How to reduce energy intensity in China's heavy industry—Evidence from a seemingly uncorrelated regression

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ABSTRACT

With rapid development and large scale urbanization, China's environmental and resource constraints are becoming increasingly severe. Compared to other industries, China's heavy industry is energy-intensive and emission-intensive, which exerts pressure on energy conservation policies. In this paper, by establishing a theoretical model of the impact factors of energy intensity, we investigate the effects of energy prices, ownership structure, and industrial concentration and R&D investment on the energy intensity of China's heavy industry, and seemingly unrelated regression model was used in the estimation of corresponding coefficients. The results show that increase in energy prices, decrease in state-owned enterprises and increase in industrial concentration may reduce the energy intensity of the industry. Also, the study points to evidence that an increase in R&D investment may reduce the oil intensity of heavy industry.

1. Introduction

The heavy industry mainly produces production materials, and also serves as the technical basis for the economy. According to the National Bureau of Statistics (NBS), the division between light and heavy industry standards is based on whether the industry produce production or consumption materials (Lin and Liu, 2016). There are also some research studies which classify heavy and light industry by the amount of energy consumed (Chen, 2011). In this paper, we use the classification method of NBS to determine a heavy or light industry (Appendix A1). In general, heavy industry mainly includes the metallurgy, machinery, energy, chemical, building material industries, etc. From the industrial chain perspective, heavy industry is an upstream industry, which means that high energy consumption is a major feature. Fig. 1 shows the primary energy consumption and electricity consumption of the heavy industry with their respective proportions in total energy and electricity consumption. From the figure, the heavy industry accounts for over 60% of China's primary energy consumption and electricity consumption, which means the China's energy consumption is highly concentrated in heavy industry.

The primary energy consumption of heavy industry is huge, the terminal energy consumption of heavy industry is also relatively high. According to the definition, terminal energy consumption means the energy consumption directly consumed by the user, while primary energy consumption means the energy harvested directly from natural resources.

Terminal energy consumption can be obtained by deducting the energy loss in energy processing, conversion and storage segments from the primary energy consumption. Due to restrictions on storage and usage methods, it is usually difficult for end-users to directly use energy obtained from nature. Therefore, it is often necessary to convert primary energy into a cleaner and more convenient terminal energy for using. Terminal energy consumption includes electricity, gasoline, natural gas and other energy products, compared with primary energy consumption, terminal energy consumption can better reflect the energy consumption characteristics and attributes of a specific industry. The terminal energy consumption structure of China's heavy industry is shown in Fig. 2.

It can be seen from Fig. 2 that the terminal energy consumption of heavy industry increased rapidly before 2011, while the growth rate began to decline from 2012, and the total amount began to

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Abbreviation and full name

R&D	Research and development
NBS	National Bureau of Statistics
GDP	Gross domestic product
AIM	Asian-Pacific Integrated Model
MECERPI	Malmquist energy conservation and emission reduction performance index
CSC	Conservation supply curve
LEAP	Long-range Energy Alternatives Planning
CDM	Clean development mechanism
SUR	Seemingly Unrelated Regression
FDI	Foreign direct investment
BAU	Business as usual
OLS	Ordinary least squares
SOE	State owned enterprises

decline in 2015. This is perhaps due to the fact that the Chinese economy has entered a "new normal" from 2012, shifting from high-speed growth to medium-high-speed growth and its economic structure has been continuously optimized and upgraded. Affected by this, the growth rate of energy consumption in China's heavy industry began to slow down or even decline.

As can be seen from Fig. 2 that the share of coal in the terminal energy consumption structure of heavy industry starts to decline after 2008, and the proportion of relatively cleaner energy such as electricity, natural gas and heat is on the rise. In 2015, natural gas, electricity and heat accounted for 5.24%, 21.77% and 3.77% of the total energy consumption of heavy industry terminals respectively, adding 30.78% of the three, exceeding the proportion of coal. The share of oil in the energy consumption structure of heavy industry terminals has been declining as a whole, which may be limited by the oil supply. In 2016, the petroleum external dependence was over 65.4%. Therefore, China's oil terminal consumption mainly concentrated in the transportation sector, with only a small part being used as industrial raw materials.

In recent years, the importance and imminence of sustainability

challenges are getting more attention (Motesharrei et al., 2016). In November 2014, the Chinese government promised to reduce carbon emissions per unit gross domestic product (GDP) by 60%–65% before 2030 compared to the 2005 level. Due to the huge energy consumption and emission of heavy industry, it will directly affect the achievement of the whole emissions reduction targets.

The government has also taken some measures to reduce the energy consumption in heavy industry and one of such measures is discriminatory electricity pricing of energy intensive industries, and accelerating the development of renewable energy is also treated as an important means of energy conservation and emission reduction (Meneguzzo et al., 2016). During the period 2010–2015, the energy intensity had decreased by 29.8%. In March 2016, the report *on the Work of Government* proposed a 15% reduction in energy intensity by 2020. Industrial sectors, especially heavy industry, are still facing great pressure on energy conservation and carbon emission reduction.

Current researches are mainly focused on the total industry, or some specific energy-intensive industries. However, as one of the important parts of China's industrial structure, the heavy industry contributes most to energy consumption, and the sub-sectors of the heavy industry have many common characteristics. Research on the heavy industry is very important especially in the context of energy conservation and emission reduction. Based on the existing literature, this paper focuses on the influencing factors of energy intensity of the entire heavy industry in China. The research results may provide some reference for the government in the development of relevant energy planning and industry development policies.

The rest of the paper is structured as follows: Section 2 gives an insight into existing literature on the topic. Section 3 provides the methods, data, and empirical models employed in this paper. Section 4 shows the empirical results. Section 5 focus on the related policy recommendations.

2. Literature review

The co-integration model is widely used to estimate the long-term relationship between energy consumption, carbon emission and economic growth with some influencing factors which
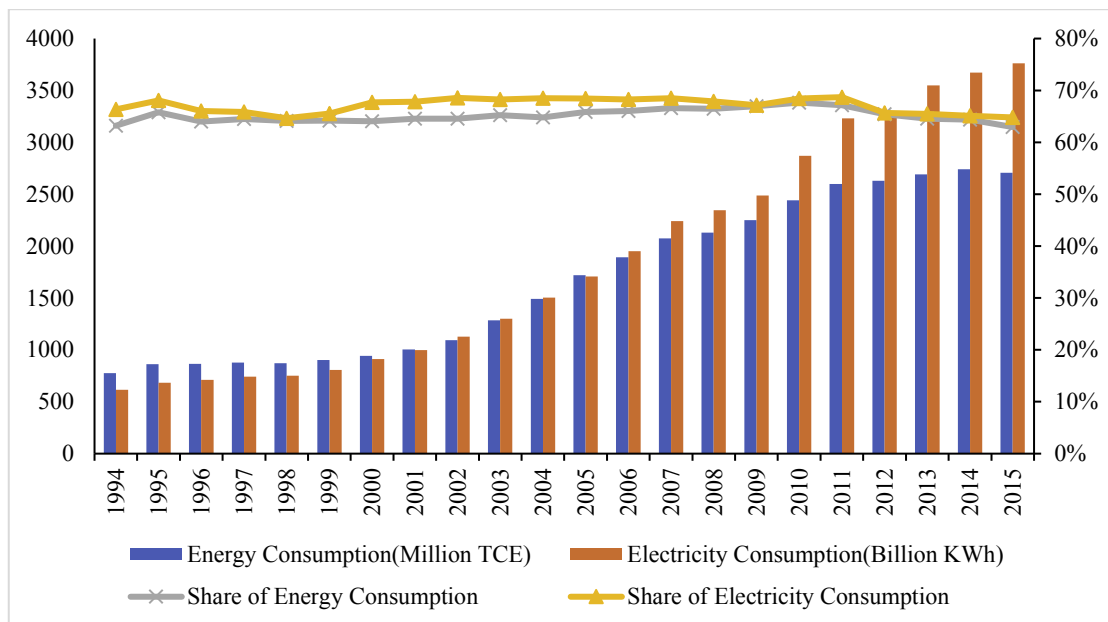

Fig. 1. The primary energy consumption and electricity consumption of China's heavy industry during 1994–2015.