Technological progress and rebound effect in China's nonferrous metals industry: An empirical study

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A B S T R A C T

As one of China's mainstay and six major energy-intensive industries, the nonferrous metals industry faces the intense contradiction between economic growth and energy & environment constraints. Technological progress does not only realize the energy savings, but also causes rebound effect by promoting output growth. Although the rebound effect is an important topic, there is still very little empirical research that focuses on the nonferrous metals industry in China. Using the LMDI method and the total factor productivity model (to calculate parameters), we estimate the size of the rebound effect in China's nonferrous metals industry over the period 1985–2014. According to the results, the average rebound effect is approximately 83.02% with a downward trend, which indicates that most of the expected energy savings are mitigated. The rebounds with a strong fluctuation are comparatively discussed in various periods, suggesting that China cannot count only on technological progress to save energy and reduce emission. Furthermore, the government should apply economic instruments, such as energy pricing mechanism reform, resource tax, and carbon tax, as supplements to realize the targets of energy conservation and emission reduction. Additionally, optimizing sub-sector structure and promoting substitution also play a significant role in the mitigation of the rebound effect.

1. Introduction

The nonferrous metals industry is one of the mainstay and six major energy-intensive industries in China.

On one hand, it is capital-intensive. Its products are widely used in various economic sectors including national defense industries as well as to directly support people's livelihood. The industry plays an important part in the industrial upgrades of relevant sectors and economic growth. It grew rapidly from the beginning of the 21st century. The proportion of the industrial value added (IVA) of nonferrous metals in GDP was 2.05% in 2014 relative to 0.66% in 2001 indicating an annual average growth rate of 16%. China became the largest producer and consumer of ten kinds of nonferrous metals in the world by 2002. Especially, China contributed the most part of refined copper, primary aluminum, lead, and refined zinc to the world's total output. Through corporate restructuring, the Aluminum Corporation of China is now the world's largest electrolytic aluminum enterprise.

On the other hand, nonferrous metals industry is a typical energy-intensive industry. The amount of energy consumed in China's nonferrous metals industry has increased by a remarkable margin in the past 30 years (see Fig. 1). Especially in 2002, its growth rate reached 13.21%, significantly higher than before. In the 1980s and 1990s, China's nonferrous metals industry consumed nearly 3–4% of the total industrial energy consumption. However, it increased rapidly from 2002 and reached 5.62% in 2007. It was affected by the financial crisis which led to a slight decline. But it returned to a record high of 6.35% in 2014. Currently, energy consumption of the nonferrous metals industry is about 11 times the level as large as what it was 30 years ago. Owing to outdated technology, heavy-oriented industrial structure, coal-dominant energy consumption structure and other factors, the energy intensity (energy consumption per unit of value added) of China's nonferrous metals industry is maintained much higher than the international average level. The higher the energy intensity, the lower energy efficiency. On the other hand, energy consumption and CO2 emission of nonferrous metals industry almost keep a consistent and increasing trend during the period of 1985–2014 except in individual years (see Fig. 2). Therefore, environmental protection faces a great pressure from the rapid development of nonferrous metals industry.

Since 2005, the non-ferrous metals industry has faced huge...
The aim of this paper is to estimate the rebound effect. Section 4 describes the data involved in the econometric analysis. In Section 5, we calculate the energy rebound effect in China’s nonferrous metals industry from a macroscopic angle. The last section presents the conclusions and some policy suggestions.

2. Literature review

There are a considerable number of articles studying rebound effect. Khazzoom JD is the first person to study the rebound effect (Khazzoom, 1980). Then Brookes did a series of studies about the rebound effect (Brookes, 1990a, 1990b, 2000). Brookes and Khazzoom formulated the well-known Khazzoom-Brookes hypothesis: When real energy prices do not change, energy efficiency gained from technological progress will greatly increase energy consumption, due to energy efficiency releasing funds to promote economic growth. Among the following relevant research, there are many in-depth theoretical analyses such as Greening et al. (2000), Berkhout et al. (2000), Hass and Biermayr (2000), Roy (2000), Jin (2007) and Sorrell (2007).

According to Greening et al. (2000), energy rebound effect induces more energy consumption through three channels. The first is the direct rebound effect. The cost of energy services will decrease with improving energy efficiency. Then, the downward price will activate more effective energy demand which means more energy consumption. The impact of effective energy cost reduction on its consumption indeed includes substitution effect and income effect. Substitution effect means that the decision-maker always prefers to use the factors with lower effective cost. Income effect means when effective energy cost of input factor decreases, the real income relatively increases, which will further increase energy demand. For indirect rebound effect, the declining effective energy costs will provoke energy demand of the downstream industries in the industrial chain. As a result, the overall energy demand will increase. Lastly, the rebound effect happens to the overall economic system. The decreasing effective energy costs will result in reduction in the price of intermediate and final products. It incurs the price adjustments of the whole economic system. The production cost gap between energy-intensive industry and the other industries will be narrowed. The decreasing relative price of energy-intensive products will further increase its consumption, leading to more energy consumption. Therefore, the improvement in energy efficiency can raise the energy demand of the whole economic system.

Fig. 3 simply describes the direct rebound effect in a mathematical form. $e_0$ and $e_1$ ($e_0 < e_1$) denote two different energy efficiency levels for energy service. When the demand for energy services is unchanged and stays at $S_0$, energy consumption reduces from $E_0$ to $E_1$, and the reduction of energy consumption is $(E_0 - E_1)$. Nevertheless, when energy efficiency is improved from $e_0$ to $e_1$, demand for energy services increases to $S_1$, and the energy consumption becomes $E_2$. So the actual
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