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Drivers of urban and rural residential energy consumption in China from the perspectives of climate and economic effects

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ABSTRACT

In this study, we investigate the driving forces behind the changes in residential energy consumption (REC) in China's urban and rural areas over the 2001–2012 period. Based on the logarithmic mean Divisia index method, the REC changes are decomposed into seven driving forces, which are climate change, energy price, energy expenditure mix, energy cost share (in total expenditure), expenditure share (in income), per capita income and population effects. According to the results, climate effect due to increasing days with abnormal temperature, energy cost share effect characterized by more expenditure to be paid for energy use, income effect describing constant income growth in the residential sector definitely increase REC in both urban and rural areas. In contrast, energy prices and energy expenditure mix effects negatively contribute to the REC increase, respectively because of the increase in energy prices and the transition from the low-priced energy to high-priced energy. Expenditure share and population effects play opposite roles in urban and rural areas, and the reasons and implications are analysed in depth.

1. Introduction

The residential sector was the third largest energy-consuming sector in 2012, accounting for 10.90% of the total energy consumption in China next to industry (67.47%) and transport, storage,[1] postal and telecommunications services sector (11.49%) (Department of Energy Statistics of National Bureau of Statistic of China, DESNBS, 2013). And, it is meanwhile the fastest-growing sector over the 2001–2012 period in China, increasing from 116.9 million tonnes of coal equivalent (TCE) to 278.2 million TCE. In addition, as shown in Fig. 1, there exist obvious different characteristics of REC growth between the urban and rural areas. The urban REC increases more quickly than the rural REC due to the accelerating urbanisation in China (Li et al., 2015), which reached 52.57% in 2012 according to National Bureau of Statistics of China (National Bureau of Statistic of China, NBS, 2001–2013), and there are several distinct differences between the driving factors of the urban and rural REC growth. In this study, we intend to investigate the driving forces behind REC changes in urban and rural areas in China respectively.

A number of scholars have analysed the driving forces behind REC changes. Using the statistical data based on regression analysis, various scholars have examined the effects of temperature and solar radiation on residential buildings' heating activities to predict buildings' heating energy consumption in the future (Fumo and Biswas, 2015; Raffio et al., 2007; Soldo et al., 2014). Using survey data, several researchers have investigated and predicted REC by calculating prediction variables, such as economic parameters, energy price, income, climate, behaviour and household characteristics (Bianco et al., 2013; Gans et al., 2013; Mardookhy et al., 2014). Mixed using of statistical data and survey data, lifestyle and behaviour effects have been analysed by researchers (Duchin, 1998; Weber and Perrels, 2000; Yohanis, 2012). For example, Bin and Dowlatabadi (2005) found the behaviour habit played important role on REC and CO_2 emissions in the USA, using the consumer lifestyle approach (CLA). Different from the aforementioned

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[1] By storage, we mean the products stored in a warehouse.

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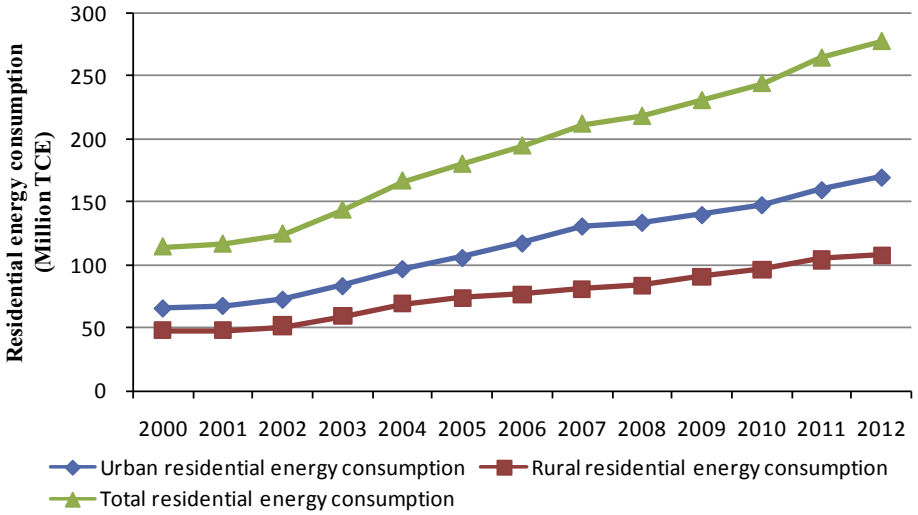

Fig. 1. Urban and rural residential energy consumption (REC) from 2000 to 2012.

studies, decomposition analysis seeks to decompose energy use into multiplication factors to investigate the underlying factors of REC. For example, Haas (1997) decomposed REC changes into nine influencing factors: demographics, economic factors, individual factors, lifestyle, culture, structure, technology, climate and policy. From 2009 to 2017, an increasing number of studies focused on analysing changes in REC and carbon emissions by using index decomposition analysis in countries such as Brazil, Ireland, the USA and China (Achão and Schaeffer, 2009; Rogan et al., 2012; Miao, 2017), most of which were based on logarithmic mean Divisia index (LMDI) method (Xu and Ang, 2014). From the perspective of income, REC was decomposed into energy intensity effect (energy consumption divided by income), income effect, population effect, and so on (Hubacek et al., 2012; Wang et al., 2015; Zha et al., 2010). The results showed that the income effect and the population effect positively contributed to the increase in REC or carbon emissions, whereas the energy intensity effect played a negative role in the changes in REC or carbon emissions. Other scholars decomposed the REC into activity effect (number of households), structure effect (house type effect),[2] intensity effect (energy consumption per household), and so on (Chung et al., 2011; Hojjati and Wade, 2012; Rogan et al., 2012). The activity effect increased REC, whereas the intensity effect played a negative role in REC changes in Hong Kong and the USA but not in Ireland. Interestingly, the house type effect increased REC in Hong Kong but had the opposite effect in the USA and Ireland (Chung et al., 2011; Hojjati and Wade, 2012; Rogan et al., 2012). Nie and Kemp (2014) and Zhang et al. (2016) investigated the influence of the floor space on REC changes. Liu and Zhao (2015) and Zhao et al. (2012) found that energy price restrained REC. Some scholars in Hong Kong (Chung et al., 2011) and Ireland (Rogan et al., 2012) also examined the influence of climate. In Hong Kong, REC for space cooling (few space heating activities due to the hot weather) increased until 2007 because of the climate effect. For Ireland, a positive climate effect on the increase in REC for space heating was found until 2008. Fan et al. (2017) emphasized the important role of urbanisation to REC growth in China and further forecasted that with the deepening of the urbanisation, REC will further increase.

The main points of the aforementioned studies are summarized as follows. First, climate is known as an important determinant of REC through influencing heating and cooling (Rogan et al., 2012; Bianco et al., 2014). Its effect on REC had been proven to be rather significant (Catalina et al., 2008; Min et al., 2010). Additionally, the climate changes a lot in different seasons in China. For example, the temperature in Harbin in the northeast of China changed from −19.4 Celsius degrees in December to 23.9 Celsius degrees in July 2012 (NBS, 2001–2013). However, the influence of climate on REC in China has so far not been investigated by researchers using index decomposition analysis. Second, the price effect in previous studies (Liu and Zhao, 2015; Zhao et al., 2012) was usually measured using REC expenditure divided by REC, which is actually represents average energy price and cannot reflect the effects of individual energy prices and energy expenditure mix. Third, the determinants of REC changes also vary depending on living in urban areas or rural residents (Liu and Zhao, 2015).

In this study, we contribute to existing theoretical framework by investigating the climate effect on urban and rural REC changes in China alongside the influences of other driving forces consisting of energy price, energy expenditure mix, energy cost share (in total expenditure), expenditure share (in income), per capita income and population effects. To our best knowledge, the climate effect has not been included in previous studies. Moreover, we use the individual energy prices instead of average energy price to measure the energy price effect, which excludes the energy expenditure mix effect. Through measuring the climate effect quantitatively and providing the individual energy prices effect, corresponding policy implications are expected to obtain.

The rest of this paper is structured as follows. Section 2 covers the methodology and data sources. The results are presented in Section 3. Section 4 gives a discussion on the decomposition results, and Section 5 summarises the findings and the conclusions.

2. Methodology and data

2.1. Index decomposition analysis model

In this study, we decompose changes in urban and rural REC into several effects within the framework of economic factors, climate effects and population. In doing so, we are able to investigate the influence of urbanisation on REC through an analysis that accounts for changes in income, climate and other factors. Based on theoretical considerations and data availability, we have opted for the

[2] Chung et al. (2011) use the term *household type* to explain the type of each house. In this paper, we use the term *house type effect*.

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