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Evaluation of energy saving effects of tiered electricity pricing and investigation of the energy saving willingness of residents

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ABSTRACT

The effects of tiered electricity pricing (TEP) on the energy saving willingness of residents and household electricity consumption behaviour are qualitatively studied through a social investigation in Guangdong, China. Furthermore, an autoregressive integrated moving average model (ARIMA model) is constructed using monthly electricity consumption data of residents in Guangdong to quantify the effects of implementing a TEP policy on energy saving. Meanwhile, to explore the opportunities for improving the policy, this research uses an ordered probit model to study the factors influencing the energy saving willingness of residents based on explanatory variables, such as personal characteristics, living conditions, etc. The empirical results demonstrate that, after the implementation of TEP, energy saving awareness among women is higher than that among men. With increasing levels of educational attainment, or having a family, energy saving awareness gradually increases. In addition, there is a U-type relationship between age and energy saving awareness, while a reciprocal U-type is present between income and energy saving awareness. Meanwhile, the housing ownership type (self-occupation or rental) is also closely related to the energy saving awareness of residents. Finally, according to the above research results, suggestions are put forward to improve the TEP policy.

1. Introduction

For a long time, the electricity pricing mechanism in China has been formulated by government. Aiming at the electricity consumption of residents, cross- subsidisation mechanisms that use industrial and commercial electricity prices to subsidise that of residents is adopted by the government. However, with the development of both the economy and Chinese society, the disadvantages of this mechanism are becoming clearer. On the one hand, the electricity price for residents has remained unchanged for a long time, while the industrial and commercial electricity price is rising, which leads to an increase in production and service costs and therefore restricts the improvement of industrial and commercial competitiveness. On the other hand, with respect to the power demand side, the more electricity consumed by users (commonly residents with high incomes), the more the cross-subsidisation of electricity prices is enjoyed by them. This phenomenon is not only conducive to generating excessive electricity consumption by residents, but also renders the cross-subsidisation mechanism unfair.

To rationalise the electricity pricing mechanism, and promote residents to save electricity, the Chinese Government has reviewed the low price preferential policy on residential electricity prices, which has been implemented for the long-term, to propose the policy of tiered electricity pricing (TEP). The purpose of the mechanism is to promote the energy saving awareness of residents and the efficiency of energy utilisation by means of the price lever. According to the pilot tiered pricing scheme for household electricity formulated by National Development and Reform Commission, since 1 July, 2012, tiered pricing for household electricity has been implemented in 29 provinces and regions in China.

To date, the TEP policy has run for 4 years: how has the energy saving effect turned out after implementing the policy? Has residential electricity consumption behaviour changed? Is the incentive mechanism in the policy sustainable? How can policy changes guide the energy saving behaviour of residents in the future? Theoretical studies and empirical tests on these issues are conducive to improving the mechanism of TEP, and also provide theoretical support for the current new round of reforms of China's electrical power market.

Abbreviations: TEP, tiered electricity pricing; ARIMA model, autoregressive integrated moving average model; AR model, autoregressive model; MA model, moving average model; ACF, autocorrelation function; PACF, partial autocorrelation function; GEN, gender; EDU, education; INC, income; HT, house type; FS, family size

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From the perspectives of the energy saving effects of the policy and the energy saving willingness of residents, this paper studies the above problems. The purposes of the study lie in two aspects: first, this research measures the energy saving effects after implementing the policy and analyses the characteristics of the energy saving effects. Second, according to the factors influencing energy saving willingness of residents, potential improvements of the policy aimed at guiding residents to save more energy are studied. Based thereon, the rest of this study is organised as follows: Section 2 reviews the relevant literature and outlines the contributions and novelty of this paper, Section 3 introduces the research objectives, methods, and data sources, Section 4 empirically verifies the energy saving effects of the policy, Section 5 discusses the policy mechanisms influencing the energy saving awareness of residents, and conclusions and policy suggestions are presented in Section 6.

2. Literature review

Developed countries have rich experience of studying TEP policies. Feldstein (1972) designed a two-staging electricity pricing scheme for Massachusetts, in the USA. Based on a Ramsay pricing strategy, Brown and David (1986) further carried out the standardised design of the mechanism of tiered pricing for household electricity. As the mechanism of TEP was popularised, many countries began to consider more factors in the design of their policies, so as to adapt it to their own economic development (Bushnell and Mansur, 2005). Apart from the above designs of tiered electricity pricing mechanisms, evaluating the effects of the policy is another major direction in research into TEP. According to the microscopic data from households, Maddock and Castaño (1991), Herriges and King (1994), Reiss and White (2008) and Stokke et al. (2010) investigated the changing trends of electricity consumption and payments in different income groups after the implementation of TEP.

Developed countries have more perfect market economic systems. In addition to the influences of TEP on electricity demand, other problems receive more attention, such as the fairness, efficiency, and income redistribution effects of policies, so that the price mechanism is not distorted by the policy design. Boland and Whittington (2000) criticised increasing tiered pricing, because it is found that these policies fail to reach the set goals of subsiding people with low incomes. As for the reasons, Dahan and Nisan (2007) found that electricity consumption of families with low incomes is not always low. For example, low income earners with more family members need to pay electricity price at a higher tariff than those with higher incomes. However, other scholars reached different conclusions: Borenstein (2008, 2010) found that expanding the set range of electricity prices can effectively subsidise families with low incomes. Meran and Von Hirschhausen (2009) further pointed out that family characteristics are closely related to the fairness of the increasing tiered pricing policy. In addition, the latest research of Woo et al. (2014) and Farrell and Lyons (2015) showed that TEP is conducive to energy saving, emissions reduction, and income redistribution but calls for detailed policy designs and relevant supporting measures. For instance, there remains a need to define low income groups properly and popularise smart meters to support the policy. Furthermore, Schoengold and Ziberman (2014) emphasised that the heterogeneity of consumer demand has to be considered in designing the mechanism of TEP.

In China, with the deepening of reforms and opening up, the power market gradually changes from complete to relative monopoly (Wang and Chen, 2012). For example, since 1985, the electricity pricing has gradually changed from being determined to being guided, by the government (Zhao et al., 2012). Accompanying with the reforms of electricity prices, scholars begin to concern the influences of electricity price changes on electricity consumptions. Based on the panel data in 29 provinces and regions in China, Lin et al. (2014) evaluated the price and income elasticity of electricity demands of residents in different regions (such as urban, rural, coastal and inland residents). The study shows that for most of the residents, the price of electricity demand is inelastic, while the income demonstrates elasticity. Furthermore, based on the computable general equilibrium (CGE) model, He et al. (2011) calculated the price elasticity of electricity demand in each industry sector (including residents' life). From December 2012 to March 2013, Renmin University of China and Xiamen University made a questionnaire survey on energy consumptions in 1450 households in 26 provinces and regions in China, which is a survey on micro-energy consumption with a large intensity and a wide range. Based on the survey data, Khanna et al. (2016) found that the price and income of electricity demands are inelastic. Therefore, the research considers that the changes of electricity price have little and even no influence on electricity demands. In the study of Yu and Guo (2016), a stochastic frontier model was used to study the energy saving potential of rural residents in china. They also believed that electricity prices have little impact on rural residents. However, by using the same data, Sun and Ouyang (2016) conducted more detailed research and divided residents into low-, medium- and high-income groups according to income levels. The research demonstrates that the absolute value of electricity elasticity of low-income groups is much higher than that of high-income groups. Therefore, the targeted reforms of electricity prices are believed to be beneficial for energy saving.

Compared with developed countries, China has implemented TEP relatively late. In 2004, three provinces including Zhejiang, Fujian, and Sichuan began the trail implementation of tiered pricing for household electricity. Since then, the TEP policy has been of interest to Chinese academics. Yang and Liu (2010) analysed the mechanism underpinning TEP based on practical experience gained in developed countries. By discussing the design principles and calculation methods of the increasing tiered pricing for household electricity in Liaoning Province, Wang (2011) proposed an increasing tiered pricing scheme that is suitable for the electricity consumption habits of residents in this province. In addition, by fuzzifying the price elasticity and grade, Li et al. (2012) established a fuzzy model for the user responses to the mechanism of TEP. Meanwhile, fuzzy optimisation theory was used to calculate the distribution intervals of each electricity price grade. By randomly selecting 816 samples from the residents in Beijing, Wang et al. (2010) discovered that it is necessary to implement TEP to enhance the energy saving willingness of residents and promote energy conservation and a reduction in its consumption. Meanwhile, they also designed a TEP scheme with two or three grades. The similar study also have Lin and Jiang (2012) and Sun and Lin (2013). Base on the questionnaire survey data of four urban cities in China, Wang et al. (2012) tried to exploring determinants of public willingness to accept tiered electricity price and finding out the acceptable range of premium.

In 2012, China started to implement TEP more broadly, and the quantitative analysis of the current implementation of the policy has gradually become a new research focus. Sun and Yan (2015) investigated the effect of the tiered pricing for household electricity in China, and found that the current schemes are effective and the distortion of cross subsidies in electricity tariffs has been reduced. Du et al. (2015) compared the residential electricity consumption data before and after the implementation of TPE in China, and found that the energy price, household income, and demographic attributes have significant impacts on residential electricity consumption. Taking Anhui province as an example, Ye et al. (2016) found that block pricing policy may help lower the residential electricity consumption at about 1.4–3.0% per year.

From the aspects of research perspectives and methods, existing studies provide effective references for the design and evaluation of TEP in China. However, few empirical studies have been conducted on the energy saving effects of the policy and the energy saving characteristics of residents. In addition, although existing research emphasises the importance of energy saving behaviours among residents, those