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Energy rebound effect in China's Industry: An aggregate and disaggregate analysis

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ABSTRACT

Considering the crucial role of industrial sectors in energy conservation, this paper investigates the impact of output growth on energy consumption in China's industrial sectors with an index decomposition model and the energy rebound effect in the industrial sectors with a panel data model using the annual data during 1994–2012. The empirical results indicate that: first, industrial output growth is proved to be the major factor in promoting industrial energy consumption, while energy intensity reduction and structure shifts across industrial sub-sectors play the dominant roles in slowing down industrial energy consumption. Second, there does exist energy rebound effect in China's aggregate Industry, which ranges from 20% to 76% during 1995–2012 (or 39% on average). In particular, the energy rebound effect in Manufacturing is relatively smaller during the sample period (i.e., 28% on average). Finally, the energy rebound effect in both China's aggregate Industry and Manufacturing exhibit an overall decreasing trend over time.

1. Introduction

As the largest developing country in the world, China has increased its GDP by a multiple exceeding 80-fold since the reform and opening-up of her economy in 1978: this has also led to huge amount of energy consumption and related CO_2 emissions (Zhang and Da, 2015). As a result, China has become the largest carbon emitter and energy consumer in 2006 and 2010, respectively. In 2015, China's primary energy consumption reached 3.01 billion tons of oil equivalent, accounting for 22.9% of the global total; meanwhile, China contributed to 27.3% of global carbon emissions (BP, 2016). Tremendous fossil energy consumption and carbon emissions make China's environmental problems increasingly noteworthy, especially since many days of damaging pollutant haze have broken out in the Beijing-Tianjin-Hebei region in recent years, and most regions in central and eastern China are also shrouded in haze throughout the year.[1] In 2013, among the 500 largest cities in China, there were fewer than 1% of them reaching the air quality standards proposed by the World Health Organisation, and there were seven cities in China among the 10 most contaminated cities in the world.[2]

To address the serious situation of tight resources and a heavily polluted environment, the Chinese Government has targeted a reduction in energy intensity (i.e., energy consumption per unit GDP) of 20%, 16%, and 15% during the 11th (2006–2010), 12th (2011–2015), and 13th (2016–2020) Five-Year Plan periods, respectively (Zhang and Hao, in press), and the concentration of $PM_{2.5}$ in 2017 should be reduced by 25% compared with that in 2012.[3] Additionally, China proposes that its carbon emissions would reach the peak in around 2030.[4] To achieve these ambitious goals, all economic sectors in China have to try every means to find appropriate ways in which to promote energy conservation and carbon emission reductions.

Moreover, the features of energy consumption, energy conservation, and pollutant emissions of various economic sectors are not the same (Zhang et al., 2014). Therefore, it is imperative to look for scientific and reasonable approaches to energy conservation and carbon emission reduction in the main sectors of the economy (Zhang and Da, 2015). Industry is usually highly energy intensive, and industrial energy

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[1] http://china.cankaoxiaoxi.com/2013/0114/150192.shtml.

[2] http://www.infzm.com/content/85163.

[3] http://news.xinhuanet.com/local/2015-12/03/c_128495796.htm.

[4] http://politics.people.com.cn/n/2014/1113/c70731-26012421.html.

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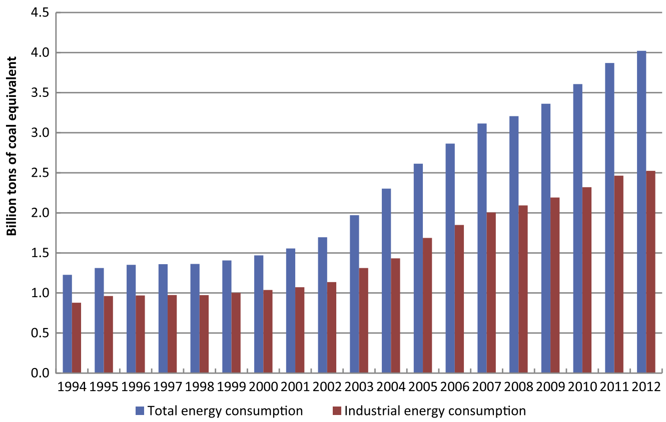

Fig. 1. The industrial energy consumption and the total energy consumption in China, 1994–2012.

consumption accounts for one third of global energy consumption (Napp et al., 2014); especially in China, Industry takes up more of a share of the energy system than in many other countries. Fig. 1 depicts industrial energy consumption and the total during 1994–2012 in China: industrial energy consumption accounts for more than 60% of the total, and the increasing trends are extremely close, with average annual growth rates of 4.71% and 4.76%, respectively. Besides, fossil fuel burning and industrial pollution are the two major sources of haze. According to Huang et al. (2014), stringent controls on volatile organic compound emissions from coal burning and petrochemical industries could be efficient strategies to mitigate haze in China. As the largest sector for energy consumption in China, Industry is supposed to take great responsibility for mitigating pollution.

Furthermore, China's Industry includes three main sectors: Manufacturing, Mining and Production and Supply of Electricity, Gas and Water, which can be further classified into 36 sub-sectors. In particular, Manufacturing consists of a wide range of industrial sub-sectors, and many of them are energy-intensive; as a result, the energy consumed by Manufacturing accounts for the biggest proportion of the total energy consumption in the aggregate Industry, with an average share of 80.15% during 1994–2012. Therefore, to achieve the aforementioned national targets for energy consumption and carbon emission reduction, effective measures taken by China's Industry, especially Manufacturing, take on extra significance.

In fact, the Chinese Government has taken numerous actions to improve industrial energy utilisation efficiency in recent years. For example, China targeted energy consumption (carbon emission) per unit industrial added value in the Manufacturing sector reduction of 18% (22%) by 2020 and 34% (40%) by 2025 compared with that in 2015, respectively. Meanwhile, China announced the establishment of one thousand green demonstration factories and one hundred green demonstration parks by 2020. In addition, the energy consumption of some heavy or chemical industries is supposed to reach a turning point, and the emission intensity of the main polluters in key industries is set to decrease 20% by 2020 (The State Council, 2015). In this way, there is no doubt that energy efficiency improvement caused by technological progress should exert a significant influence on energy conservation and carbon emission reduction (Wang et al., 2015b), but the real effect of energy conservation brought about by efficiency improvement or technological change is often not consistent with expectations. Therefore, the energy rebound effect has to be taken into consideration to estimate the actual energy conservation achieved, and to avoid overestimating the effectiveness of energy efficiency improvement caused by technological progress.

The contribution of this paper includes four aspects: first, in view of the key role of industrial sector in energy conservation and carbon emission reduction in China, we consider the energy rebound effect in China's aggregate Industry rather than the economy-wide energy rebound effect so that we can find more targeted policy implications. In particular, given the dominant role of Manufacturing in the aggregate Industry, we also detect the energy rebound effect in Manufacturing to examine its energy conservation effectiveness.

Second, we consider the contribution of energy-resource technological progress rather than total technological progress to industrial output growth, so as to avoid any bias in the energy rebound effect measurement by regarding technological progress to be equal to energy efficiency improvement, as is widely the case in previous related literature.

Third, we investigate the major factors affecting industrial energy consumption in China using the index decomposition method.

Besides, we adopt panel data from 36 industrial sub-sectors during 1994–2012 rather than limited time series observations. In theory, a finer level of disaggregation would be preferred for the measurement (Su et al., 2010). Thus, we improve the reliability of existing related empirical results and provide a more scientific evaluation of the energy rebound effect in China's aggregate Industry and Manufacturing, and we also evaluate their effectiveness with regard to the energy conservation caused by energy-specific technological change.

The rest of this paper is structured as follows: Section 2 reviews the literature covering the energy rebound effect, Section 3 presents the methods and data description, Section 4 lists the results and discusses them, and Section 5 concludes the paper and provides some important policy implications of the work.

2. Literature review

The energy rebound effect has received increasing attention, and the related literature has been abundant. We review the literature mainly from three perspectives, i.e., the origin and mechanisms of the energy rebound effect, the research methods used to evaluate the energy rebound effect, and the energy rebound effect in the industrial sectors.

First of all, the concept of energy rebound effect originated from the Jevons paradox proposed by Jevons in The Coal Question in 1865 (Jevons, 1866). He argues that technological progress improves the efficiency of energy utilisation, but energy consumption would not decrease because of the energy rebound effect even the backfire effect. Specifically, when technological progress causes an increase in efficiency by 1%, the reduction in energy consumption to obtain the same products is often less than 1% because there is rebounded energy consumption. There are two main reasons for this: on the one hand, an improvement of energy efficiency usually leads to a decline in the real cost of useful energy, which may change consumer behavioural responses and eventually cause an increase in energy consumption (Khazzoom, 1980). On the other hand, energy efficiency improvement comes about because of more widely advanced technology, but at the same time, advanced technology generates rapid economic growth and then energy demand and consumption increase substantially (Brookes, 1990).

As for the mechanisms governing and underpinning the energy rebound effect, it can be classified as direct effect, indirect effect and economy-wide effect (Greening et al., 2000; Frondel et al., 2008): the economy-wide energy rebound effect consists of direct and indirect energy rebound effects. Meanwhile, different sizes of energy rebound effect represent different meanings; specifically, energy rebound effect between zero and one is called partial energy rebound effect (Sorrell et al., 2009; Wei, 2010), which implies that real energy consumption is more than the expected but less than that originally prevailing, and a part of the energy conservation caused by energy efficiency improvement is offset by the extra energy consumption thereafter. Energy rebound effect more than one is called backfire effect (Sorrell et al., 2009), which means that the real energy consumption is greater than that originally, and the rebounded energy consumption is more than the expected energy savings. Besides, energy rebound effect less than zero is called super-conservation, which indicates more than