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# The energy rebound effect in China's light industry: a translog cost function approach

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ABSTRACT

China is in its industrialization and urbanization development stage, which requires strong energy support. With the largest population in the world, the energy endowment of China is relatively small. Therefore, energy conservation is one of the key tools for China's sustainable development and energy security. When making policies for conservation, the Chinese government needs to deal with rebound effect carefully. In 2012, China's light industry consumed 316 million tons of coal equivalents, accounting for 9 percent of the country's total energy consumption, which is about the total amount of energy consumed by South Korea. Based on the translog cost function, the magnitude of rebound effect in China's light industry is estimated for the first time using the dynamic ordinary least squares and seemingly unrelated regression methods. Considering the asymmetric effects of energy prices on energy consumption, the rebound effect is approximately 37.7% and all the inputs are substitutes except for labor and energy. The different magnitude of rebound effect between light and heavy industry is discussed and some policy implications are provided for more effective energy conservation, allowing for the rebound effect.



## 1. Introduction

The boom of China's economy in the 21st century has induced rapid growth of energy consumption (Li and Shui, 2015). China accounted for 22.4% of global energy use and 49% of the world energy consumption growth in 2013 (BP, 2014), which means that China is the main driving force of world total energy consumption. Recently, the smog has severely impaired people's health in northern and eastern China and “PM2.5” has become more and more frequent in the mainstream media (Tie et al., 2009; Quan et al., 2011; Miao et al., 2015).[1] As China's economy has gradually recovered from the 2008 financial crisis, dealing with air pollution appears in the political agenda. The world also focuses attention on China's energy consumption and carbon emissions. Nowadays, China is urgently seeking ways to conserve energy in order to maintain the high growth rate of its economy as well as ensure environmental sustainability. Renewable energy is environment-friendly. However, it costs more than conventional energy. China is still a developing country, and high energy cost is not favorable to the economy. Furthermore, due to lack of grid capacity (Zhao et al., 2014), the power generated from wind and solar rich areas in north China cannot be easily transformed to the load center in the southeast.[2] As stated above, currently the wide use of renewable energy is still not applicable, although the Chinese government urges to make a sustainable energy supply. Thus, energy conservation is still crucial to slow down the growth rate of overall energy consumption and is also the key to China's low carbon transmission (Lin and Liu, 2013; Lin and Zhao, 2015).

In order to save energy, improving energy conservation technologies is usually one of the most popular measures considered by the government. However, the rebound effect induced by

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[1] Particulate matter 2.5 (diameter of 2.5 mm or less) is the particles suspended in air, which are bad for health.

[2] Zhao et al. (2014) also listed other four main barriers for Renewable Portfolio Stand (RPS).

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technology innovation can offset the outcome of energy conservation (Greene et al., 1999; Allan et al., 2007; Druckman et al., 2011) and may even cause “backfire”. Thus, when making energy conservation policies, it is crucial for the government to take rebound effect into consideration (Lin and Liu, 2012, 2013). In 2012, China's light industry consumed 316 million tons of coal equivalents, accounting for 9 percent of the country's total energy consumption; which is about the total amount of energy consumed by South Korea. There have been plenty of studies related to rebound effect. However, the researches on energy consumption in varies industries is relatively rare. Since different industries have different features, the energy consumption may differ significantly. It is necessary to examine the energy consumption of each industry. Industries are usually classified into light industry and heavy industry. The light industry provides goods that people consume in daily life; and the heavy industry produces machines and materials for the economy's reproduction. The light industry includes the manufacturing of textile, paper and paper products, processing of food from agricultural products, manufacturing of rubber and plastic products etc. Compared with the heavy industry, the firm sizes of the light industry are smaller, and the production process is much more heterogenous, making the behavior of energy consumption in the light industry different from that in the heavy industry.

Compared with other fossil fuels, China's coal reserve is relatively rich. Coal is the main energy resource and provides more than 60% of the country's total energy consumption. China is now facing increasing dependence on foreign energy. In 2013, about 58% oil was imported and more than 30% natural gas consumption was supplied by other countries (CNPC, 2014).[3] The situation that the main energy resource is coal cannot be changed in a relatively short period, considering the energy endowment and the importance of energy security (Lin et al., 2012). The carbon emission factor of coal is higher than that of other fossil fuels such as natural gas, and coal produces more pollutants during the burning process. For China, a country of huge energy consumption, studying the energy rebound effect makes a big difference in dealing with the energy problems. Also, this helps to slow down the overall energy consumption, reduce carbon emissions and prevent the environment from being polluted.

This paper presents a rough picture of the energy consumption in China's light industry. Fig. 1 shows the share of energy consumed by China's light industry in 2012, accounting for 8.7% of the total energy consumption. In 2000, coal accounted for approximate 60%, and electricity accounted for 22% of total energy consumption in China's light industry. During the following twelve years these ratios changed substantially. In 2012, the consumption of coal and electricity in China's light industry were almost similar, accounting for 46.4% and 46.0% of total energy use respectively. In 2012, the output value of China's light industry reached 22 trillion RMB. The export was 3.2 trillion RMB and the import was 0.75 trillion RMB. The domestic sales proportion was 1.1 percent higher than that of the previous year, reaching 86.8%.

This paper uses historical data, combines dynamic ordinary least squares (DOLS) and seemingly unrelated regression (SUR) and uses the translog cost function to estimate the energy rebound effect in China's light industry. In addition, by allowing for the rebound effect, some policy recommendations for more effective energy conservation are promoted. Section 1 is the introduction. Section 2 shows the literature review and Section 3 presents the methods. Section 4 is data resource description. Section 5 is the analysis of econometric results and Section 6 shows the conclusions and policy implications.

## 2. Literature review

Jevons (1866) first noticed that the extensive use of steam engines in the 19th century caused the rise of coal consumption, but this phenomenon had not drawn the eyes of the mainstream economists at that time. Then, Daniel Khazzoom and Leonard Brookes (Saunders, 1992) presented the paradox that energy efficiency is improved while the amount of energy consumption increases. From then on, the rebound effect was considered by most economists. A case is used here to have the rebound effect more easily understood. For instance, if the energy efficiency improves by 10% and the consumption behavior does not change, intuitively a 10% reduction of energy consumption is expected. If the reduction is less than 10%, say 8%, then 2% is missing and the magnitude of rebound effect is 20%.

The most prevailing classification of energy rebound effect is shown below, in which the rebound effect is classified into three categories. The first is the direct rebound effect, which refers to the substitution and income effect caused by lower price of effective energy services. It is induced by the advance of energy conservation technologies, and can be calculated through econometric analysis. The second is the indirect rebound effect, to see the details at Sorrell (2007). Lower energy prices mean the reduction of prices of overall commodities, and households become relatively richer and consume more goods, leading to the increase of energy use embedded in the production and transportation process. The third is the economy-wide effect, which means that the advance of energy conservation technologies stimulates the whole economy and pushes the production possibility frontier to move outwards. As a result, the overall energy consumption of the whole economy increases. Sorrell et al. (2009) gave a good summarization on the details of empirically estimation for the direct rebound effect, in which the quasi-experimental approach and econometric approach were summarized. Sorrell (2007) pointed out that there were very few quantitative estimations of indirect rebound effect which still had certain flaws. Grepperud and Rasmussen (2004) proposed that the energy economic models of the macro-economy could be used to estimate the economy-wide effect.[4]

The magnitude of rebound effect varies with time spans, different countries and sectors. Berkhout et al. (2000) showed that rebound effect varied from 0% to 30% in Dutch each year. They also declared that technology advance did reduce the overall energy consumption. However, the final result was partly offset by the reduction of energy price. Employing the DOLS method, Bentzen (2004) found that the rebound effect in US manufacturing sector was approximately 24%. He also pointed out that rebound effect was closely related to own-price elasticity and substitution elasticity of input factors. Sorrell and Dimitropoulos (2008) brought together the theories of rebound effect, as well as showed the limitations and extensions of the previous work in this field. Saunders (2013) presented the rebound effect of various sectors in the US and also provided a tool kit.

As for the energy rebound effect in China, Zhou and Lin (2007) used the time series data from 1978 to 2004 and estimated that the rebound effect induced by technology innovation fluctuated between 30% and 80%. Lin and Liu (2008) pointed out that the time series data could not show the differences among various regions and might cause estimation errors because of multicollinearity.

[3] CNPC refers to China National Petroleum Corporation (CNPC), one of the largest state-owned corporations in China's energy industry.

[4] The modes include computable general equilibrium (CGE) models etc.