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Contribution of price/expenditure factors of residential energy consumption in China from 1993 to 2011: A decomposition analysis

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ABSTRACT

Since the establishment of the market economy in 1993, the residential consumption of commodities, including energy, has been highly influenced by prices in China. However, the contribution of the factors related to prices in residential energy consumption is relatively unexplored. This paper extends the KAYA identity with price and expenditure factors and then applies the LMDI method to a decomposition of residential energy consumption in China from 1993 to 2011. Our results show the following: (1) Though the prices of a majority of residential energy sources in China declined, the effect of energy prices restrained residential energy consumption because the expenditure structure changed during the period. (2) During the research period, the urban energy expenditure proportion experienced two progresses of rising and falling, and the rural proportion, which was stable before 2002, sharply increased. (3) The energy consumption intensity effect, which is the negative of the average energy price effect, contributed to most of the decrease in energy consumption, whereas residential income played a key role in the growth of consumption. According to the conclusions, we suggest further marketization and deregulation of energy prices, the promotion of advanced energy types and guidance for better energy consumption patterns.

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1. Introduction

The excessively rapid increase in fossil energy consumption has resulted in climate change and air pollution. This increase has had negative effects on both natural and socioeconomic systems all over the world. Residential energy consumption (REC) accounted for 7.6% of the total national energy consumption in China in 2011; this percentage is far below the world average, which is approximately 30% [33].

The residential sector is recognized as an important source of energy consumption and a driver of CO_2 emissions. Though the percentage of REC has decreased from 28% of the total national consumption in 1993 to 7.6% in 2011, the quantity of Chinese REC amounted to 264.94 million tons of standard coal equivalent (TCE), or 185.45 million tons of oil equivalent (TOE) in 2011. By contrast, the national energy consumption of England was 286.43 TCEs, or 200.5 million TOEs, and the national energy consumption of Italy was 242.29 TCEs, or 169.6 TOEs, in the same year [12]. The cause is that after China's reform and opening up, particularly after the establishment of market economics, the constantly increasing energy consumption in the daily life of Chinese urban and rural residents, the high-speed economic development, and the continuous residential income growth led to increasing energy consumption. Therefore, understanding the characteristics of REC is urgently required to help formulate effective policies for local energy strategies and ultimately achieve the overall national target of a 16% decrease in national energy intensity from 2011 to 2015.

Residential energy consumption is influenced by many factors, such as energy intensity, resident income, urbanization, population growth, energy mix, changing consumer preferences, the adoption of electric appliances and private vehicles. Existing research has decomposed REC and relative CO_2 emissions into many different contribution factors. The classic method decomposes the REC into the following factors: population, income, energy intensity (energy consumption per income), and energy structure (the portion of a type of energy in the total consumption). Energy efficiency is another widely used indicator. Some researchers studied the population structure to identify the REC patterns of different populations. The structure of activities that use energy is also regularly observed in papers on REC and CO_2 emissions. However, factors that reflect the effect of energy prices or energy expenditure are rare in the existing decomposition analysis research.

The consumption of fossil fuels, which are the major constituent of REC, is heavily affected by the market prices [22,11]. It is

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noteworthy that the market economy was established in China in 1993. Since then, the government has gradually been substituting market-oriented energy pricing mechanisms with price control. Consequently, energy prices in China are lower than international levels, and the relationship between energy supply and energy consumption is distorted. Additionally, with the improvement of resident living standards, energy consumption patterns have changed consistently. For example, the consumption of gasoline has increased since the popularization of family cars. Like the Engel coefficient, the proportion of energy expenditure in residents' income, which is a coefficient of energy consumption patterns, reflects the relationship between energy consumption and residents' living standard. Accordingly, the study of the past data, energy consumption and energy prices in China's residential sector is interrelated; nevertheless, existing studies on REC focus primarily on energy intensity, the energy structure and residents' income and rarely focus on energy prices. This is partly because energy intensity, which reflects the influence of residents' income and covers the influence of expenditure, is widely used. It is known that expenditure is a variable related to consumption and price. The motivation of this paper is to identify the contribution of price/expenditure and relative factors.

The rest of this paper is organized as follows: Section 2 reviews previous research on REC in China. Section 3 introduces the logarithmic mean Divisia index (LMDI) method and applies the method to our REC model. In Section 4, we discuss data. Section 5 introduces the results and the discussion. Section 6 concludes this paper with policy implications.

2. Literature review

There have been a number of studies on the energy consumption of China's residential sector and the corresponding CO_2 emissions. Wei et al. [41] quantified the direct and indirect effect of the lifestyle of urban and rural residents on China's energy use based on the Consumer Lifestyle Approach (CLA). Feng et al. [19] used the Grey Model on the CLA and showed the differences in the relationship between the energy consumption and consumption expenditure of urban households and rural households. Yao et al. [44] analyzed rural residential energy consumption in China and found an obvious transition from non-commercial energy to commercial energy. Price factors were not involved in these studies on the relationship between lifestyle and REC and CO_2 emissions.

Index Decomposition Analysis (IDA) is widely used to identify the effect of predetermined driving factors in the research on household energy consumption and CO_2 emissions. Zha et al. [46] concluded that energy intensity and income effects, respectively, contributed most to the decline and the increase of residential CO_2 emissions for both urban and rural China by applying the LMDI decomposition analysis. With urbanization effect concerned, Liu et al. [25] combined the LMDI method with China's input–output tables to analyze the direct and indirect CO_2 emissions from household consumption. Zhao et al. [49] decomposed China's urban residential energy consumption at the disaggregated product/activity level with expenditure data of 5 types of energy utilization collected from a wide range of sources. Zhang et al. [48] discussed the decoupling effect of rural residential commercial energy consumption in China by developing the decoupling index based on the factors identified by the LMDI method. Decomposition analyses help to distinguish the contribution of different factors, such as energy intensity, energy structure, residents' income and the population. However, the effect of prices is concealed by the energy intensity factor. In fact, Zhao et al. [49] obtained a result related to the effect of energy prices by using the expenditure data of different products/activities, but the data from different sources is heterogeneous and uncomprehensive. Nie [33] decomposed the dramatic increase of residential energy use in China in 2002–2010 and found that the effect of floor space per capita become increasingly important over time. However, the contribution of expenditure to REC is rarely investigated in the existing research. Additionally, Ma [28] figured out that there was sector heterogeneity in China's energy consumption and the relevant GDP or expenditure. Therefore, it is important for the research to adopt homogeneous data.

Previous studies have demonstrated a co-integration relationship between energy prices and energy consumption in not only industrial sectors but also the residential sector in China. Hang and Tu [20] indicated that increasing prices would improve energy efficiency and increase energy supply but also add more burdens to vulnerable households. Yuan et al. [45] concluded that higher energy prices would decrease household energy consumption in the long run and increase it in the short run. Tao and Yu [38] investigated the energy efficiency standards of household refrigerators/freezers in China and found that due to the historically low electricity price and the little emphasis on energy efficiency in the Chinese economy, manufacturers, retailers and consumers were uninterested in high-efficiency products. Ouyang et al. [34] indicated via a standard Life Cycle Cost (LCC) method that the gradually increasing electricity prices in a market economy helped upgrade the aging residential buildings in China. Wang et al. [40] explored the determinants of the public acceptance of tiered electricity price (TEP) reform in China and showed that the middle income earners were the groups that were most opposed to TEP, and public environmental awareness should be highlighted during the implementation of TEP. Daioglou et al. [16] developed a model for household energy use in developing countries including China and found that prices likely repressed the transition from traditional to commercial fuels amongst households sensitive to price fluctuations. Lin and Liu [23] showed that the electricity tariff reform might be an effective method for mitigating the rebound effect of residential electricity consumption. Liu et al. [26] analyzed how to adjust the state-administered residential electricity price to adapt to the market-driven coal prices. Sun et al. [37] found that rising energy prices help to reduce the residential energy consumption and suggested that energy price can be an important instrument for the government to advocate green lifestyles. Lin and Ouyang [24] indicated that fossil fuel subsidies resulted in the excessive and wasteful consumption of energy and environmental deterioration, and most subsidies went to the rich residents rather than the poor.

These studies demonstrate that energy prices have effects on energy consumption, though generally, there was only one type of energy selected to represent household energy consumption in each study above. With only one type of energy investigated, the structural change of the energy prices—i.e., the transition from high-priced energy types to low-priced energy types or vice versa—was ignored. Furthermore, after the demonstration, the quantification of the contribution from energy prices factors to REC is necessary.

As observed from the literature review above, the relationship between energy prices and REC in China has been shown. A study about the contributions of price factors to the change in China's REC is absent. This paper attempts to give a decomposition analysis of the REC within price factors by applying the LMDI method. To avoid the deflection caused by the heterogeneity of the data, residential consumption price data from a sole origin are necessary. Considering the differences between urban and rural China, the two cases are studied in this paper. We discuss the proportions of the different energy carriers in the consumption/expenditure structure and then explain the relationship between the decline in the prices of a majority of residential energy carriers in China

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