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Regional differences in the CO_2 emissions of China's iron and steel industry: Regional heterogeneity

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HIGHLIGHTS

- We explore the driving forces of CO_2 emissions in China's steel industry.
- Industrialization dominates CO_2 emissions in the iron and steel industry.
- Energy structure has large potential to mitigate CO_2 emissions in the steel industry.
- The influence of urbanization has significant regional differences.

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ABSTRACT

Identifying the key influencing factors of CO_2 emissions in China's iron and steel industry is vital for mitigating its emissions and formulating effective environmental protection measures. Most of the existing researches utilized time series data to investigate the driving factors of the industry's CO_2 emission at the national level, but regional differences have not been given appropriate attention. This paper adopts provincial panel data from 2000 to 2013 and panel data models to examine the key driving forces of CO_2 emissions at the regional levels in China. The results show that industrialization dominates the industry's CO_2 emissions, but its effect varies across regions. The impact of energy efficiency on CO_2 emissions in the eastern region is greater than in the central and western regions because of a huge difference in R&D investment. The influence of urbanization has significant regional differences due to the heterogeneity in human capital accumulation and real estate development. Energy structure has large potential to mitigate CO_2 emissions on account of increased R&D investment in energy-saving technology and expanded clean energy use. Hence, in order to effectively achieve emission reduction, local governments should consider all these factors as well as regional heterogeneity in formulating appropriate mitigation policies.

1. Introduction

Carbon dioxide (CO_2) produced by human activities has become a culprit of increasing global warming and environmental degradation (Zhi et al., 2015). In 2012, China's CO_2 emissions were estimated to be approximately 10 billion tons, accounting for 28% of the world's total emissions (Frieler et al., 2013). Therefore, China has become a focus of global efforts to reduce CO_2 emissions amidst increasing international pressure. However, rigid energy demand continues to exist due to industrialization and urbanization. This leads to difficulty in reducing CO_2 emissions. The industrial sector is the largest energy consumer in China, is pollution-intensive and has become a major source of CO_2 emissions (Lin and Ouyang, 2014). Thus, understanding and investigating the influencing factors of CO_2 emission in China's major industries are of vital importance (Lin and Moubarak, 2014; Lin and Xie, 2014).

China is currently in the stage of rapid industrialization and urbanization (Jiang and Lin, 2012). As a pillar industry of the national economy, the iron and steel industry (ISI) has enjoyed rapid growth along with economic development (Hasanbeigi et al.,

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2013). According to the latest China Statistical Yearbook, crude steel production rose from 101 million metric tonnes (Mt) in 1996 to 779 Mt in 2013, pig iron production increased from 107 Mt to 709 Mt, and finished steel products increased 10-fold over the same period. The average annual growth rates of crude steel, pig iron and finished steel production were 13%, 12% and 15% respectively, higher than GDP growth rate of 11% in the same period. At present, China is the largest iron and steel producer and consumer in the world (Wen et al., 2014), accounting for nearly 50% of global steel output (World Steel Association (WSA) 2012). In 2013, the industry consumed 624.9 million tons of standard coal equivalent (tce) and released 1687.2 million tons of CO_2, accounting for 16.2% of China's total CO_2 emissions. Consequently, in order to cope with increasingly severe environmental challenge in China, there is the need to pay attention to CO_2 emissions in the industry. Identifying the key driving forces of the industry's CO_2 emissions is essential for formulating effective environmental protection and emission reduction policies.

The CO_2 emissions in China's steel industry have been analyzed extensively (Smyth et al., 2011; Zhang et al., 2014; Morfeldt et al., 2015; Yu et al., 2015a). Most existing studies focus on the country's CO_2 emissions using time series or cross-sectional data, while few are based on panel data. Time series and cross-sectional data are prone to some problems in the actual application process. First, owing to small sample data, it results in a less robustness of the model estimation results. Second, cross-sectional data has significant heterogeneity due to significant differences among individuals. For example, because economic development among different provinces has significant difference, there is a big gap between their coal consumptions, the levels of urbanization, and industrialization levels. Third, time series data is much easy to create multicollinearity problem (Liddle and Lung, 2015). For instance, China's urbanization and industrialization have similar development process. If the time series data is used in empirical analysis, it would possibly lead to multicollinearity problem. In general, relying on a large number of sample data and observed individuals, panel data can control individual heterogeneity, reduce the effects of collinearity among the variables, and improve the estimation efficiency. Meanwhile, China has a vast territory, with significant regional differences in resources distribution and economic growth. Moreover, the level of urbanization and technological advancements also vary in different regions. Hence, the ISI's CO_2 emissions are affected by regional characteristics whether on the gross level or on the per capita level. The studies investigating the driving forces of the ISI's CO_2 emissions from a national perspective ignore regional heterogeneity, therefore resulting in a biased estimation (Lin and Wang, 2015).

The paper investigates the different impacts of the driving forces of CO_2 emissions in China's steel industry using 30 provincial penal data over the period 2000–2013. Taking into account significant regional differences in resources distribution and economic progress, we employ the panel data regression models to explore the heterogeneous influences of the driving factors of the ISI's CO_2 emissions.

The remaining parts of the paper are organized as follows. Section 2 briefly reviews the related literature and previous studies on the steel industry's CO_2 emissions. Section 3 describes the applied method and sample data. Section 4 presents the empirical results. Section 5 discusses the results of the empirical analysis. Conclusions and policy suggestions are provided in Section 6.

2. Literature review

The existing literature has extensively studied CO_2 emissions in the iron and steel industry using different methods.

The methods researching the ISI's CO_2 emissions are basically divided into four categories. Firstly, the classical approach is the index decomposition method. The industry emissions are decomposed into energy-efficiency effect, structure effect and fuel share effect. Ozawa et al. (2002) and Sheinbaum et al. (2010) studied the change in the steel industry emissions in Mexico by fuel mix and energy efficiency. Kim and Worrell (2002) extended the above analysis to the steel industry's energy intensity and concluded that scale effect was one of the main drivers of CO_2 emissions for seven countries including South Korea, India, China, Mexico and Brazil. The second method is the bottom-up analysis. Moya and Pardo (2013) examined the effects of the Best Available Technologies and Innovative technologies on CO_2 emissions in European steel industry with a bottom-up method. Morrow et al. (2014) developed a bottom-up Conservation Supply Curve (CSC) model to investigate energy efficiency related to CO_2 emissions in India's steel industry. The method was also used to survey the role of energy efficiency in reducing the US steel industry CO_2 emissions (Karali et al., 2014). The third method is system optimization. This method has been widely applied in research on the reduction potential of energy consumption and CO_2 emissions in the iron and steel industry (Han et al., 2014; Kim et al., 2014; Nakaso et al., 2015) and in the study of policy effect (Li et al., 2015; Pellegrino et al., 2015). The fourth method is econometric models. Using data envelopment analysis (DEA) model, Morfeldt and Silveira (2014) examined the energy efficiency in European steel industry; Hamada et al. (2014) researched CO_2 reduction in Egypt and other countries; Riccardi et al. (2015) surveyed the implementation of the European Emissions Trading Scheme on CO_2 emissions in European steel industry with an equilibrium model.

With increasing emissions from the iron steel industry and growing pressure surrounding emissions-mitigation, more attention has been focused on China. Using Logarithmic Mean Divisia Index (LMDI) decomposition method, Sun et al. (2011) decomposed the change in China's steel industry emissions into four forces-structure effect, emission factor effect, energy intensity effect and production scale effect. Tian et al. (2013) and Hasanbeigi et al. (2014) researched the steel sector's emissions with a similar method. They emphasize that the total scale effect and structure effect are the major driving force for CO_2 emission growth in China's steel industry, respectively. Furthermore, most of the documents use LMDI method to study the changes in CO_2 emissions in terms of the overall perspective or different time periods, but few studies are based on a regional perspective. Applying a bottom-up model, Chen et al. (2014) surveyed the steel production and CO_2 emissions in China's steel sector between 2010 and 2050, and suggested that steel output will reach a peak point of 772 Mt in 2020. Liu et al. (2014) analyzed the role of carbon tax and command-and-control in reducing the steel sector's emissions with a similar method. Their results show that command-and-control is more effective than carbon tax. Ma et al. (2014), Zhang et al. (2014) and Dai (2015) assessed the operation efficiency, structure and scale of the steel industry using the system optimization method. They found that energy efficiency improvement helps reduce CO_2 emissions and the steel sector's energy consumption continues to increase. Notwithstanding, the rate of increase gradually declined. By applying econometric vector autoregression (VAR) model, Yu et al. (2015b) explored the effects of economic growth, technological progress and investment activities on the CO_2 reduction in the steel industry and indicated that technical improvement and economic growth have a positive effect on CO_2 emission mitigation, which is boosted by investment activities. Ma et al. (2002) and He et al. (2013), employing data envelopment analysis (DEA) model, also reached the conclusion that technical efficiency improvements help abate CO_2 emissions in the steel industry.