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Is the implementation of the Increasing Block Electricity Prices policy really effective?— Evidence based on the analysis of synthetic control method

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ABSTRACT

The implementation of Increasing Block Electricity Prices (IBEPs) aims to guide residents towards electricity savings and rational energy use, but there are questions over the effectiveness of the IBEPs to achieve these goals. To this end, this paper uses residential IBEPs policy implemented in Sichuan Province of China in 2006 as a natural experiment to answer the question of whether IBEPs effectively regulate residents' electricity demand. Synthetic control method (SCM) was used to evaluate the treatment effect of the policy. The paper finds that the IBEPs policy significantly reduces urban and rural residential electricity consumption. The per capita electricity consumption of urban residents fell by 26.87–100.76 kWh/year with an average of 51.40 kWh/year, equivalent to a decrease of 5.93%–17.50% and average of 11.17%. On the other hand, the per capita electricity consumption of rural residents decreased by 20.86–48.28 kWh/year with an average of 26.28 kWh/year, which is equivalent of a decreased of 7.8%–16.79% and average of 12.75%. Electricity demand in urban areas decreased more than in rural areas, but rural residents are more sensitive to IBEPs than urban residents. In order to achieve "equity" and "efficiency", China needs to further improve the design mechanism of residential IBEPs.

1. Introduction

With rapid economic development, residential electricity consumption in China has risen sharply [1]. In 2017, China's electricity consumption was 6077.7 billion kWh, of which the residential sector consumed 865.5 billion kWh, accounting for 13.78% of the total electricity consumption. Residential electricity consumption increased by 766% over the period 1995–2012, with an average annual increase of 10.31%. China surpassed the United States as the largest electricity consumer in the world as early as 2011 [2], and currently faces severe environmental pressure. In 2016, thermal power accounted for 74.4% of China's power supply structure. Therefore, it is necessary to regulate and manage residential electricity demand via electricity price in the case of high energy dependence and residential electricity demand.

Electricity price can regulate the supply and demand of electricity and is a core part of the electricity market. The government controls the pricing of all aspects of electricity generation, transmission, distribution and sales in China's electricity market [3]. Electricity price mechanism, as an economic lever, can improve energy efficiency by promoting the rational and economical use of electricity. Efficient price signals play a very important role in achieving social goals [4].

Nowadays, the main types of pricing/tariffs include flat-pricing tariff, increasing/decreasing block prices (I/DBPs), time-of-use (TOU) tariffs and Critical-peak pricing tariffs [5]. Flat-pricing tariff is to implement the same price at any time, and it cannot effectively shift the electricity load for different periods. Increasing/Decreasing Block prices (I/DBPs) is mainly used for demand management in residential sectors, which can regulate the user's electricity consumption. The basic electricity load of residents is inelastic, but the higher electricity load is elastic. The implementation of IBPs can reduce electricity consumption. Time-of-use (TOU) tariffs can encourage users to shift their electricity use in peak periods to off-peak periods. Compared with residents and business users, industrial users tend to shift their electricity loads under TOU

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conditions [6]. Real-time pricing (RTP) is more efficient relative to Time-of-use (TOU) tariffs in the long term [7]. However, because users are limited by some factors such as frequent active, RTP does not apply to everyone.

Electricity is crucial in promoting the convenience of modern life [8]. Rational electricity price can transfer scarce information resources, which can effectively guide residents' rational electricity consumption and improve electricity utilization efficiency [9]. In the reform of the residential electricity price, China has implemented the Increasing Block Electricity Prices (IBEPs) policy to replace the flat-pricing ([10–12]). The IBEPs can guarantee efficiency and equity relative to the flat-pricing. According to the National Development and Reform Commission of China, residents' electricity consumption is divided into basic electricity demand, normal electricity demand and higher electricity demand. IBEPs refers to the electricity price mechanism that the unit electricity price increases gradually with the rise in electricity consumption. In addition, the design of IBEPs should ensure that approximately 80% of residents' electricity bills are not higher than the electricity bills under the flat-pricing. As shown in formula 1, Q_i is the threshold of electricity consumption in the i-th block and P_i is the price in the i-th block, Q is the real amount of electricity consumption [13]. If $P_n > \ldots > P_2 > P_1$, it is n-blocks Increasing Block Electricity Prices. The electricity price of the first block is generally lower than the marginal cost or average price. The electricity price of the highest block is generally higher than the average price, which is close to the long-term marginal cost. The first block can guarantee the basic electricity demand of residents and the higher prices plays a market regulatory role on the non-basic electricity consumption.

$$P = \begin{cases} P_1 & 0 \le Q \le Q_1 \\ P_2 & Q_1 < Q \le Q_2 \\ & \cdots \\ P_n & Q_{n-1} < Q \end{cases} \tag{1}$$

As early as June 1974, Japan began to implement residential IBEPs. The United States also began to impose electricity bills in the mode of the IBEPs in the 1970s. Increasing Block Prices is not only used in the field of the residential electricity sector, but also in the water and gas sectors in many countries and regions. Table 11 in the appendix describes the structure of IBEPs in Japan and several states of the US.

Due to the differences in economic development and resource abundance, the structure of the IBEPs in different countries also differs greatly. The blocks of IBEPs range from two to five. Comparing Tables 10 and 11, the differences in IBEPs structure among states in the United States are more obvious than in China. With regard to the effectiveness of IBEPs implementation, Borenstein [14] conducted a study on California and found that the IBEPs results in modest wealth redistribution to low-income groups. However, studies have also shown that IBPs does not properly target subsidies to poor households in developing countries [15].

In China, the implementation of residential IBEPs is relatively late. Fujian and Zhejiang province began to implement residential IBEPs in 2004 as pilot provinces with three-block structure. Sichuan province implemented residential IBEPs in July 2006 with a four-block structure. In July 2012, China began to implement the IBEPs on the mainland in addition to Xinjiang and Tibet. The structure of the electricity prices and block setting are shown in a Table 10 in the appendix.

The IBEPs can encourage residents to make rational use of electricity [16]. It can also improve the status of cross-subsidies [13] and provide a living guarantee for the poor. The implementation of the IBEPs plays an important role in optimizing the allocation of electricity resources and mitigating environmental pressure.

Overall, the purpose of government's implementation of the IBEPs is to ensure “efficiency” and “equity”. In other words, when the price is straightened and efficiency is ensured, equity can be promoted.

There are, however, questions about whether IBEPs policy truly contributes to a reduction in electricity consumption and realization of electricity resource conservation. Another question is whether it has different impacts on the electricity demand of urban and rural residents. In this paper, we use the synthetic control method for the empirical research. Taking urban and rural areas in Sichuan Province as case studies, we examine the impact of the implementation of IBEPs on residential electricity demand.

The contribution of this paper is mainly reflected in the following three aspects. Firstly, this paper extends the application of the synthetic control method to the study of the IBEPs policy in China's residential electricity sector, enriching the existing literature on synthetic control method. As a new research method in recent years, the synthetic control method has many advantages. This method can also be extended to study other policies implemented in the energy sector. Secondly, with regard to the study of IBEPs, this study is different from others that used such methods as Discrete/Continuous Choice approach (DCC) and Regression Discontinuity Design (RDD) to evaluate the IBEPs. This is the first time that synthetic control has been used to evaluate the implementation effect of this policy. As a reference, other countries and regions can also apply this method to the research of the Increasing Block Prices in the electricity, water and natural gas sectors. Thirdly, the data used in the previous literature on China's IBEPs policy research are based on household micro-survey data. The data and methods used in this paper provide a more macroscopic perspective to evaluate the implementation of IBEPs.

The rest of this article includes the following sections: The second part is the literature review on IBEPs policy and related research. The third part is the research method and the data used in this study. The fourth part is the main results. The fifth part deals with the robustness test. The sixth part is the analysis of current residential IBEPs in China. The seventh part is the main conclusions and recommendations.

2. Literature review

As a policy tool to promote equity, resource conservation and efficiency, Increasing Block Prices is generally used in the public sector, such as in residential electricity, water, solid waste [17] and natural gas sectors. Compared with a flat-pricing mechanism, IBEPs can better regulate consumption habits to promote conservation and improve the allocation efficiency of resources.

Regarding the application of IBEPs in the electricity sector, Huang & Chie [4] studied the efficiency and equity of Taiwan's residential electricity consumption. Hung & Huang [9] studied the dynamic demand for residential electricity in Taiwan under seasonality. Henson [18] used Washington, Oregon, Idaho, Montana as case studies while Borenstein [19] used California as a case study to explore the electricity demand response of residents under the IBEPs policy.

The application of Increasing Block Prices in the water sector has obtained divergent views. Concerning the study of price elasticity, Wichman [20] found that residential water demand is price inelastic in North Carolina. Klaiber et al.'s [21] point of view is that large users are insensitive to price. In terms of equity, the residential water price structure should focus on promoting interpersonal equity [22]. Studies on Ghana also call for a further restructuring of the Increasing Block Prices to achieve equity [23]. In addition, the household size should also be the focus of the Increasing Block Prices design [24]. California's evidence shows that