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Measuring energy rebound effect in the Chinese economy: An economic accounting approach

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ABSTRACT

Estimating the magnitude of China's economy-wide rebound effect has attracted much attention in recent years. Most existing studies measure the rebound effect through the additional energy consumption from technological progress. However, in general technological progress is not equivalent to energy efficiency improvement. Consequently, their estimation may be misleading. To overcome the limitation, this paper develops an alternative approach for estimating energy rebound effect. Based on the proposed approach, China's economy-wide energy rebound effect is revisited. The empirical result shows that during the period 1981–2011 the rebound effects in China are between 30% and 40%, with an average value of 34.3%.

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1. Introduction

In past decades, China's energy consumption had been rising dramatically. According to NBSC-a (2012), in 2011 China's energy consumption reached 3480 million tons of coal equivalent (Mtec) which increased from 602.75 Mtec in 1980, indicating an annual growth rate of 5.8%. Moreover, as shown in Fig. 1, the consumption grew even more dramatically after 2002. At present, China has been the largest energy consumer as well as the largest emitter of greenhouse gas (GHS) in the world. It was also projected that China's energy consumption will grow steadily in the next decade due to the fact that China is still in the process of industrialization and urbanization. Consequently, China is facing increasing pressure on energy security and environmental pollutions.

Energy efficiency has been widely regarded as the most cost-effective way for dealing with energy challenges and environmental deterioration (Ang et al., 2010). In practice, the Chinese government has taken measures to improve energy efficiency for controlling or slowing down the growth of energy consumption. For instance, in the "11th Five-Year (2006–2010) Plan" the Chinese government set a target of reducing its energy intensity by 20% compared to that in 2005 and also initiated detailed policies to realize the target. However, taking into account the energy rebound effect, the impact of improving energy efficiency on energy use may be discounted.

Energy rebound effect means that an increase in energy efficiency may not lead to an expected decrease in energy use owing to the behavior change of economic agents (Wang et al., 2012). The idea can date back to Jeavons (1865). Over the past decades, energy rebound effect has been a hot topic in energy economics. There is already a large body of studies in this field. Representative literatures include Van Es et al. (1998), Schipper and Grubb (2000), Grepperud and Rasmussen (2004), Barker et al. (2007), Brännlund et al. (2007), Guerra and Sancho (2010), Wei (2010), Wang et al. (2012), and Ghosh and Blackhurst (2014). Some excellent reviews can also be found in the existing literatures, e.g., Greening et al. (2000), Dimitropoulos (2007), Sorrell and Dimitropoulos (2008), Sorrell et al. (2009), and Madlener and Alcott (2009).

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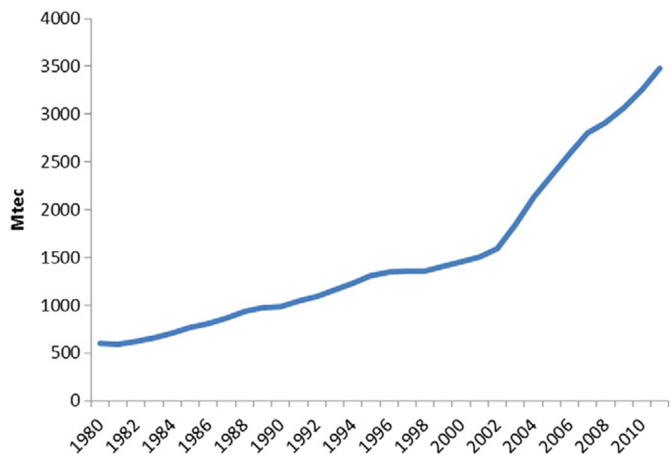

Fig. 1. Energy consumption in China, 1980–2011.

Estimating the magnitude of China's economy-wide rebound effect[1] has attracted much attention in recent years. There are mainly two methods used in the existing studies, i.e., the computable general equilibrium (CGE) model and the economic accounting approach. For example, Zha and Zhou (2010) constructed a CGE model and use China's 2002 input–output table to estimate China's energy rebound effect. They found that a 4% improvement of energy efficiency would generate a 33% energy rebound. Li and Lu (2011) also used a CGE model to measure the energy rebound effect in China. But the data they used is China's 2007 input–output table. They found that a 5% increase in energy efficiency would lead to a 178.61% rebound in the long run. The CGE model is a system modeling method which describes explicitly the response of economic agents to energy efficiency change. One distinct merit of the CGE model is that it has microeconomic foundations so that the mechanisms of the rebound effect can be explained in depth. However, a series of strict assumptions are needed for CGE modeling, e.g., utility function, production function, and technological change, etc. Saunders (2008) shows that the choice of function can inadvertently pre-determine results. Another shortcoming of CGE models is that simulation analysis based on the subjective setting of energy efficiency improvement is conducted to estimated energy rebound effect (Shao et al., 2014). Consequently, the result may be far away from the actual rebound.

Compared to the CGE model, economic accounting approach is designed to estimate the rebound effect directly. Due to the ease of use, this approach has widely been employed in recent years. The accounting framework was first proposed by Zhou and Lin (2007). Their estimation is built on the logical relationships among technological progress, economic growth, energy intensity, and energy consumption. Specifically, Zhou and Lin (2007) based on the change of energy intensity to estimate the efficiency derived savings and used Solow remainder method to measure the increment of energy consumption due to economic growth which is derived by technological progress. Taking into account the fact that industrial structure change also contributes to energy intensity change, Wang and Zhou (2008) proposed an improved model based on the LMDI method which can exclude the influence of industrial structure change. In view of the limitations of Solow remainder method, Lin and Liu (2012) proposed using DEA method to estimate the technological change. A recent study, Shao et al. (2014), further revised Zhou and Lin (2007) model and provided the theoretical basis for the accounting framework. Additionally, Shao et al. (2014) used the latent variable approach to estimate the contribution of technological progress to economic growth which can overcome the shortcomings of the Solow remainder method and the DEA method.

Thanks to the contribution of pioneer studies, the accounting framework of economy-wide energy rebound effect has been well developed. However, one particular issue is needed to be noted. In previous studies technological progress is regarded equivalently to energy efficiency improvement. It is true when technological progress is Hicks neutral. But this is very strict and strong assumption which may be far away from the reality. Despite energy efficiency gains, capital-saving or labor-saving technology can also improve the productivity. Therefore, in general the energy rebound arising from energy efficiency improvement may be not equal to that derived from technological progress. As a result, the estimate of energy rebound effect would be biased.

The purpose of our paper is to further refine the economic accounting approach and revisit China's economy-wide energy rebound effect. To estimate the energy rebound arising from energy efficiency gains consistently, we distinguish energy efficiency improvement from technological progress through constructing an energy efficiency index. This strategy enables us to measure the contribution of energy efficiency improvement to economic growth directly and then calculate the actual energy rebound effect.

The rest of our paper is organized as follows. In Section 2 we describe the methodology in detail. Section 3 presents the results and discussion of our empirical studies. Section 4 concludes the paper.

2. Methodology

2.1. Theoretical background

According to Brookes (1984) and Sorrell et al. (2009), the economy-wide energy rebound effect can be tracked down as the additional energy consumption derived by output growth which stems from the energy efficiency gains. Specifically, energy consumption is induced by the demand of goods (services). The improved energy efficiency reduces the effective price of energy service, thereby cutting down the cost of the supply of goods (services). Furthermore, the decreased cost will bring down the price of goods (services) which stimulates the demand and then promotes output growth. Consequently, energy consumption is driven to go up so that the original energy savings are partly offset.

In empirical studies, energy rebound effect at economy-wide level is often calculated as the ratio of the additional energy consumption from the growth effect to the original energy savings. See, for example, Zhou and Lin (2007), Lin and Liu (2012), and Shao et al. (2014). In this paper, we distinguish the growth effect derived from energy efficiency improvement from that derived from technological progress which is often represented by total factor productivity. The definition of economy-wide rebound effect can be formulated as Eq. (1).

$$RE = \frac{AE}{OE} \times 100\% \tag{1}$$

where *RE* denotes the energy rebound effect; *AE* represents the additional energy consumption caused by economic growth derived from energy efficiency improvement; and *OE* represents the original energy saving. In this sense, the key to measure energy rebound effect lies in the estimate of the additional energy consumption and the original energy savings. The original energy savings directly result from energy efficiency gains[2] while the calculation of the additional energy consumption is not very straightforward. We first need to quantify the impact of output growth on energy consumption. Then we need to account the contribution of energy efficiency improvement to output growth so that the additional energy consumption from energy efficiency gains can be singled out. To serve our purpose, Index decomposition analysis (IDA) and growth accounting approach are used in this paper. The procedure of our approach is described detailedly in the following sections.

[1] According to Greening et al. (2000), there are mainly three types of energy rebound effect, i.e., direct, indirect and economy-wide rebound effect. This paper focuses on economy-wide energy rebound effect.

[2] That is to say, an increase in efficiency is equivalent to a decrease in energy consumption.

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