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A decomposition analysis of energy-related CO_2 emissions in Chinese six high-energy intensive industries

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ABSTRACT

China's six high-energy intensive industries use more energy than any other industrial sectors, consuming almost 90% of manufacturing energy and more than 50% of national energy and contributing over 50% of national energy-related CO_2 emissions. Thus, this study is motivated to identify the drivers of energy-related CO_2 emissions change of high-energy intensive industries in China based on the Logarithmic Mean Divisia Index (LMDI) method. Results demonstrate that CO_2 emissions in China's high-energy intensive industries were on the rise during 1986–2013 with annual growth rate of 7.8%. The expansion of industrial scale, which increased 52.14 billion tons of CO_2 emissions in six high-energy intensive industries, was the leading force explaining CO_2 emissions change; and the effect of which was most significant in power industry (20.52 billion tons of CO_2 emissions increase). Energy intensity was the major contributor to promote the decline in CO_2 emissions, and the effect was most significant in chemical industry and non-metallic mineral products industry. Besides, energy structure and industrial structure effects have relatively small impacts on CO_2 emissions change due to the relatively stable energy structure and industrial structure during the study period. Policy recommendations are made for future emission reductions in Chinese six high-energy intensive industries.

1. Introduction

Numerous studies have shown the inevitable trend of global warming (Wang and Feng, 2017a, b). According to Prasad et al. (2017), if population growth and carbon emissions continue to grow at the current level, global temperature will rise in the range of 1.6 up to 5.8 degrees Celsius by the end of 21st century. As the major constituent of greenhouse gas, the reduction of CO_2 emissions especially from fossil fuels is a top priority in curbing global warming. As the largest global emitter accounted for around 28% of global CO_2 emissions, China is faced with considerable pressure on the reduction of CO_2 and thus has established a set of targets and policies to control energy consumption and promote energy and carbon intensities reduction. However, the governance of global climate change has faced enormous challenge after President Trump announced plans to withdraw the U.S. from Paris Climate Agreement on 1 June 2017. In this context, it is expected that China would play a more important role in climate change mitigation.

In order to achieve emission reduction targets, it is necessary to investigate the drivers of CO_2 emissions change of Chinese high-energy intensive industries. According to the National Economic and Social Development Statistical Bulletin, China's high-energy intensive industries include iron and steel industry, non-ferrous metals industry, non-metallic mineral products industry, petroleum refining and coking industry, chemical industry and power industry. Specifically, energy usage of high-energy intensive industries, which increased from 568.35 million tons of coal equivalent (MTCE) in 1994–2194.43 MTCE in 2015 with the average annual growth rate of 6.81%, accounted for 86.67% of manufacturing energy consumption and more than 50% of national energy usage during 1994–2015. However, energy intensity of high-energy intensive industries was significantly higher than those of other industrial sectors, and energy-related CO_2 emissions of the six high-energy intensive industries accounted for more than 60% of the overall industrial sectors (Yuan and Zhao, 2016; Lin and Tan, 2017). Given that China's rapid industrialization and

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urbanization lead to a surge in demand for building materials (cement and steel, etc.) and energy (coal, oil, gas and electricity), and thus lead to the extensive growth of high-energy intensive industries, it is necessary to investigate the influencing factors of CO_2 emissions change in high-energy intensive industries (Xu et al., 2016, 2017; Xu and Lin, 2017; Gao et al., 2017; Jiang et al., 2017; Wang and Feng, 2017a, b; Wang et al., 2017; Zhang et al., 2016).

Based on the above analysis, the contributions of this paper lie in the following aspects: (1) We investigate the most powerful driving forces behind energy-related CO_2 emissions (disregard the emissions embedded into products) of China's six high-energy intensive industries based on the LMDI method covering the years from 1986 to 2013. (2) We compare energy utilization and industrial development characteristics among the six high-energy intensive industries, analyze the major contributors as well as the detailed contributions of each driving force to CO_2 emissions change for each high-energy intensive industry to provide a comprehensive understanding of energy-related CO_2 emissions in the six high-energy intensive industries. Moreover, we explained the reasons behind the results. (3) Some specific policy recommendations are suggested to promote energy intensive industries become more energy efficient and promote industry changes from heavy and energy intensive to lighter and high value added in the context of China's supply-side structural reforms.

The remainder of this paper is structured as follows. Section 2 presents the literature review. Section 3 describes the methodology and data source. Section 4 analyzes CO_2 emissions of six high-energy intensive industries. Section 5 discusses the empirical results. Section 6 summarizes our findings and provides policy recommendations.

2. Literature review

2.1. Factor decomposition methods

Structural Decomposition Analysis (SDA) and Index Decomposition Analysis (IDA) are the two commonly used methods in energy-related environmental analysis (Wang and Feng, 2017a, b). SDA method can analyze detailed industrial sector emissions, but it has application limitation for one special industry due to the requirements for the complete input-output table (Ang and Zhang, 2000). Many scholars have adopted SDA method to analyze the drivers of Chinese CO_2 emissions at national, regional or provincial levels (Guan et al., 2008; Wei et al., 2016; Xu et al., 2017a, b) and the influencing factors of CO_2 emissions in Spain (Cansino et al., 2016), Singapore (Su et al., 2017), the Spanish service industry (Alcantara and Padilla, 2009) and so on. In contrast, IDA method has its advantages in decomposition analysis because it is easy for use and the time series data of index numbers for analysis are available for a specific industry (Wang and Feng, 2017a, b). For this reason, IDA is more commonly used to quantify drivers behind changes in an aggregate of energy consumption, energy intensity or CO_2 emissions.

The IDA methods can be grouped into Laspeyres, Shapley/Sun, and Divisia index methods (including logarithmic mean Divisia index, arithmetic mean Divisia index and other parametric Divisia index methods). In which, the Laspeyres and the Divisia index methods were the two most often used index decomposition methods during the last decade. The Laspeyres index method measures the impact of a variable by allowing the specific variable change while holding the other variables at their respective base year values (Ang and Zhang, 2000). However, due to the residual term problem of the conventional Laspeyres method and other Divisia methods, the LMDI method has taken a dominant position in IDA in recent years (Moutinho et al., 2015; Shao et al., 2016; Zhang et al., 2016; Chong et al., 2017; Jiang et al., 2017; Wang and Feng, 2017a, b). LMDI is easy to apply irrespective of the number of factors, and according to Xu and Ang (2013), there is a strong preference for LMDI when the number of factors exceeds five. With the overwhelming usage, Ang and Liu et al. (2007) proposed solutions for the 0 value problem in the LMDI method, and the LMDI method has been gradually improved (Ang and Liu, 2001; Fernández González et al., 2014; Ang, 2015).

2.2. Driving forces of energy/CO_2 emissions at industrial level

Considering that the industrial sector exerted a strong impact on national energy usage, emissions and environmental systems, exploring the driving forces of CO_2 emissions at industrial level has received considerable attention from policy makers, practitioners and academics in recent years. For instance, by tracking CO_2 emissions in the EU (European Union) power sector through LMDI decomposition, González et al. (2014) found that there was a strong impact of changes in the energy mix on CO_2 emissions reduction, and innovation and technical change were less helpful tools when eliminating the price effect.

The LMDI decomposition is the most commonly adopted method in the study of the factors that changes carbon dioxide emissions. Studies such as Liu et al. (2007), Zhao et al. (2010), Du and Sun (2015), Lin and Xie (2015), Ouyang and Lin (2015), Xie et al. (2016) and Yang et al. (2018) found that industrial activity is the major factor that contributes to the increase of industrial CO_2 emissions while energy intensity is the major contributor to the decrease of CO_2 emissions. Based on the LMDI method, Wang et al. (2011) showed that the per capita economic activity effect and transportation modal shifting effect are responsible for increasing CO_2 emissions, and the transportation intensity effect is the main driver for reducing CO_2 emissions in China's transport sector. Xu et al. (2012) showed that the growth of cement output is the most important factor driving energy consumption up, while clinker share decline, structural shifts mainly drive energy consumption down (similar for CO_2 emissions) in China's cement industry. According to Lin and Ouyang (2014), industrial activity is the leading force explaining emission increase while energy intensity is the major contributor to the emission mitigation in China's nonmetallic mineral products industry. By adopting the LMDI method based on the extended Kaya identity, Ren et al. (2014) indicated that the output effect was most important for the increase of CO_2 emissions, and reduction of energy intensity has contributed significantly to emissions decrease in China's manufacturing industry. The study also demonstrated that factors such as emission factors, industry structure, and energy structure were not the determining factors to the changes of CO_2 emissions.

Based on the empirical study on the food industry in China from 1991 to 2012, Lin and Xie (2016) showed that the energy intensity has significant inhibitory effects on CO_2 emissions decrease, while the effects of intermediate use and domestic final demand are the two biggest contributors to the increase of CO_2 emissions. By employing a subsystem input–output decomposition analysis, Yuan and Zhao (2016) found that the external component is primarily responsible for increased CO_2 emissions and the demand effect is the key factor in the decrease of CO_2 emissions for China's energy-intensive industries. Based on the empirical analysis on energy consumption in China's logistics industry, Dai and Gao (2016) showed that energy efficiency gains showed slight but promising effect of curbing the energy rise in China's logistics industry. By utilizing time series data and provincial panel data, Lin and Long (2016) showed that energy intensity and energy structure were conducive for decrease in carbon emissions in China's