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How do urban households in China respond to increasing block pricing in electricity? Evidence from a fuzzy regression discontinuity approach

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ABSTRACT

China is the largest electricity consumption country after it has passed the United States in 2011. Residential electricity consumption in China grew by 381.35% (12.85% per annum) between 2000 and 2013. In order to deal with rapid growth in residential electricity consumption, an increasing block pricing policy was introduced for residential electricity consumers in China on July 1st, 2012. Using difference-in-differences models with a fuzzy regression discontinuity design, we estimate a causal effect of price on electricity consumption for urban households during the introduction of increasing block pricing policy in Guangdong province of China. We find that consumers do not respond to a smaller (approximately 8%) increase in marginal price. However, consumers do respond to a larger increase in marginal price. An approximately 40% increase in marginal price induces an approximately 35% decrease in electricity use (284 kW h per month). Our results suggest that although the increasing block pricing could affect the behavior of households with higher electricity use, there is only a limit potential to overall energy conservation.

1. Introduction

China has a rapid growth in electricity consumption with an average annual growth rate of 10.44% between 2000 and 2013 (NBS, 2005, 2014), and now China is the largest electricity consumption country after it has passed the United States in 2011 (EIA, 2014). Since most of electricity in China is generated from coal (about 78% in 2013) (NBS, 2014), higher growth in electricity consumption is associated with higher sulfur dioxide emissions that fall as acid rain and carbon dioxide emissions that have a great impact on climate change. Acid rain and climate change have already imposed significant pressure on the economy and environment in China: Acid rain has caused China an annual economic loss of US$ 13 billion (Hao et al., 2007), and climate change has already had certain impacts on the agriculture and livestock industry, forest, natural ecosystems, water resources, and coastal zone in China (NDRC, 2007).

In terms of electricity consumption, the residential sector in China is the second largest sector after the industrial sector. From 2000–2013, although the residential sector accounted for only 12.89% of total electricity consumption which was much smaller than the share of industrial sector in total electricity consumption (i.e., 72.39%), residential electricity consumption was growing faster than industrial electricity consumption. Residential electricity consumption grew by 381.35% (12.85% per annum) between 2000 and 2013, while industrial electricity consumption grew by 306.45% (11.39% per annum) over the same time period (NBS, 2005, 2014). From Fig. 1, it appears that a co-moving volatile trend existed between these two annual growth rates of electricity consumption before 2009. However, these two growth rates were divorced after 2010: An apparently increasing trend was seen for the growth rate of the residential sector after 2010; in contrast, the growth rate in the industrial sector was slowing down after 2010. Rapid urbanization along with increasing income of households in China are two primary driving forces which will continue to drive growth of electricity consumption in the residential sector in the future (Wang, 2014; Cai and Jiang, 2008). Hu et al. (2013) explore the relationship between economic development and electricity demand in China, and they project that total residential electricity demand could reach 4161 TW h in the year 2050, almost equivalent to China's 2012 total national electricity consumption.

In order to deal with rapid growth in residential electricity consumption, the National Development and Reform Commission (NDRC) issued an increasing block pricing (IBP) policy in electricity consumption for residential consumers covered all provinces in the mainland China staring from July 2012, and required provinces establish their own IBP policies. Before the IBP policy was issued, electricity consumption in the residential sector of China was charged

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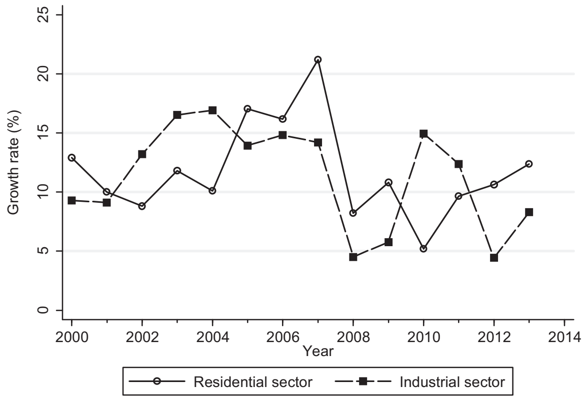

Fig. 1. China electricity consumption annual growth rates in residential and industrial sectors (2000–2013).
Sources: Own calculation from electricity consumption data in the China's energy statistical yearbook 2014 & 2005.

in a flat rate structure, and this flat rate may change sometimes associated with electricity generation costs and other purposes (Liu et al., 2013). According to the proposals on implementation of the IBP policy in the residential sector issued by the NDRC on October 9, 2010, the objectives of the IBP policy include addressing social equity, promoting energy conservation and environment protection (NDRC, 2010).

Whether price tools such as the IBP policy could achieve above objectives depends on how Chinese residential electricity consumers would respond to the complex price structure as the IBP tariffs, which requires to estimate price elasticity of residential electricity demand under the IBP structure. Although several studies use aggregated data, time series data or household level data to estimate price elasticity of electricity (e.g., Holtedahl and Joutz, 2004; Shi et al., 2012; Zhang and Kotani, 2012; Zhou and Teng, 2013) and natural gas (e.g., Yu et al., 2014) in China, there is still a lack of empirical studies in China's IBP policy for the residential electricity or other public utilities.[1] Moreover, all these empirical studies are based on the regression methods which could not address the price endogeneity problem, leading to biased and inconsistent estimates of parameters. In particular, this endogeneity problem could not be solved by using instrumental variables and two- and three-stage least squared estimations under the IBP structure (Olmstead, 2009; Hewitt and Hanemann, 1995).

To deal with simultaneous choice of the block and the block consumption under the IBP structure, recent studies use the discrete-continuous choice (DCC) models to estimate demands of water and electricity in countries other than China. Hewitt (1993) and Hewitt and Hanemann (1995) introduce the DCC models from the tax literature developed by Burtless and Hausman (1978) and Hausman (1979) to analyze U.S. water demand under the IBP structure. The DCC models are consistent with utility theory by maximizing utilities subject to piecewise-linear budget constraints, and they can produce unbiased and consistent estimates of parameters compared to the regression methods of estimation, including instrumental variables and two- and three-stage least squares regression (Olmstead, 2009; Hewitt and Hanemann, 1995). Since then, some studies have employed this approach to estimate water demand (e.g., Baerenklau et al., 2014; Miyawaki et al., 2011; Olmstead, 2009; Olmstead et al., 2007; Pint, 1999; Rietveld et al., 2000) and electricity demand (e.g., Bolduc et al., 2008; Reiss and White, 2005; Herriges and King, 1994). However, in addition to being complicated to implement DCC models, the price elasticity estimated by the DCC models is the conditional elasticity within each consumption block. Olmstead et al. (2007) have showed that the unconditional price elasticity is a function of both the conditional price elasticity and the income elasticity. Consequently, it is not clear the direct relationship of the unconditional price elasticity to the conditional elasticity (Klaiber et al., 2014).

Recently, Nataraj and Hanemann (2011) use a regression discontinuity (RD) design approach to test whether consumers respond to the introduction of a third price block in an IBP structure for water. The advantage of this RD approach is that a causal effect of price changes on consumption can be derived from this quasi-experimental approach. Wichman (2014) follows the spirit of Nataraj and Hanemann (2011) to examine consumption behavior at a discontinuous block endpoint during the introduction block rates for a North Carolina utility.

In this study, following the methodology of Nataraj and Hanemann (2011) and Wichman (2014), we use difference-in-differences (DD) models within a fuzzy regression discontinuity (FRD) design approach to empirically estimate households' response to the IBP policy in residential electricity consumption of China. Employing the urban household survey data in Guangdong province of China, we investigate a causal effect of price on electricity consumption through this quasi-experimental FRD design approach. We find that urban households in Guangdong do not respond to a small increase in marginal price, but they do respond to a larger increase in marginal price under the IBP structure.

This study contributes to the literature on residential electricity demand in several respects. First, to our knowledge, it is the first study that uses quasi-experimental approach to empirically estimate electricity consumption changes in response to the introduction of increasing block rates for urban households in China, and thus could have important implications for Chinese policymakers to evaluate and improve the IBP policy in electric and other utilities. Second, this study is among a few studies that use micro household level data in China which are more informative and could address heterogeneity to make valid inferences. Third, our study adds to an important and growing literature that attempts to address what is the appropriate price to include in demand models when consumers face nonlinear budget constraints (Borenstein, 2009; Nataraj and Hanemann, 2011; Wichman, 2014; Ito, 2014). Among these studies, Ito (2014) uses the encompassing test approach and exploits price variation at spatial discontinuities in electricity service areas to examine whether consumers respond to marginal price or alternative forms of price under nonlinear pricing and his result shows that consumers respond to average price rather than marginal or expected marginal price, and Wichman (2014) provides evidence that residential water consumers respond to average price under the increasing block rates by identifying perceived price through a billing anomaly in which changes in marginal and average prices move in opposite directions. Our results show that consumers respond differently to different magnitudes of marginal price. Although the co-movement of marginal and average price in our data prevents us to directly identify consumers' perceived price, inconsistent responses to changes in different magnitudes of marginal price imply that consumers may respond to average price rather than marginal price under the IBP structure, since a small increase in marginal price leads to an even smaller increase in average price about which consumers may not care, but a large increase in marginal price leads to a large increase in average price which may induce consumers to respond. As noted by Ito (2014), it can be rational for most consumers to use average price as an approximation of their true marginal price under the complex nonlinear structure of their pricing.

The paper proceeds with a section on the introduction to the IBP policy in Guangdong province of China, followed by research methodology and data in Sections 3 and 4, respectively. Subsequently, results are presented and discussed in Section 5 before the conclusions and policy implications section.

[1] There are several studies address policy effects of the IBP on residential electricity consumption or water consumption in China. However, these studies are either in a theoretical analysis framework (e.g., Lin and Jiang, 2012) or in a simulation framework (e.g., Sun and Lin, 2013; Chen and Yang, 2009).