful tool to understand the influencing factors resulting in the changes of CO_2 emissions, economic, environmental and some other socio-economic indicators [3]. System optimization method is used to incorporate CO_2 emissions into an optimization model that can explain the emission changes and forecast future emissions. This kind of method is now widely used such as in Paravantis and Georgakellos [4] where they constructed a model taking aggregate car ownership and bus fleet into account. Fuel consumption and CO_2 emissions from passenger cars or buses could be compared and forecasted by this model. Similar studies include Shakya and Shrestha [5], Simões and Schaeffer [6] and so on. The essence of factor decomposition analysis is to represent carbon emissions as the product of several factor indicators. Since there are several ways to express the weight of different factors, there are also several ways to determine the increment share of each index. Generally, it can be classified into two main approaches: structural decomposition analysis (SDA) and index decomposition analysis (IDA). Ang and Zhang [7] traced the new development of index decomposition methodology and classified the existing researches as well.

The basis of SDA is input-output analysis, therefore it can distinguish the direct and indirect impacts from other sectors when analyzing the changes in energy consumption and CO_2 emissions of a specific sector [8]. The first study use the SDA method is Leontief and Ford [9]. They decomposed air pollution factors in the USA in 1972. Following that, a lot of studies employing SDA have been conducted from a regional or a specific industrial persepective. For example, Zhang and Qi [10] used SDA to analyze the production-source CO_2 emissions in China in the period 1992–2002. The results showed that final demand for goods and services mainly increased CO_2 emissions while technical improvement could decrease emissions. Chang et al. [11] analyzed the change in industrial CO_2 emissions in Taiwan. Industrial energy coefficient, CO_2 emission factors, exports and domestic final demand were the factors positively related to the increment of emissions. Su and Ang [12] reviewed the latest developments in SDA, compared four

[3] The data are from *China Energy Statistical Yearbook*.

[4] Belt and Road Initiative refers to the new silk road economic belt and Maritime silk road economic belt in the 21st century. Belt and Road Initiative is the platform provided by China for global and regional development. It aims to develop the economic partnership with the countries in the initiative. Also, the community of interests, of fate and of responsibility among China and the countries is to be built. Belt and Road Initiative can combine the interests of China and the countries along the route together. The advantages of capital, industrialization and infrastructure construction are expected to be complemented between China and the involved countries. By this way, the trade, transport and logistics conditions will be improved and the industrialization process will be accelerated.