Journal of Cleaner Production 194 (2018) 253–262

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Exploring the influencing factors and decoupling state of residential energy consumption in Shandong

Ming Zhang [a, b, *], Chunyu Bai [a]

[a] School of Management, China University of Mining and Technology, Xuzhou, 221116, China
[b] Jiangsu Energy Economics and Management Research Base, China University of Mining and Technology, Xuzhou, 221116, China

ARTICLE INFO

Article history:
Received 27 June 2017
Accepted 16 May 2018
Available online 19 May 2018

Keywords:
Residential energy consumption
LMDI method
Decoupling analysis
Shandong province

ABSTRACT

This paper aims at analyzing the current situation of residential energy consumption in Shandong, identifying the influence factors governing energy consumption based on the LMDI (Log Mean Divisia Index) method, and describing the decoupling relationship between residential energy consumption and residential income based on the Tapio decoupling method. The main results are as follows: (1) The residential energy consumption structures of urban and rural have become multilevel. Furthermore, the gap in per capital residential energy consumption between urban and rural regions narrowed. (2) The energy intensity had an obvious inhibitory effect on decreasing urban residential energy consumption. Per capital income and population structure increased the urban residential energy consumption over the study period. However, per capital income and energy intensity played a more significant role in promoting rural residential energy consumption. And the population structure decreased rural residential energy consumption. During the study period, the contributions from both energy consumption structure and total population effect were negligible. (3) Since 2000, the decoupling index for both urban and rural resident gradually declined, which also shows that residential energy consumption in urban and rural regions was gradually less depend on residential income.

1. Introduction

Nowadays, residential energy consumption is the second largest energy use category (10%) in China (Zhao et al., 2012). With the increase of resident income and the desire of improving living standard, residential energy demand is likely to continue its rapid growth, which make environmental problems more worse. Thus, exploring the related topic on residential energy consumption has attracted many researchers' interest.

With the growing concern on residential energy consumption, many research strands have emerged. The first strand of research focuses on the influencing factors governing residential energy consumption, which were explored by many methods, such as the environmental Kuznets curve, structure decomposition analysis (SDA), STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) method, and index decomposition analysis (IDA), and so on (Pachauri and Spreng, 2002). Among the numerous methods, the LMDI (Log Mean Divisia Index), which is one kind of IDA, was widely used (Liu et al., 2011). Chung et al. (2011) applied the LMDI to analyze the residential energy consumption in HongKong from four dimensions, including family quantity, family residence type, energy efficiency and climate condition. Zhao and Li (2011) also used the LMDI to analyze major influence factors of the growth of energy consumption from 1993 to 2007 in China. The study concluded that the most important reasons for the rapid growth of energy consumption were the increasing purchasing power and the transformation of energy intensive products for consumption structure.

The second strand of research focuses on the change of residential energy consumption pattern. With rising income in China, residents began to pursue high quality energy. Thus, natural gas and petroleum will gradually replace coal, and there are obvious regional differences in Chinese urban energy consumption. Sathaye and Tyler (1991) found that the residential energy consumption structure had changed from traditional biomass to commercial fuel types in urban China, India, the Philippines, Thailand, and Hong Kong. Using the slacks-based measure model, Liu et al. (2016)

* Corresponding author. School of Management, China University of Mining and Technology, Xuzhou, 221116. China.
E-mail addresses: zhangmingdlut@163.com (M. Zhang), 770413408@qq.com (C. Bai).

https://doi.org/10.1016/j.jclepro.2018.05.122
0959-6526/

analyzed the carbon dioxide emission efficiency based on energy consumption structure and pointed that energy consumption structure in China's urban areas has undergone great changes in the past 20 years.

The third strand of research focuses on the direct and indirect energy requirement of resident. Residential direct energy consumption is referring to that residents use energy directly, including lighting, cooking, heating, private transportation, and so on. Residential indirect energy consumption means that the energy consumption of goods and services in the raw materials, production, transportation and marketing (Li and Zhang, 2008). There are two main methods to estimate the indirect energy requirement of the residents, i.e. the consumer lifestyle approach and input-output method. The consumer lifestyle approach was utilized by Reinders et al. (2003) to evaluated the direct and indirect energy requirement of households in 11 EU member states. Based on the consumer lifestyle approach, Feng et al. (2011) studied the indirect energy consumption of rural household in China during the period 2005–2007. The input-output analysis was utilized by Pachauri and Spreng (2002) to explore the indirect energy requirements of Indian households. Liu et al. (2011) also utilized the input-output method to study the impact of urban and rural household energy-related carbon emissions in China.

The fourth strand of research focuses on residential building energy consumption. Li and Yao (2009) explored the impact of the fast urbanization development to building energy consumption and building energy efficiency in China. Based on the survey of typical residential buildings in the urban areas of Beijing city, Hu et al. (2010) examined the material flows of urban residential building system. The challenges and opportunities of building energy efficiency for sustainable development in China was studied by Li and Yao (2012). Based on the statistical data on demography and energy from three main regions in the Yangtze River delta, the effect of urbanization on residential energy consumption in China was studied (Huang et al., 2014a). The effect of urbanization on residential energy consumption and CO_2 emission in Chongqing was also explored by Huang et al. (2014b). Huang et al. (2015) explored the shelter and residential building energy consumption within the 450 ppm CO2eq constraints in different climate zones. Bohne et al. (2016) analyzed the global residential building energy consumption in the eight climate zones.

Nowadays, the increasing greenhouse gases emission produced by energy consumption has led to global warming. Thus, countries around the world are trying their best to improve energy efficiency and reduce greenhouse gases emission. As the biggest CO_2 emitter in the world, China government had made two major commitments (Zhang et al., 2009). One is that China's carbon emission will reach peak value in 2030 and try to achieve the peak as early as possible. The other is that carbon dioxide emission per GDP in 2030 will drop 60%–65% than that in 2005. In order to achieve these commitments, China government had put the climate change problem into “thirteenth Five-Year plan”. Each province, municipality and autonomous region in China should recognize their own energy consumption, and make reasonable plan to reduce CO_2 emission. Currently, there are many researches on residential energy consumption. However, few paper pay attention to regional residential energy consumption. Chen et al. (2017) used the deviation index and Gini ratio to analyze regional differences in china's fossil energy consumption from 1997 to 2013. Zhu (2016) pointed that the gap of regional difference in energy consumption had been narrowing in recent years, and the gap in the eastern region was more obvious than western area.

Shandong province located in eastern coastal areas in China is one of the most populous provinces and leading provinces in economy. The local residents have higher levels of disposable income, which lead to rapid increase of resident's energy consumption. During the study period 1995–2013, the residential energy consumption accounted for over 6.74% of total terminal energy consumption. However, the ratio of residential energy consumption to terminal energy consumption increased quickly since 2010. Shandong is selected as the representative for other provinces in China. Therefore, it is necessary to conduct a further study of residential energy consumption in Shandong province, which can provide reference for other regions to make out resident's energy saving emission reduction policy. Thus, this paper has three purposes. Firstly, the current situation of residential energy consumption is presented. Secondly, the LMDI method is used to explore the influence factors governing residential energy consumption. At last, the Tapio decoupling index is utilized to study the decoupling relationship of residential energy consumption from residential income.

The rest of this paper is organized as follows. Section 2 describes the methods and data used in this paper. Results and discussions are presented in Section 3. Finally, we draw our conclusions in Section 4.

2. Methodology and data

2.1. The LMDI method

At present, there are three kinds of factor decomposition method: i.e. SDA, IDA, and PDA (production-theoretical decomposition analysis). The SDA depends on the input-output tables. The SDA method was utilized to examine the sources of changes in energy use of the Brazilian economy of industries and households from 1970 to 1996 (Ulrike et al., 2009). However, the PAD presented by Zhou and Ang (2008) is based on production theory, distance functions and data envelopment analysis. The PDA was utilized by Zhang and Da (2013) to decompose China's CO_2 emission changes at the provincial region levels during the 11th Five-Year Plan period. Compared to the SDA and PDA, the IDA is widely utilized to decompose the changes of energy consumption of CO_2 emission into their driving factors. The advantage of IDA is easy to obtain data and master this method.

The IDA also includes two kinds of method, i.e. the Laspeyres and Divisia index approaches. But the Laspeyres index approach has residual terms in decomposition results. Then, Sun (1998) proposed a complete decomposition analysis where the residual term is distributed among the considered effects, which is called the refinement of Laspeyres index, to settle the residual problem. Based on the refinement of Laspeyres index, Zhang et al. (2009) explored the nature of the influence factors governing energy-related CO_2 emission over 1991–2006 in China. The Divisia index method mainly contains the AMDI (arithmetic mean Divisia index) and LMDI. The difference of the AMDI and LMDI is the weight function. However, the advantage of LMDI is no residual terms in decomposition results. Because there are the logarithmic terms in the LMDI formula, complications arise when the data set contains zero values. Ang and Liu (2007) presented eight strategies to handle zero values in LMDI method. In 2004, Ang (2004) gave a review of all decomposition techniques and concluded that the LMDI method had been the best method used to study influencing factors. Thus, the LMDI has been widely used by many researchers. Achão and Schaeffer (2009) used the LMDI to decompose the residential electricity consumption in Brazilian state into television, refrigerator, freezer and washing machine. Based on the LMDI, Wang et al. (2005) also analyzed CO_2 emission from 1957 to 2000 in China and discussed the effects of energy structure, population, energy intensity and economic growth on CO_2 emission.