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The low-carbon technology characteristics of China's ferrous metal industry

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ABSTRACT

The ferrous metal industry is the largest energy-consuming industrial sector in China. This paper examines the low-carbon production characteristics of this industry during the period 1980–2013. We employ the duality theory of the Weighted Russell Directional Distance Function to propose a general procedure for modeling production characteristics with carbon emissions being considered the undesirable output. Using the Weighted Russell Directional Distance Function model, we measure the carbon-adjusted technical efficiency and environmental regulatory costs for this industry. To investigate policy effects, we test the Porter hypothesis using the Granger causality between regulatory cost and technical efficiency. By using the dual model of Weighted Russell Directional Distance Function, we estimate the carbon shadow pricing and inter-factor substitution possibilities. Results show that the carbon-adjusted technical efficiency and environmental regulation costs of the Chinese ferrous metal industry have significantly increased in recent decades. However, the latter does not significantly cause the improvement of former. The indirect Morishima elasticities of substitution reflect that the increase of fixed assets will effectively improve the carbon emissions performance of the Chinese ferrous metal industry. Finally, some policy implications are suggested.

1. Introduction

The ferrous metal industry is one of the basic industries in the process of economic development and industrialization. With the extraordinary growth of China' economy, the ferrous metal industry also has experienced booming in the last three decades. However, with the slowing down growth and the severe environmental pollution nowadays, the ferrous metal industry of China has to face great challenges as well as deep reform. The ferrous metal industry has consumed the most energy among the entire industrial sector in China during recent years. In 2009, the government set a target for reducing CO_2 emissions per unit of GDP by 40–45% by 2020, compared to 2005 levels. Therefore, the first challenge is how to balance the growth and environmental protection. However, no studies have been focused on the energy and carbon emissions characteristics for this industry in China, so that to shed lights on the future reform in this industry. The aim of this study is to investigate the low-carbon technology characteristics of the Chinese ferrous metal industry for future reform and sustainable development.

For this purpose, we employ the recently developed Weighted Russell Directional Distance Function (WRDDF) and its duality theory. The WRDDF based measure is evaluated in linear form and hence processes the attractive advantages of easy computation and easy extension of incorporating the additional undesirable outputs into the programming problems (Chen et al., 2010; Lozano et al., 2011; Barros et al., 2012). It out performs the existing measures in cases where inputs are not equally productive and provides similar measures in all other cases (Ruggiero and Bretschneider, 1998). By using the WRDDF, we measure the annual carbon-adjusted technical efficiency of this industry. Meanwhile, by comparing the regulated and unregulated environmental technology, we can simulate the regulatory cost of carbon emissions. Therefore, we can also test the Porter hypothesis to investigate the effects of environmental regulation for this industry. By using the dual model of WRDDF, we estimate the shadow price of carbon emissions to analyze the marginal abatement cost of this industry. Finally, the

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inter-factor substitution possibilities are calculated by employing the Morishima elasticity of substitution.

The contributions of this study are summarized as follows: First, this study fills a gap in the scholarship by empirically examining the carbon technology issues of the Chinese ferrous metal industry, as no studies have focused on this industry. Second, we use the duality theory of WRDDF to estimate the shadow price of carbon emissions and inter-factor substitution for this industry, based on which we could provide some meaningful policy suggestions. Third, we use the data of this industry, which covers a relatively long period (1980–2013) in order to obtain more dynamic insights.

The remainder of this paper is organized as follows. Section 2 introduces the background of the Chinese ferrous metal industry. Section 3 presents a literature review focused on environmental technology characteristics. Section 4 introduces the methodology of the WRDDF approach and its dual model, including measuring carbon-adjusted technical efficiency, carbon emissions regulatory cost, shadow pricing, and the Morishima elasticity of substitution. In Section 5, an empirical study of the Chinese ferrous metal industry during the period from 1980 to 2013 is conducted using the proposed methodology. Section 6 concludes and suggests some policy implications.

2. China's ferrous metal industry

The ferrous metal industry is a pillar industry in China. Within this industry, iron and steel are the most important and have garnered much more attention in the literature. The iron and steel industries have made great progress in the past decades, and China has been the world's largest steel producer for nearly 20 years (Hasanbeigi et al., 2014). Meanwhile, according to the analysis of Manyika et al. (2012), the ferrous metal industry is also one of the most energy-intensive industries. As shown in Fig. 1, the energy consumption of the Chinese ferrous metal industry has increased from 189,623 to 596,681 million tons of standard coal equivalent during the period from 2000 to 2012. This industry typically accounts for approximately 15% of total energy consumption in the whole of China and 22.36% in the industrial sectors.

The expanding production of the ferrous metal industry was considered an indicator of industrialization in the early period of reform; this industry had been given first priority by the Chinese government. Meanwhile, increased demand from massive infrastructure projects including construction, housing and the automobile market have played a vitally important role and stimulated the prosperity of the ferrous metal industry. Fig. 2 shows the development of the ferrous metal industry in China. Its revenue reached 401,979 billion yuan in 1999 and then increased about 18

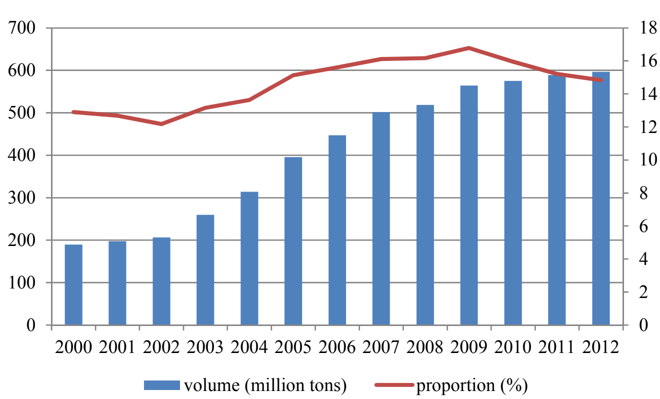

Fig. 1. The energy consumption of China's Ferrous Metal Industry.
Sources: China Statistical Yearbooks 2002–2014.

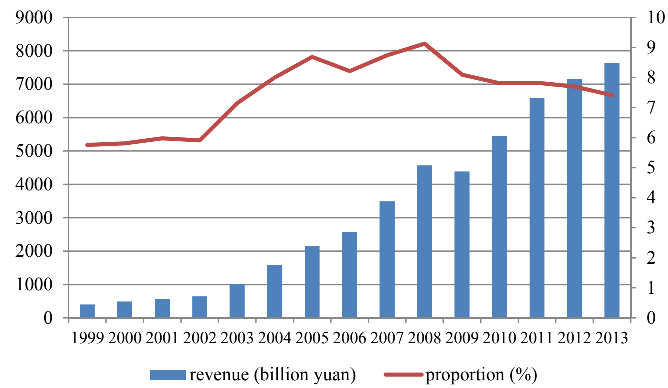

Fig. 2. The revenue of China's Ferrous Metal Industry.
Sources: CEInet Industry Database (cyk.cei.gov.cn).

times to 7,631,693 billion yuan in 2013,[1] and it accounts for approximately 7.48% of the total revenue of all industrial enterprises combined. Moreover, 62 ferrous metal companies ranked in the top 500 domestic companies in 2007, and their revenue reached approximately 1600 billion yuan. The giant companies among these are iron and steel producers with some degree of monopoly power, like the Baosteel Group Corporation, Wuhan Iron and Steel Corporation and the Shougang Group.

Due to the energy-intensive nature of this industry, and the pollutant emissions that it causes, the ferrous metal industry has continued to be subject to environmental regulations. In the 1990s, small ferrous metal companies were forbidden by the government from implementing the policy of "grasping the large and letting go of the small." Later, the government began to limit new projects that did not use innovative technology, and since 2005, the government has promoted the technological upgrading and transition of existing ferrous metal companies. To further control the CO_2 and pollutant emissions, the Ministry of Industry and Information Technology (MIIT) of China[2] formulated requirements for operations and emissions for ferrous metal companies. In recent years, the government has implemented stricter regulations on the ferrous metal industry. In 2014, the MIIT of China released two blacklists of ferrous metal companies with old technology and overcapacity. These companies will be shut down in the near future. Thus, it is very meaningful to investigate the low-carbon technology characteristics of this industry.

3. Literature review

3.1. Empirical studies for China

As the low-carbon development has become an increasing concern for China's sustainable development, a number of empirical studies have attempted to address the environmental and carbon efficiency issues in China. For instance, there have been studies conducted at a provincial-level (Hu and Wang, 2006; Choi et al., 2012; Du et al., 2012; Wei et al., 2012; Lin and Du, 2013, 2015; Wang et al., 2013b; Evans et al., 2014; Li and Lin, 2015; Wang and Feng, 2015; Zhang et al., 2015), for industrial sectors (Wu et al., 2012; He et al., 2013; Wang and Wei, 2014; Bian et al., 2015), the manufacturing industry (Lee and Zhang, 2012; Cheng et al., 2015), the power generation industry (Zhou et al., 2012;

[1] According to the CEInet Industry Database (cyk.cei.gov.cn), the revenue of ferrous metal industry in China just includes the large and medium size enterprises.
[2] http://www.miit.gov.cn/.

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