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Analysis of energy savings potential of China's nonferrous metals industry

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ABSTRACT

China is one of the world's leading producers of refined copper, primary aluminum, lead, refined zinc, refined nickel, antimony, primary magnesium, manganese ore, tin ore, tungsten, and molybdenum. The production of the nonferrous metals industry is also energy-intensive, its energy consumption increased from 31.5 million tons of oil equivalent in 2000 to 112 million tons of oil equivalent in 2012, which is almost the same as Australia's total energy consumption (133 million tons of oil equivalent) in 2012. Thus, it is imperative for the industry to reduce its energy consumption. This study tries to analyze the energy savings potential of China's nonferrous metals industry by employing the directional distance function approach to model the nonferrous metals industry's production system. Further, the energy savings ratios and energy savings amounts of the 27 administrative regions of China during 2003–2009 are also discussed. The results show that the nonferrous metals industry, overall, can save more than 20% in energy consumption, and that none of the 27 regions show a year-on-year decrease in their energy savings ratios. In addition, the study finds that the regions with a high proportion of output of secondary nonferrous metals have low energy savings ratio. Another key finding of this study is that the energy savings potential significantly differed according to regional characteristics, and the energy savings opportunities are great in the central and western regions of China. Finally, this study provides several recommendations to improve the energy efficiency of the nonferrous metals industry.

1. Introduction

China is one of the world's leading producers of refined copper, primary aluminum, lead, refined zinc, refined nickel, antimony, primary magnesium, manganese ore, tin ore, tungsten, and molybdenum. For more than 10 years, the increasing production of Chinese nonferrous metals rendered it the largest nonferrous metals producer, and it has led the production of several nonferrous metals, such as primary aluminum, lead, and zinc. In 2013, China's output of refined copper and primary aluminum was 6.48 tons and 22.05 million tons, respectively, accounting for 32.07% and 46.35% of the world's total output, respectively, as shown in Fig. 1. In addition, its tungsten and magnesium outputs accounted for about 80% of the world's total output.

In recent years, the nonferrous metals industry's production of China has dramatically increased. From 1990 to 2012, China's output of refined copper, primary aluminum, and lead increased 10, 23, and 15 times, respectively, as shown in Table 1. Its energy consumption has also increased from 31.5 million tons of oil equivalent in 2000 to 112 million tons of oil equivalent in 2012, which is almost the same as Australia's total energy consumption (133 million tons of oil equivalent) in 2012. Consequently, the industry received much attention from the government with regard to reducing energy consumption. For example, according to the "11th Five-Year Plan for the Nonferrous Metals Industry" released by the Ministry of Industry and Information Technology, the average annual growth rate of the industry's value-added products should reach 10%, while its energy consumption per unit of value-added should fall to 18%. Therefore, simultaneously increasing output and reducing the energy consumption is the long-term development strategy for the industry.

In the same time, the energy consumption of the nonferrous metals industry has drawn attention of researchers. Yanjia and Chandler (2010) focused on the energy consumption disaggregated by the regions of the nonferrous metals industry. Lin and Zhang (2013) estimated the electricity saving potential of China's nonferrous metals industry, and found that R&D intensity,

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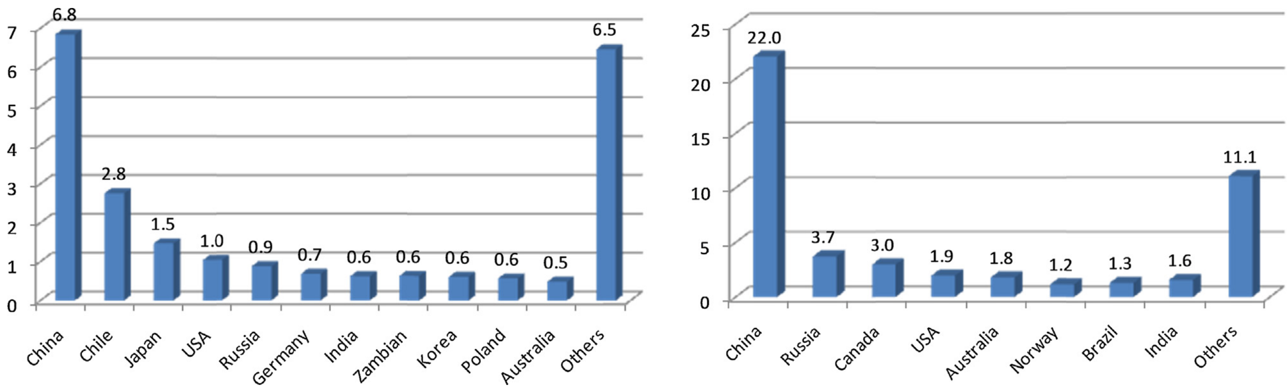

Fig. 1. The main refined copper and primary aluminum producing countries and their output in the world in 2013. Note: The left image represents the main refined copper producing countries and their output and the right one is the main primary aluminum producing countries and their output in 2013.

Table 1
Outputs of main nonferrous metals.

Products	1990	1995	2000	2005	2010	2012
10 kinds of nonferrous metals	239.3	496.6	783.8	1639	3136	3697
Refined copper	56.2	108	137.1	260	454	587.9
Primary aluminum	84.7	167.6	279.4	780.6	1624.4	2025.1
Lead	29.7	60.8	110	239.1	415.8	459.1
Zinc	55.2	107.7	195.7	277.6	520.9	488.1
Nickel	2.8	3.9	5.1	9.5	15.9	19.7
Tin	3.6	6.8	11.2	12.2	14.9	14.8
Antimony	6	1295	11.3	13.8	19.3	24.2
Magnesium	0.5	9.4	14.2	45.1	65.1	69.8

Note: The data are from the China Nonferrous Metals Industry Yearbook 2013, and the unit for all the products is 10^4 ton.

industrial electricity price, enterprise scale, and labor productivity affect the industry's electricity intensity. Some researchers have examined the sub-industry's energy efficiency and energy savings potential, using several sophisticated approaches. For example, González Palencia et al. (2013) developed a linear programming optimization model of energy use in secondary production and semi-fabrication in the nonferrous metals industry and analyzed the potential energy efficiency improvement in Colombia. Although there has been abundant research on the energy savings potential of industries in China (Lin and Zhang, 2013), however, in the aforementioned studies, the authors generally focused on the sectional energy consumption, while focusing less on the regional energy savings potential of the Chinese nonferrous metals industry. Since the energy efficiency of nonferrous metals depends on region-specific characteristics including their mineral resources, geographical location, degree of industrialization, and resource development policy. Therefore, the energy savings potential and the energy requirements for each material production is not the same as in different regions of China. Thus, the energy savings potential of the 27 administrative regions is discussed to provide an insight into China's nonferrous metals industry production.

For the production system of the nonferrous metals industry, on one hand, as one of the fundamental raw materials, the production of nonferrous metals to satisfy economic growth is one of the most important development targets of the industry. On the other hand, the production of nonferrous metals industry is energy-intensive. Its energy savings issue has a significant effect on the entire country's energy savings targets. Therefore, the industry's energy consumption should decrease while output increases. To address the industry's energy savings potential in different regions of China, the directional distance function approach is employed to model the nonferrous metals industry's production system, which has been applied in the energy efficiency analysis after setting the directional vector (Riccardi et al., 2012; Wang et al., 2013a,b, 2014). Furthermore, after considering the energy surplus and output shortage of the nonferrous metals industry, we extend the traditional directional distance function after considering the contraction of the energy input and expansion of the output, which is defined by the corresponding direction vector.

This paper contributes to related literature in several aspects. First, to our knowledge, this is the first study calculating and analyzing the nonferrous metals industry's energy savings ratio and energy savings amount. Second, the study analyzes the main characteristic of the energy savings potential in different regions. Third, it studied the relationship between several influencing factors with the energy savings ratio/energy savings amount, and provided valuable information. Finally, the research results are helpful for both enterprises as well as policy makers, and the suggestions may help China improve its nonferrous metals industry's energy efficiency. The remainder of the paper is organized as follows. In Section 2, the directional distance function model is discussed. In Section 3, a description of the inputs and outputs is provided, followed by the results and discussion in Section 4. Finally, Section 5 provides the conclusions and policy recommendations.

2. Methodology

The directional distance function is a generalization of Shephard's input and output distance function (Chambers et al., 1996), which enables the estimation of efficiency scores by incorporating all types of inputs and outputs (Watanabe and Tanaka, 2007). The method was further developed by Shephard and Färe (1974), Gilbert and Johnson (1985), Luenberger (1992a,b), Chambers et al. (1998) and Chung et al. (1997) first proposed a directional distance function that simultaneously incorporates the increase of desirable outputs and the decrease of undesirable outputs.