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Energy efficiency of Chinese service sector and its regional differences

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A B S T R A C T

The energy consumption of the service sector in China is larger than the total energy consumption of Japan, great importance should be attached to the energy efficiency of Chinese service sector. Considering undesirable output and regional heterogeneity, a meta-frontier slack-based efficiency measure (MSBM) approach is adopted in this paper to measure the energy efficiency of Chinese service sector using provincial panel data of China during 1995–2013. The empirical results show that, the energy efficiency of the service sector in China is 0.62 and 0.85 under meta-frontier and group-frontier technologies. The eastern regions show the best performance in energy efficiency, the central region follows and the western region shows the poorest performance. Only the eastern region shows an increasing trend in the energy efficiency of Chinese service sector. The potential of energy efficiency improvement for Hainan, Guizhou, Qinghai, Ningxia, Gansu and Shaanxi are relatively high. Some policy recommendations are proposed to improve the energy efficiency of Chinese service sector.

1. Introduction

Under the process of economic restructuring and urbanization in recent years, the development of the service sector in China is accelerating. It was clearly stated in the *Rules of Clarification of Three Industries* (NBSC, 2013) that Chinese service sector is the tertiary industry by definition. The service sector refers to the industries except for the primary industry and the secondary industry. Table 1 presents the classification of three industries in China. As shown in Fig. 1, the proportion of Chinese service sector in gross domestic product (GDP) is increasing, and the role of the service sector in driving economic growth is also getting more important. In 2015, the added value of the service sector accounted for 50.5% of GDP. The service sector has surpassed the secondary industry, and became the largest among the three industries in China since 2012. From the perspective of employment, in 2011 the employment share of the service sector was 35.7%, surpassing the primary industry and becoming the highest of the three industries. In 2015, the service sector covered 329.4 M employees, accounting for around 42.4% of total employees in China. From the proportions of both value added and employment in three industries, the service sector has overtaken the secondary industry becoming the largest sector in China.

Although compared with the secondary industry, the service sector has relatively low energy consumption and low emission, its rapid development also leads to rapid growth in energy consumption and carbon emissions. From 2000 to 2014, the average annual growth rates of total energy consumption and energy consumed by the service sector in China were 7.9% and 8.7%, which indicates the energy consumption of the service sector increased faster than that of the whole country (Fig. 2). The energy consumption of Chinese service sector is larger than the total energy consumption of many other countries. In 2014, the energy consumption of the service sector in China was 672.9 Mtce, larger than the energy consumption of Japan which was 651.4 Mtce. Some subsectors in the service sector are also energy-intensive, such as the transportation, which accounts for more than half of Chinese service sector. The same with the energy structure of the whole China, fossil energy occupies a large proportion in energy consumption of Chinese service sector. In 2014, the proportion was over 80%. Huge energy consumption and energy structure given priority to fossil fuels lead to serious environmental pollution and CO_2 emissions. The energy consumption and carbon emission of Chinese service sector are not just about China's energy and environmental problems, they also have influence on global energy market and climate change.

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Abbreviation

MSBM	Meta-frontier slack-based efficiency measure
GDP	Gross domestic product
TFEE	Total-factor energy efficiency
SFA	Stochastic frontier analysis
DEA	Data envelopment analysis
SBM	Slacks-based measure
CO_2	Carbon dioxide
SO_2	Sulfur dioxide
COD	Chemical oxygen demand
ETFEE	Ecological total-factor energy efficiency
MID	Malmquist Index Decomposition
NDDF	Non-radial directional distance function
DDF	Directional distance function
GETFEE	Group-frontier ecological total-factor energy efficiency
METFEE	Meta-frontier ecological total-factor energy efficiency
DMU	Decision-making unit
VRS	Variable returns to scale
MTR	Meta-technology ratio
TGEE	Technology gap pertaining to energy efficiency
EEI	Energy efficiency improvement
EEI^G	Potential energy efficiency improvement under group-frontier technology
EEI^M	Potential energy efficiency improvement under meta-frontier technology
PIM	Perpetual inventory method

Table 1
The classification of three industries in China.

	Industries included
The primary industry	Agriculture Forestry Animal husbandry and fishery
The secondary industry	Mining industry Manufacturing industry Electric, heat, gas and water production and supply industry Construction industry
The tertiary industry	Wholesale and retail trade Transportation, warehousing and postal service Accommodation and catering industry Information transmission, software and information technology services Finance, real estate, leasing and business services Scientific research and technical services Water conservancy, environment and public facilities management Residents service, repair and other services, education, health and social work Culture, sports and entertainment, public management, social security Social organizations, international organizations, Service industries involved in the primary and secondary industry

Source: National Bureau of Statistics of China in 2013.

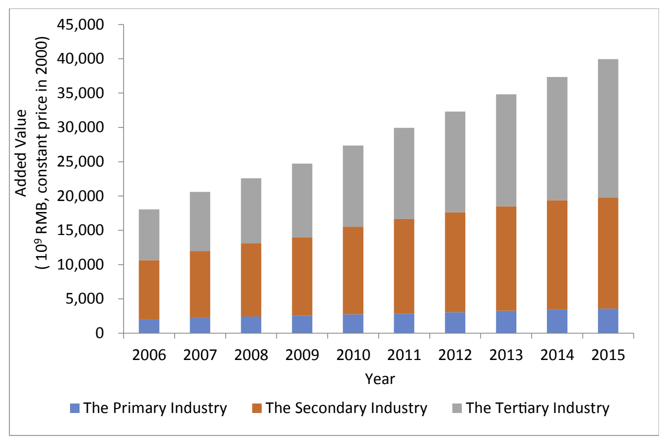

Fig. 1. Composition of GDP by industry in China.

Energy saving and emission reduction should be on the basis of economic development, improving energy efficiency is one of the most effective way in solving the energy and environmental problems. According to Shi (2006), researches on energy efficiency can be divided into two categories based on the number of input factors, they are single-factor energy efficiency and total-factor energy efficiency (TFEE). The former is defined as the ratio of the effective output to the total energy input, while is simple and easy to understand, but cannot estimate the substitution effect between factors. The latter is derived from the microeconomic theory of total-factor productivity, which can not only consider the substitution effect between input factors accurately, but can also reflect the overall utilization level of energy under a certain production factor structure of a region. In the analysis of TFEE, how to define the efficiency frontier is the key point, stochastic frontier analysis (SFA) and data envelopment analysis (DEA) approach are two main methods in recent years. SFA is a parameter estimation method and the parameters are estimated by maximum likelihood estimation. Lin and Yang (2013) adopted SFA to estimate the average efficiency of energy inputs and cumulative energy saving potential in China's thermal power industry over 2005–2010.

DEA is a linear programming method for nonparametric estimation. Compared with SFA, the biggest advantage of DEA is that it does not need to assume an equation form for the efficiency frontier. So it has developed rapidly in recent years. Hu and Wang (2006) first attempted to use DEA to calculate the TFEE of China and made a comparison of different regions. DEA can construct the optimal boundary to measure the relative efficiency of decision unit through measuring the distance between decision-making unit and the optimal boundary. Energy is one of the most important inputs for economic growth, which also leads to a huge number of undesirable outputs such as carbon emissions, waste gas and water, and solid waste during the process of production (Liang et al., 2016). Taking into account the desirable and undesirable outputs is more reliable when measuring the TFEE. Carbon dioxide (CO_2), sulfur dioxide (SO_2) and chemical oxygen demand (COD) are the most frequently used as undesirable outputs in the energy efficiency analysis, for instance, Li and Hu (2012) considered CO_2 and SO_2, Rao et al. (2012) considered COD and SO_2 and Zhang et al. (2015a) considered all the three types. Tone (2001) first proposed the slacks-based measure (SBM) which was developed by Zhou et al. (2006) considering the undesirable output. Li and Hu (2012) combined the method of common frontier DEA by O'Donnell et al. (2008) and the SBM model considering the undesirable output by Cooper et al. (2007) to calculate the ecological total-factor energy efficiency (ETFEE) of 30 regions in China. Zhang