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Factor and fuel substitution in China's iron & steel industry: Evidence and policy implications

Xiaolei Wang [a], Boqiang Lin [b,*]

[a] School of Management, China University of Mining and Technology, Xuzhou, Jiangsu 221116, China
[b] Collaborative Innovation Center for Energy Economics and Energy Policy, China Institute for Studies in Energy Policy, Xiamen University, Xiamen, Fujian 361005, China

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ABSTRACT

Climate change which is induced from energy consumption and CO_2 emissions has got people's attention; hence, many strategies and ways are being adopted to mitigate CO_2 emissions. Energy substitution is crucial to the promotion of energy conservation and CO_2 emissions reduction. The purpose of this paper is to estimate both inter-factor and inter-fuel substitution in China's iron & steel industry during the period 1985–2011. Empirical results show several conclusions for China's iron & steel industry: (1) own-price elasticity of energy is negative, so increase in energy price will reduce energy input; (2) energy and capital, and energy and labor are substitutes, and the substitution in energy/capital is relatively stronger; (3) though coal, oil and electricity are also substitutes, the substitution effect is not so obvious because of pricing distortions in China. The driving forces of energy efficiency change are further discussed and the results show that technology progress is the key factor determining energy intensity. Therefore, market-oriented reforms in terms of energy prices, improvement in energy substitution (including inter-factor and inter-fuel substation) and promotion of energy saving technologies are important means for ensuring future energy conservation and CO_2 emissions reduction practices in China's iron & steel sector.

1. Introduction

Nowadays, the challenge of climate change has been one of the hotly discussed issues. As industry is the most important energy consumption sector, greenhouse gases emissions from industry accounted for just over 30% of global GHG emissions in 2010 (IPCC, 2014). The iron & steel sector is a typical energy-intensive and CO_2 emission industrial sector. Along with China's economic reform and opening up, China's iron & steel sector has developed at a very large scale. From 1985 to 2011, the production of crude steel increased from 46.5 million tons to 683.3 million tons, and the production value in 2011 was 45.04% of the world's total steel production (WSA, 2012). The industrial value added rose from 16.78 billion yuan in 1985 to 287.83 billion yuan in 2011, with an average annual growth rate of 13%. The industrial value added in the iron & steel sector is about 9% of the total industrial sectors. Thus, the study on China's iron & steel sector is of great importance to saving energy and mitigating climate change.

The sources of output growth in the iron & steel sector are technology progress and increases in factor inputs. Technology progress has close relationship with research and development (R&D) expenditure. As shown in Fig. 1, R&D expenditure of China's iron & steel industry increased from 237.38 million Yuan in 1985–51,264 million Yuan in 2011, with an annual growth rate of 26.5%. In 2011, total R&D personnel stood at 113 thousand men, and the percentage of R&D personnel of total employees in the iron & steel sector was 3%, 1% higher than that of the entire industries. In the 12th Five Year Plan of the iron & steel industry, the target of technical progress, which is the proportion of R&D expenditure in business income, was set at 1.5% by 2015. Therefore, during the past 30 years, the modern production techniques and facilities were adopted gradually, and the technical level of China's iron and steel production improved considerably. For example, before the 1980s, China only introduced aging technologies and equipment from the former Soviet Union and Eastern Europe because of political reasons Fujii et al. (2010). As modern production equipments were

* Corresponding author. Collaborative Innovation Center for Energy Economics and Energy Policy, China Institute for Studies in Energy Policy, Xiamen University, Xiamen, Fujian 361005, China.

E-mail addresses: bqlin@xmu.edu.cn, bqlin2004@vip.sina.com (B. Lin).

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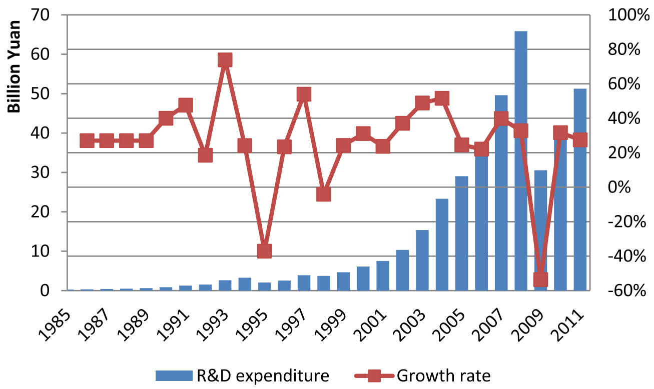

Fig. 1. R&D expenditure in China's iron & steel industry.
Source: China Statistical Yearbook on Science and Technology (China Statistics Press, 1986–2012).

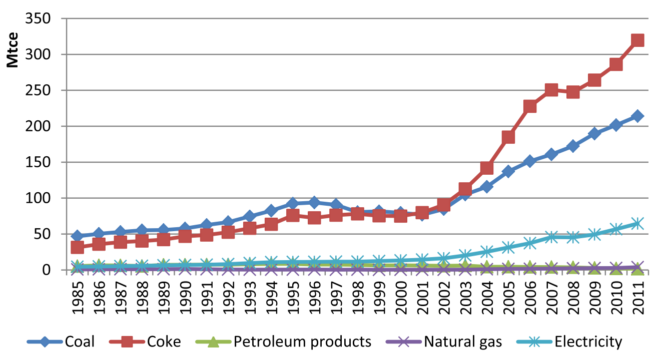

Fig. 2. Energy consumption in China's iron & steel industry.
Source: China Statistical Yearbook (China Statistics Press, 1986–2012).

gradually invested, production techniques were dramatically changed in 1990s. The continuous casting ratio increased from only 6% in the 1980s to more than 95% in recent years.

With respect to changes in input factors, during 1985–2011, labor input changed from 2430 thousand persons to 3399 thousand persons; and capital stock increased from 40.2 billion Yuan to 426.9 billion Yuan (in 1985 price level). At the same time, as a major production input factor, consumption of energy resources also experienced a sharp increase from 76.4million tons of coal equivalent (mtce) to 586.8 mtce. The average annual growth rate of labor, capital and energy factor is 1.56%, 11.48% and 8.48% respectively, which confirmed that the development of China's iron & steel industry is accompanied by capital expansion and excessive use of energy. In 2011, energy consumption of the iron and steel sector accounted for 29.39% and 24% of energy consumption in the manufacturing sectors and the entire industrial sectors respectively.

The main energy resources consumed in China's iron & steel industry include coal, coke, oil, electricity, etc,[1] as shown in Fig.2. The main energy resources in terms of relative importance are coal-related fuels, electric power, oil-related fuels and natural gas. In the energy structure of China's iron & steel sector, the highest shares are coal and coke, with each accounting for about 40%. This is followed by electricity consumption, with an average proportion of 6%. The share of the consumption of natural gas is very small accounting for only 0.42%. Therefore, on the whole, coal-related fuels were the main energy resources in the past 30 years. However, along with the promotion of modern technology, the proportion of coal-related fuels in the total energy consumption showed a slowly declining trend; it fell from 82% in 1985 to 75.5% in 2011. Relatively, the proportion of electricity consumption increased, reaching 9% in 2011.

As can be seen, the coal-dominated energy structure has undermined sustainable development. First, coal, oil and other fossil fuels are non-renewable energy sources, so excessive mining leads to resource depletion. Second, mass combustion of fossil fuels leads to environment-related issues. According to the empirical results in OECD countries of Fujii and Managi (2013), along with economic growth, iron & steel industry show an N-shape curve relationship between CO_2 emission and economic growth because of a shift from shaft furnace (SF) production to electric arc furnace (EAF) production. Therefore, study on energy substitution (factor substitution and fuel substitution) in China's iron & steel production is very important for carbon reducing practice.

The remainder of this paper is organized as follows. Section 2 provides a brief review of existing literature on energy substitution. Section 3 describes the estimation methods used in this paper. Section 4 outlines the main variables and the relevant data. Section 5 offers the empirical results of the trans-log cost function and estimates factor substitution and fuel substitution effect in China's iron & steel industry. The final conclusions and policy implications are presented in Section 6.

2. A brief literature review

Along with China's economic growth and fossil-fuel consumption, China's CO_2 emissions have rapidly increased for the past 30 years. Since 2007, China has overtaken America as the world's largest CO_2 emitter (Hao et al., 2016). In 2011, China's CO_2 emissions from fuel combustion reached 7999.6 million tons (IEA, 2013). The government is making great effort to reduce coal consumption and also increase clean energy usage in heavy industry. According to IEA (2015), China's CO_2 emissions would experience a flatten increase and reach a peak around 2030. On November 12th, 2014, the Chinese president declared his commitment to increase the proportion of non-fossil energy to 20% and reach the CO_2 emissions peak in 2030 (XNA, 2014). The level of CO_2 emissions of the iron & steel industry is about 15% of the total emissions in China (Xu et al., 2013). Therefore, study on factor and fuel substitution of China's iron & steel industry is of great importance to mitigating CO_2 emissions.

There are enormous literature focusing on energy substitution. Some verify the substitutability between energy and non-energy factors, while others indicate that there is complementary relationship in some cases. Using the trans-log cost function model, Berndt and Wood (1975) estimated the price elasticities of U.S. manufacturing sector from 1947 to 1971 and found that energy and capital are substitutes, but energy and labor are complements. Using the same model, Griffin and Gregory (1976)'s study arrived at the same conclusion with cross-country data. Medina and Vega-Cervera (2001) verified the existence of a consistent substitution between energy and labor for Italy, but the substitution between energy and capital was weak. Using quarterly data from 1981 to 1997, Cho et al. (2004) verified that changes in wage rates and sudden increase in oil consumption have had a significant impact on the inter-factor and inter-fuel substitution relationship in Korea. Arnberg and Bjørner (2007) studied the factor substitution and inter-energy substitution in Danish manufacturing firms. Their

[1] There are 9 kinds of energy resources and the conversion coefficients of standard coal come from "China Energy Statistical Yearbook (China Statistics Press, 2012)". According to the Yearbook, coal is mainly used for power generation in the iron & steel plants and electricity resource refers to the electricity bought by the iron & steel plants from power sector.