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Technology gap and regional energy efficiency in China's textile industry: A non-parametric meta-frontier approach

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A B S T R A C T

Based on the theory of total factor production, this paper analyzes energy efficiency in China's textile industry at the regional levels using non-parametric meta-frontier approach and a provincial panel data during the period, 2000–2012. We further analyze the regional differences in energy utilization technology gap using the technology gap ratio. Irrespective of the frontier (meta or group), the empirical result depicts a tremendous energy saving potential in China's textile industry. Relative to meta-frontier, the average energy efficiency of China's textile industry is 0.673 during the sample period; hence, the energy saving potential is 32.7% if output remains unchanged. Relative to group frontier, the average efficiency of China's textile industry is 0.797, which may overestimate the true level of energy utilization. From the regional perspective, significant differences exist in energy technology within the textile industry. During the sample period, the energy utilization technology gap ratio (TGR) of the Textile Industry in eastern China remains above 0.95 and it's steadily improving, approaching the optimum for the whole textile industry. Moreover, the textile industries in central and western China have improvement potentials of 19.6% and 27.4%, respectively. Finally, based on the results from the regional energy efficiency analysis, future policy priorities are suggested.

1. Introduction

Energy is a powerful driver of social and economic development. With China's rapid development, the dependence of the economy on energy has obviously increased. Moreover, the issue of shortage of resources and energy has increasingly become a serious problem (Lin and Tian, 2016). To solve the energy source gap, we will depend more on the international energy market, which has not only affected China's energy security, but also has made the volatility of the international energy market a serious challenge to national stability (Lin and Ouyang, 2014). China's heavy consumption of non-renewable fossil fuels such as coal and petroleum is a direct and major cause of national environmental deterioration (Xu and Lin, 2015). Therefore, to ease the conflict between economic growth and the environment, energy conservation and improvement in energy efficiency have become the inevitable choices at present and in the future (Lin and Du, 2013).

The textile industry, well known as a traditional pillar industry in China, is an important sector of the national economy and international trade. Its role aids market growth, promote employment, and increase the income of farmers; thus accelerating the process of urbanization and promoting social harmony. It is worth to note that China is the largest textile and garment producer and exporter in the world; sustainable growth of textile exports is therefore essential to ensure stable growth of China's foreign exchange reserves, balance of international payments, and stability of exchange rate. Textile exports (in proportion to the total global textile export) increased from 10.3% in 2000 to 35.2% in 2012 (CEIC China Database, 2015). It can be said that the textile industry has developed rapidly since China's reform and opening up. In 2012, enterprises at national scale in industry had a total industrial output value of 4.7612 billion Yuan (approximately USD 764 million), up by 27.46% from a year earlier, and accounted for 6.58% of that of all designed size enterprises nationwide (CEIC China Database, 2015).

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However, the textile industry also causes serious pollution (Alkaya and Demirer, 2014). Energy consumption of the industry accounts for approximately 4.3% of total energy consumed by the manufacturing sector,[1] and it follows that it is one of China's largest pollution emitters. The rapid development of China's textile industry has resulted in continuous increases in energy consumption and carbon dioxide emissions (see Fig. 1). Simultaneously, China faces severe challenges related to energy resources and environmental constraints; these challenges include inefficient resource use, high energy consumption and serious pollution. Under the background of increasingly scarce energy resources and the need for sustainable development, China's textile industry faces considerable energy constraints. Effective allocation of resources and maximization of energy efficiency have become critical to the development of the industry. In current situation of serious energy and environmental constraints, improving energy efficiency is considered to be the most realistic, most effective, and the lowest cost way of energy saving and emission reduction. Scientific measurement of the energy efficiency of China's textile industry provides a basis for comparison of regional differences in energy technology level, and so can guide the formulation of regional energy saving and emissions reduction policies.

This paper therefore evaluates the energy efficiency of China's textile industry in different provinces. Based on technology gap ratio (TGR), the regional energy technology gap of the textile industry is analyzed quantitatively, in order to establish differences in energy saving targets in the textile industry, and provide a basis for decision-making. The rest of the paper is organized as follows: section 2 introduces the methods and data in detail. Section 3 undertakes empirical analysis. Section 4 presents the related discussion. Section 5 gives conclusions and policy suggestions.

2. Methods and data

2.1. Literatures review

In recent years, research on energy efficiency measurement methods has made important progress. Methods for measuring energy efficiency can be classified into two types: single factor and total factor. Single factor measurement methods mostly use energy intensity as a metric of energy efficiency, and this is also the case of early studies on energy efficiency. Although this measure is simple, it takes energy as the only factor of production, ignoring other factors. It also does not consider alternative elasticity of energy and other production factors. To make up for this defect, total factor energy efficiency is used.

Foreign scholars began studying energy efficiency earlier than Chinese scholars, and there are numerous international studies on energy efficiency. Hu and Kao (2007) developed an energy saving ratio based on energy efficiency, and then calculated this ratio (including per capita calculations) for the 17 APEC economies during 1991–2000. The results showed that China had the highest energy saving rate among the 17 economies compared, implying that China faced a serious problem of energy waste. F. Hernández-Sancho et al. (2011) used the DEA method to analyze energy efficiency and the impact factors of industrial waste water treatment in Spain. The results showed that only 10% of industrial enterprises used energy efficiently. Azadeh et al. (2007) integrated the PCA and DEA methods, and evaluated the energy efficiency of the major OECD countries in energy intensive industries. The results showed that energy saving potential for fossil fuels was far greater than that of electricity. Similarly, Olanrewaju et al. (2012) first proposed the integration of the IDA-ANN-DEA method to study energy consumption in 15 industrial sectors in Canada. Toshiyuki and Mika (2012) applied the DEA-DA method to model the scoring and ranking of efficiency of Japanese electric power industry and enterprises, and found almost no changes for Japanese power companies during 2005–2009.

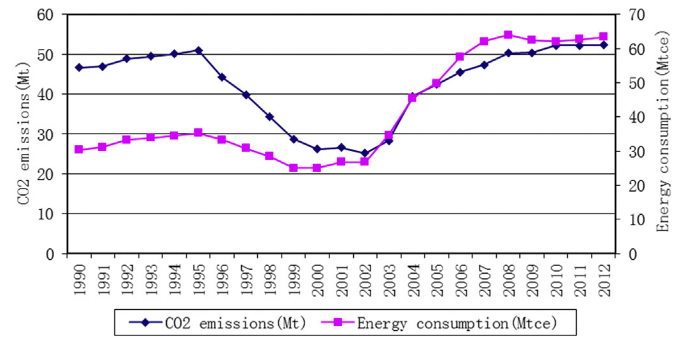

Fig. 1. Energy consumption and CO_2 emissions of China's textile industry during 1990–2012.
Source: Chinese Energy Statistical Yearbook

In recent years, research on China's energy efficiency has made fruitful achievements. Domestic and foreign scholars have studied China's energy efficiency using different data and models. Hu and Wang (2006) first adopted the DEA model of constant scale return, and studied total factor energy efficiency in China from 1995 to 2002. Based on the factorization method and the structure index method, Shi (1999) argued that since the reform and opening up, Chinese energy efficiency had improved significantly. This study thus concluded that the nation's opening up, industrial structure and economic system were the important determinants of energy efficiency. Yang and Shi (2008), Lin and Long (2015), and Li and Cheng (2008) also studied the total energy efficiency of various regions of China using the DEA method. Shi (2006) studied the regional energy efficiency of China, comparing energy efficiency among different provinces and evaluating the energy saving potential for different regions. This study found that energy efficiency in the southeast coast was higher, while China's inland areas had abundant coal resources and relatively lower energy efficiency.

Strictly speaking, the precondition for the comparison of technical efficiency must be that all production units share a similar technical level. Otherwise, we cannot find the real reason for the loss of production unit efficiency because of a lack of uniform standards. Imbalances in regional economies and social development in China have also caused differences in energy utilization technology. Therefore, the technology frontier varies among the regions (eastern, central and western) in China. Energy technology level is clearly higher in the eastern region than in the central and western regions. However, existing researches on energy efficiency are based on the assumption that the three regions share the same technology level and hence evaluate the efficiency of the decision-making units with different technology frontier at the same frontier. Examples of such studies include Hu and Wang (2006), Wei and Shen (2007), Qu (2009), Shi (2006) and so on.

To overcome the problem that decision making units with different technology fronts are at the same frontier, Battese and Rao (2002) took the technical differences between the groups into consideration. Based on stochastic frontier analysis (SFA), the meta-frontier production function research framework was proposed. Assuming that not all production units shared the same technical level, they analyzed and compared the technical efficiency of production units under group frontier and meta-frontier. O'Donnell (2007) further used data envelopment analysis (DEA) to construct

[1] The data is from the annual report of the Chinese textile industry for 2013.