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Industrial sectors' energy rebound effect: An empirical study of Yangtze River Delta urban agglomeration

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ABSTRACT

As the most prosperous area and one of China's major economic centers, Yangtze River Delta urban agglomeration (YRDUA) shows the largest concentration of adjacent metropolitan areas in the world. Its energy conservation and emissions reduction efforts are critical for developing a low carbon economy in China. Based on panel data of 14 cities from 2003 to 2013, this study estimates the rebound effect's magnitude in YRDUA's industrial sectors using dynamic ordinary least squares (DOLS) and seemingly unrelated regression (SUR) methods. The empirical results are as follows: (1) Significant substitute relationships exist between energy and capital factors and between energy and labor factors. (2) The own-price elasticity of labor is the most elastic, followed by those of energy and capital. (3) The rebound effect is approximately 40.04%. Evidence suggests that promoting financial development, conducting structural reform in the supply side, and establishing reasonable controls of industrial growth and scale expansion are conducive for energy conservation and pollution alleviation of YRDUA's industrial sectors.

1. Introduction

1.1. Research background

The rapid pace of industrialization and urbanization has made China one of the countries with the highest quantity and fastest growth of energy consumption worldwide. According to statistical data from the BP [1], China's primary energy consumption in 2013 amounted to 2852.4 million tons of oil equivalent (MTOE), accounting for 22.4% of global energy use. From the growth perspective, although the growth rate of China's energy consumption declined in 2013 (4.7%), which was lower than the average growth rate of 8.6% recorder over the previous 10 years, it was still far above the global growth rate (2.3%). The Chinese economic boom of the past decades has accelerated energy demands, while intensifying the energy supply-demand contradiction. However, it has also posed severe challenges related to the traditional extensive economic growth model, whereby energy issues have been given more prominence [2,3]. Energy technology innovation is considered an important method to improve energy efficiency. Innovations and applications in energy technologies are vital for coping with energy-related problems, such as the depletion of conventional energy resources and environmental damage. Therefore, energy efficiency has been called “the fifth fuel” after coal, petroleum, nuclear power, and renewables; it is seen as a cost-effective tool for accelerating the transition to a green economy.

However, in fact, researchers have challenged the effectiveness of energy efficiency advances in reducing energy demand. The fundamental cause of this lies in the “rebound effect of energy consumption,” which was originally introduced in *The Coal Question* [4]. According to the Khazzoom-Brookes postulate, energy efficiency improvements might increase, rather than decrease, energy consumption [5–9]. The main reasons for this are as follows. On the one hand, enhanced energy efficiency reduces the amount of energy required to produce energy services. In this case, energy demand would increase due to reduced prices of energy services. On the other hand, increased efficiency in energy utilization stimulates economic growth, which then accelerates energy use, ultimately increasing energy demand on the macroeconomic level [10,11]. Hence, rebound effect of improved energy efficiency deserves more research, considering its marked significance for energy conservation, alleviation of energy-related environmental

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pollution, and the effectiveness of energy and climate change policy [12,13].

This study selects the industrial sectors of the urban agglomeration in the Yangtze River Delta for the following reasons. First, the Yangtze River Delta Economic Zone accounted for approximately 20% of the national GDP, and was responsible for one third of China's imports and exports. YRDUA, which lies in the convergence zone of the "Belt and Road" and the Yangtze River Delta Economic Zone, is an important engine to drive China's economic and social development. Second, China's energy consumption was dominated by the industrial sector (70%). In 2003–2013, the YRDUA's industrial sectors contributed to more than 18% of the national industrial energy usage. For instance, their energy consumption was 466.43 million tons of coal equivalent (MTCE) in 2013, accounting for 16% of the national industrial energy usage. In particular, the industrial value added (IVA) of YRDUA accounted for approximately 24% of the national IVA. Third, these sectors are the driving forces of energy intensity reduction in China's larger industrial sector. As shown in Fig. 1, energy intensities of YRDUA's industrial sectors were only approximately 30% of that of the national industry sector. Although the nationwide energy use intensity showed a decreasing trend, industrial sectors at both national and regional levels still showed a slight increase in energy intensity during 2003–2013. Therefore, energy intensity of YRDUA industrial sectors was at a relatively high level, which created a bottleneck for Chinese industrial development.

1.2. The contributions of this study

In recent years, research on the energy rebound effect in China has significantly increased. However, most studies have focused on the rebound effect at the provincial or industrial level. Empirical studies, specifically on influential economic regions (like the Beijing-Tianjin-Hebei, Pearl River Delta, and Yangtze River Delta economic zones, which play a decisive role in China's green energy development), is relatively scarce. China is a large developing country, which expends enormous effort in improving energy efficiency in energy-intensive industries and economic zones. Consequently, given YRDUA industrial sectors' prominence in the national economy and the low carbon transition, studying its energy rebound effect has profound value.

Evidently, to save energy and reduce environmental pollution, the Chinese government had promoted a series of measures on advancing energy efficiency (E.g., in the "12th Five-Year Plan (FPY)," whereby energy intensity was required to be lowered by 16%; detailed plans to ensure its realization were also released. However, the energy-saving effect of efficiency improvement was discounted due to the rebound effect [14]. Thus, estimating the magnitude of the rebound effect would be helpful for policymakers who must take effective measures. Previous studies estimated China's energy rebound effect by mainly using provincial and industrial data. This paper first uses city-level data to provide new evidence. More importantly, China is a large country with particularly unbalanced regional development; its policies also vary by region. Thus, exploring the energy rebound effect in a certain area could provide important insights. Since urban agglomerations in the Yangtze River Delta are the most developed regions in China, it is both academically and practically valuable to explore the extent to which the energy-saving effect is discounted due to the rebound effect. Based on the trans-log cost function, this study estimates the industrial rebound effect in YRDUA by using the dynamic ordinary least squares (DOLS) and the seemingly unrelated regression (SUR) methods. Then, policy proposals are put forward that could improve industrial energy efficiency, energy savings, and emission reduction in the YRDUA.

The rest of the paper is organized as follows. Section 2 reviews the literature. Section 3 describes the methodology and data source. The results and discussion of the empirical study are presented in section 4. Finally, section 5 concludes the paper, along with a discussion on policy implications.

2. Literature review

The energy rebound effect refers to any expected energy saving from improvements in energy efficiency—due to the technological progress—that may be partly or wholly offset or even surpassed by the increase of energy demand [4]. This is the famous Jevons paradox, which holds that technological progress might ignite resource consumption; thus, the effectiveness of energy efficiency policy should be revalued. Khazzoom [6] and Brookes [7,15]

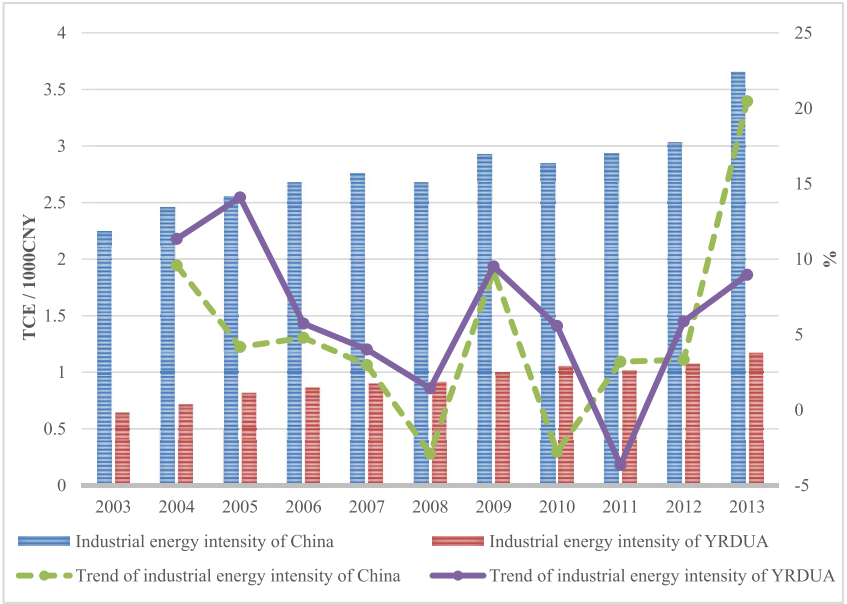

Fig. 1. Industrial energy intensities of China and YRDUA (2003–2013).*Data source:* China Statistical Yearbook [51]; Zhejiang Statistical Yearbook [69].