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Energy efficiency analysis of the economic system in China during 1986–2012: A parallel slacks-based measure approach

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A B S T R A C T

The economic system in China is composed of three internal parallel industries: primary, secondary and tertiary industries. To examine energy efficiency of the economic system, this paper proposes a parallel slacks-based measure approach. In the described approach, the measures of energy efficiencies and energy saving potentials for the whole system and its three industries are defined. Application of the proposed approach to the economic system in China during 1986–2012 shows that it can be effectively used to measure energy efficiency of the evaluated system with several parallel sub-systems. The institutional influential factors of energy efficiency in China are also examined. The following findings can be achieved based on the application results: (1) the inefficiency of the economic system in China is mainly sourced from the lower energy performance of the secondary industry; (2) energy efficiency of the economic system increases during the study time period with an exception during 2001–2005; (3) it is better for the whole economic system to improve energy efficiency, which can help to save much more energy consumption in production in China; and (4) economic development is estimated to have positive impacts on national energy efficiency, while energy structure adjustment and industrial structure optimization have negative effects on national energy efficiency.

Contents

1. Introduction

China has made great progress in socioeconomic development during the past three decades. As the second largest economic entity, Chinese GDP (Gross Domestic Product) reached to about

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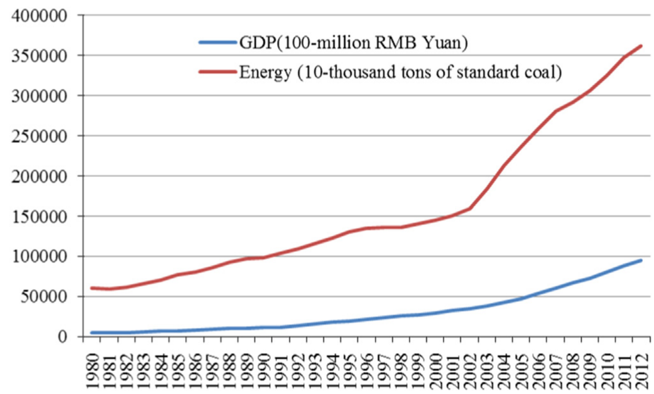

Fig. 1. GDP growth and energy consumption in China from 1980 to 2012.

8.23 trillion U.S. dollars in 2012, which following by United States of 16.16 trillion U.S. dollars [1]. China's scale-driven economic development has led to great energy consumption in the production process during the recent 30 years. From 1980 to 2012, China's GDP has increased about 20.88 times, while energy consumption (standard coal equivalent, SCE) in 2012 is about 6.0 times that of 1980 [2]. The trends of GDP growth and energy consumption from 1980 to 2012 are shown in Fig. 1.

As depicted in Fig. 1, significant positive relationship between economic development and energy consumption in China can be observed, i.e., GDP grows along with the evident increase of energy consumption. This is further confirmed by Pearson's correlation coefficient between GDP and energy consumption, i.e., the coefficient value is 0.994 with $p=0.00$. This may also partially coincide with the conclusion suggested by Narayan et al. [3], that energy usage has positive impacts on economic development and productivity growth. Since 2010, China has overtaken United States and become the largest energy consumer in the world. Total energy consumption in China is about 2.43 billion TOE (tonne of oil equivalent) in 2010, which is larger than that of U.S. (2.29 billion TOE) [4]. The aggressive increase of energy consumption has also given rise to energy shortages, energy crisis, energy price going up and serious pollution and ecological problems [5]. For instance, in 2010, CO_2 (carbon dioxide) emissions in China accounts for about 28.53% of the world's total CO_2 emissions, which is much larger than that of U.S. (15.88%) [6]. In this regard, China has also been the largest emitter of CO_2 emissions in the world. With the consideration of economic growth, environmental pressure and sustainable development, energy use has become a major concerned research issue in recent years.

On the other hand, although China has abundant energy mines, its per capita available energy is relatively low [7]. In 2011, per capita primary energy consumption in China is only about 77.54 million Btu, which is much lower than that of America (312.79 million Btu) [8]. As such, energy saving and the assessment of energy use performance should be taken into account under the framework of China's energy policies. In recent years, various plans and strategies have been carried out to save energy or enhance energy efficiency in China, e.g., increasing investment and speeding up constructions of energy instruments, placing greater emphasis on energy conversation and energy efficiency. Yet, due to fossil energy (including coal, oil and natural gas) dominated energy consumption structure, the effectiveness of the implemented policies is not significant in the current circumstance. Therefore, in order to develop more effective energy policies, it is necessary for China to explore the detailed energy efficiencies.

To effectively evaluate energy efficiency of China, it is better for us to thoroughly understand the operational structure of China's economic system. In China, the national economic system can be divided into three industries, i.e., primary (agriculture), secondary (industry and construction) and tertiary (service industry) industries. The secondary industry is the largest industry in the national economic system. For example, its GDP output in 2012 is 7838.555 billion RMB Yuan, followed by the tertiary industry (3774.031 billion RMB Yuan); and the primary industry has the lowest GDP output in the year, i.e., (793.271 billion RMB Yuan) [2]. The uneven economic development has resulted in uneven energy consumption. In 2012, the secondary industry consumes 2586.30 million tons of SCE, which accounts for about 80.30% of total energy consumption in China [2]. The primary and the tertiary industries consume 67.84 million tons of SCE and 566.51 million tons of SCE, respectively [2]. In such a case, we argue that it is essential to examine the energy efficiencies of the three industries as well as the whole national economic system rather than only that of the system. We believe that this might provide more inefficiency information of energy use sourced from the economic system for energy efficiency improvement.

To effectively measure energy efficiency of the economic system in China, the current paper proposes a parallel efficiency evaluation model following the slacks-based measure (SBM) approach [9]. In the introduced model, energy efficiencies for the whole economic system and its three industries can be estimated simultaneously. The rest of this paper is organized as follows. Section 2 reviews the most relevant literature. In Section 3, a parallel slacks-based measure approach is developed to cope with the energy efficiency evaluation issue for the economic system and its three industries in China. The proposed approach is applied to investigate the efficiencies of energy consumption for the economic system in China during the period of 1986–2012 in Section 4. The institutional influential factors of energy efficiency are also examined in this section. Section 5 concludes this study.

2. Literature review

Energy efficiency is a relative concept, and various definitions can be found in the literature [10]. The general definition is “a ratio between an output of performance, service, goods or energy, and an input of energy”, given in Directive 2006/32/EC of the European Council and Parliament on energy end-use efficiency and energy services [11]. As we know, energy alone cannot produce any output. It has to be accompanied by other inputs, e.g., labor and capital, to produce outputs. Therefore, a multiple-factor model should be applied to correctly measure energy efficiency for a unit (e.g., company, industry, region or country).

As suggested by Zhou and Ang [11] , Hu and Wang [12] and Shi et al. [13], data envelopment analysis (DEA) has recently been widely applied to evaluate energy efficiencies of different entities (regions or countries), or to monitor the trends of energy efficiency over time for a region or a country. DEA firstly proposed by Charnes et al. [14], is a well-established non-parametric programming approach for measuring the relative efficiencies of independent decision making units (DMUs) that consume multiple inputs to produce multiple outputs. As indicated by Zhou et al. [15], there is a rapid increase in the studies using DEA to evaluate DMUs' energy efficiencies. Generally, these research results can be mainly classified into two types.

The first type focuses on measuring energy efficiency or computing energy saving targets without taking pollutant factors into consideration. Ramanathan [16] uses DEA to compare energy efficiencies of alternative transport modes. Hu and Wang [12], Hu and Kao [17] and Honma and Hu [18] develop a kind of total-factor energy efficiency index using DEA to measure energy efficiencies or energy saving targets of regions in China, APEC countries and regions in Japan, separately. Mukherjee [19] proposes several DEA