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A study on the contribution of industrial restructuring to reduction of carbon emissions in China during the five Five-Year Plan periods

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ABSTRACT

In China, environmental problems associated with excessive energy consumption are escalating with rapid economic development, and the greenhouse effect caused by increased carbon dioxide emissions has risen into the focus of domestic and even international attention. Based on the reduction target China committed in 2015 Paris Climate Agreement, the study proposes a dynamic factorization model to decompose and compare the effect of industrial structure on the reduction of carbon emissions during the five Five-Year Plan (FYP) Periods from 2006 to 2030 at the dimensions of industries and sectors. Results show that China's industrial restructuring exerts a positive impact on reduction of carbon emissions and the impact varies with the ratio of sectors within the economic structure, in the later five years, carbon reductions emissions causing by restructuring in the three major industries and in the secondary industrial sectors account for 28.22% and 4.26% of the national total carbon reductions emissions respectively; in industrial sectors to mitigation was less than in the three major industries in the past two FYP Periods, but will increase in the next three FYP Periods. These findings are significant for the government in formulating environment and economy policy and planning.

1. Introduction

Carbon emissions have attracted increasing attention as a large amount of greenhouse gas (GHG) emissions have caused serious natural disasters. In 2007, China overtook the United States as the world's largest carbon emitter, according to International Energy Agency (IEA). China's carbon emissions increased rapidly from 3350.3 million tons in 2000–8250.8 million tons in 2012 (Li et al., 2017). Industrialization effectively promotes the rapid growth of the world economy and also requires massive fossil energy such as coal, oil, natural gas, etc. which have already increased rapidly (Xu and Lin, 2017). Massive fossil energy consumption due to industrial production emits large amounts of carbon and affects people's lives. Given a coal-dominated energy structure, China also experiences a continued increase of energy consumption and carbon emissions with rapid economic growth. China faces increasing global pressure on curbing domestic carbon emissions. The completion of emission reduction targets will be supported by the decrease of carbon intensity targets, which impacts the development of China's low-carbon economy significantly (Zhao et al., 2016; Zhou et al., 2017). Against this backdrop, the major challenge facing the country is to actively explore ways to reduce emissions with a view to sustainable development of low-carbon economy.

Environmental problems, which have always been the focus and hotspot of economic development, are closely related with the adjustment of industrial structure (Janicke et al., 1989; Llop, 2007). In the process of compliance-oriented evolution, industrial restructuring is stimulating economic growth and vice versa (Kabiraj and Chyi Lee, 2004). To mitigate the greenhouse effect, China has set a series of voluntary targets on emission reductions. During the 'eleventh five-year plan' period (11th FYP, 2006–2010), China reduced more emissions of main pollutants than expected through non-structural, structural and management measures, wherein structural measures were estimated to contribute to 18% of sulfur dioxide emission reductions (Jiang et al., 2015b). Studies at home and abroad have shown that the emission reduction policy exerts a long-term impact indirectly by restructuring the economy and such impact varies depending on the forms of structural adjustment (Panayotou, 2001; Minihan and Wu, 2012). The

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industrial structure reflects the proportion of industry of a country (or a region), as well as the related variation trend. Industrial restructuring is not only the key factor to achieve a low-carbon economy, but also the determining element for the economic growth rate and quality. Besides, the industrial structure is also an important factor in ecological environment, as its evolution affects the national or regional economic growth and the development model (Peneder, 2003). Its own evolution pattern shows that interferences impel fluctuations of the sight industrial structure, which also leads to the changing of the whole industrial structure as time goes on. Thus, the impact of the industrial output on the carbon intensity showed a dynamic characteristic. To reduce CO_2 emissions, China needs to change its industrial structure by focusing on industrial groups as defined by linkage characteristic (Chang, 2015). Regulating industrial structure and optimizing the structure of industrial enterprises are suggested as imperative measures for carbon mitigation in the region (Xu et al., 2017). The in-depth analysis of the effect of industrial restructure on carbon dioxide emissions is an important prerequisite for energy conservation and emission reduction in China, which is of high significance for developing a low-carbon economy and achieving emission reduction targets (Shao et al., 2014; Hao et al., 2016; Xu and Lin, 2017). It becomes a top priority for the government to curb domestic carbon emissions, as it is of great significance for China in developing a low-carbon economy and achieving carbon reduction targets (Chen et al., 2016; Xu and Lin, 2016a).

The decomposition method is more commonly used by researchers at home and abroad to study the factors that affect carbon emissions. More specifically, the studies on the impact of industrial structure are mainly carried out from three perspectives. (Zhao et al., 2010; Zhang and Ren, 2011; Zhang and Xue, 2011; Kofi Adom et al., 2012; Dong et al., 2013; Zhou et al., 2013). First, the regression models (Lin and Moubarak, 2014), such as the EKC model (He and Wang, 2012; Liu, 2012), uses the structure effect as a control variable, and examine its impact on carbon emissions. For example, MAM Tamayao adopted the regression model containing dummy variables to examine the influencing factors of over carbon dioxide emissions in urbanization and vehicle electrification (Tamayao, 2014). Li Shu uses the GMM model to calculate the coefficient of influence of industrial structure on emission reductions (Shu, 2011). Second, from an energy point of view (Choi and Ang, 2001; Wang et al., 2005; Guan et al., 2008; Zhang et al., 2009a; Tan et al., 2015), the input-output Model (Su et al., 2010; Zhang and Huang, 2012; Mi et al., 2015; Su and Ang, 2015; Zhao et al., 2017) and the Tobit Model (Zeng, 2010) etc. and the like are used to analyze energy structure, intensity, or efficiency. Third, mathematical models are built to decompose the environmental effects according to scale, structure and technique. The applicable decomposition methods include Malmquist Productivity Index Decomposition Method (Kumar, 2006; Liu et al., 2007), STIRPAT Model (Wang et al., 2013; Xu and Lin, 2016b; Yuan et al., 2015), Logarithmic Mean Divisia Index (LMDI) (Oh et al., 2010; Ang and Su, 2016), etc (Ang and Liu, 2001; Zhang et al., 2009b; Akashi et al., 2011; Wen et al., 2014; Cao et al., 2016)

Even though a number of researchers have used index decomposition analysis to study the carbon-related emissions in China's industrial structure, there is still blank space in the research. First, very few studies went further to explore the contributions of individual industrial branches to the driving factors. Second, the studies explored the contributions of industrial branches to each driving factor rarely consider the future-period contribution analysis (Liu et al., 2015). To fill in the above gaps, this study intends to analyze the impact of industrial structure on carbon dioxide emissions at the industrial and sector levels through the measurement of industrial restructuring contribution to emission reductions during the 'eleven five-year plan' and 'twelve five-year plan' (12th FYP, 2010–2015) Periods, and assessment of potential emission reductions brought by industrial restructuring during the 'thirteen five-year plan' period (13th FYP, 2015–2020), 'fourteen five-year plan' period (14th FYP, 2020–2025), and 'fifteen five-year plan' period (15th FYP, 2025–2030), which means the present study will cover the period between 2006 and 2030.

The rest of the study begins with Section 2 where the principles and methods used are discussed. Section 3 then presents the data used and discusses the results from two levels. Section 4 concludes the study and provides policy implications.

2. Method

With the evolution and upgrading of industrial structures, the dominant industries contribute more to reduction of carbon emissions due to smaller demand for energy and resources. In the early stage of evolution, carbon emissions were limited because the economy was dominated by agricultural. As the evolution went on, carbon emissions exhibited an upward trend and the changes of industrial structure became the most significant factor of emission reduction. In the late stage of evolution, carbon emissions would gradually decline with the decrease in use of energy and resource. There are three aspects to look into the mitigation effect of industrial restructuring: (1) higher resource utilization efficiency and lower carbon emissions intensity owning to technological progress; (2) replacement of resource-intensive industrial sectors with large carbon emissions by better-performing industrial sectors; and (3) increase of carbon emissions with increased energy consumption in a growing economy. At the industrial level, the economy is divided into three components (primary, secondary and tertiary industries); at the sector level, the three industries can be divided into different sectors. The study focuses on the impact of structure on emission reduction, covering structural adjustments in the 3 industries and 39 sectors and no longer provides separate analysis of energy structure and energy intensity.

The dynamic factorization model is used to measure the contribution of industrial restructuring to emission reduction. Factor decomposition is essentially a differential approach based on the idea that a change in a factor causes a change in the explanatory variable when other factors remain constant. The quantity of carbon emissions in Year t can be calculated as follows:

$$\begin{aligned} Q_t &= p_t \times q_t \\ &= P_t\alpha_t V_t + P_t\beta_t W_t + P_t\gamma_t U_t \end{aligned} \tag{1}$$

wherein Q refers to the quantity of carbon emissions, p the industrial value added and q carbon intensity. Further, t and 0 are used to stand for the reporting period and the base period respectively, and α_0 and $\alpha_t(0<\alpha<1)$ to denote the proportions of the primary industry in GDP in base year and in year t respectively, β_0 and $\beta_t(0<\beta<1)$, the proportions of industry in the two years, and γ_0 and $\gamma_t(0<\gamma<1)$, the proportions of tertiary industry, then $\alpha_t+\beta_t+\gamma_t=1$.

V_0 and V_t indicate carbon emission intensity (carbon emission per unit of GDP) of the primary industry in the base year and the year t; W_0 and W_t, the carbon emission intensity of the secondary industry in the two years; U_0 and U_t, the carbon emission intensity of tertiary industry; P_0 and P_t stand for GDP in the base year and the t year respectively, Q_0 and Q_t, the quantity of carbon emissions,

Incremental carbon emissions are calculated as follows: