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Consumer responses to critical peak pricing: Impacts of maximum electricity-saving behavior

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ABSTRACT

A summer residential CPP experiment in Japan that varied CPP prices by as much as 10 times the baseline rate induced 6.5–8.8% additional maximum electricity-saving behavior, but the behavior's price sensitivity was limited. Of the total amount of electricity saved during CPP hours, 50.4–60.9% was attributed to maximum-saving behavior.

1. Introduction

Electricity demand control for households during peak consumption hours is an important issue in energy management. Dynamically changing the unit electricity price is considered a key policy tool for addressing this issue. A central issue of the research regarding dynamic pricing is the estimation of price elasticity, or the change in demand due to a change in the electricity rate (e.g., Faruqui and George, 2002; Faruqui et al., 2009). There is also interest in the details of consumer responses to price changes. For example, the heterogeneity of responses among consumers has been investigated (e.g., Faruqui and George, 2005; Newsham and Bowker, 2010). Further research in this area is necessary, because it helps policymakers identify the most responsive target population and, thus, design more effective mechanisms of implementing dynamic pricing (Flaim et al., 2013).

This study investigates household responses to critical peak pricing (CPP). According to the Federal Energy Regulatory Commission (2012), CPP is defined as a "rate and/or price structure designed to encourage reduced consumption during periods of high wholesale market prices or system contingencies by imposing a pre-specified high rate or price for a limited number of days or hours." We, in particular, shed light on households' maximum electricity-saving behavior (hereafter, maximum saving behavior). This behavior means that the household turns off all manually controllable electric devices in the house. A household that practices maximum saving behavior in response to a modestly high CPP rate cannot reduce electricity consumption any further in response to even higher CPP rates. In this case, policymakers must find other households to target if additional demand reduction is required during peak hours. Therefore, information about the occurrence of maximum-saving behavior during CPP is useful.

The household sample used in this study responded to CPP by manually controlling their electronic devices. Manual control of electric devices, such as turning off a television or air conditioning, is discretionary. Therefore, as Herter and Wayland (2010) remarked, "one can imagine that market quickly becomes inelastic as all discretionary end-use loads are curtailed in response to CPP prices." In theory, households can automatically respond to CPP by having installed an appropriate energy-controlling device such as a home energy management system. There is some evidence that

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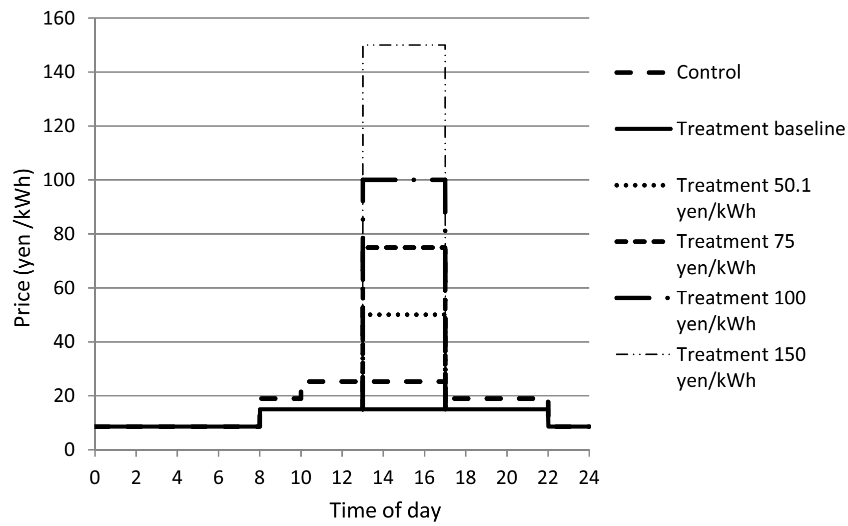

Fig. 1. Electricity price schedule.

such automatic control can reduce electricity consumption more effectively than does manual control (Newsham and Bowker, 2010). At present, however, automatic controlling devices are somewhat uncommon, and many studies of dynamic pricing have recorded the results from manual control (Hu et al., 2015)[1]. Thus, information on manually controlled responses is necessary for improving the current demand-control policy.

Typical maximum-saving behavior is leaving the home during CPP hours. Kii et al. (2014) conducted an Internet research panel survey of people in the Kinki area of Japan during February and March 2012 regarding such decisions. They asked hypothetical questions regarding electricity price changes during the summer and winter. They found that during CPP hours, the share of households absent from their homes increased when the hypothetical electricity price increased. The rate of increase in absenteeism declined as the electricity price reached more than six times the baseline price, suggesting some households face increasing difficulty in leaving their houses. However, whether hypothetical questions can accurately predict behavior is challenged within the environmental economics literature (Green and Tunstall, 1999; Louviere et al., 2000). Therefore, we investigate household decisions based on actual data on electricity consumption during a CPP experiment conducted in the Higashida area of the Kitakyushu Smart Community Creation Project in Japan.

The literature on maximum-saving behavior is limited. This article, based on the case study, provides the following three major results:

- Effects of CPP prices on maximum-saving behavior,
- Share of electricity saved during CPP hours attributable to maximum-saving behavior, and
- Household and housing attributes related to maximum-saving behavior.

[1] The time cost for consumers to checking the current electricity price, from designated information sources, may contribute to reducing electricity-saving responses, but this cost is considered small and, therefore, ignorable (Wolak, 2011).

2. Methodology

An experiment of randomized controlled trials of electricity demand control was conducted in the households in the Higashida area of the City of Kitakyushu, an area of about 120 hectares. According to the project introduction by The Research Association of Kitakyushu Smart Community Project, “About 900 residents, 6000 (daily commuters) workers and 70 companies or organizations are located in this area, which receives about 1 million visitors annually.” In 2012, a total of 180 households in one apartment complex agreed to participate in the experiment. At the time of the experiment, the summer of 2013, 176 households remained in the panel. Households were randomly assigned to either a treatment group or a control group. This experiment design was done by Takanori Ida of Kyoto University and his colleagues (Ida et al., 2013). The treatment group was subjected to CPP between June and September of 2013[2]. The baseline price schedule for the treatment group was a time-of-use (TOU) style. The price was 15 yen per kWh during 8:00–22:00 (peak hours) and 8.58 yen per kWh otherwise. Even higher CPP prices were charged between 13:00 and 17:00 on specified weekdays: 50.1 yen per kWh, 75 yen per kWh, 100 yen per kWh, and 150 yen per kWh. For the duration of the experiment, on days when the temperature was expected to exceed 30 °C, one of the four higher CPP prices was randomly chosen and charged to the households in the treatment group. The households in the treatment group were notified of the designated CPP price on the evening prior to each CPP event. For households in the control group, the electricity price was fixed at 25.29 yen per kWh during 10:00–17:00, 8.58 yen per kWh during 22:00–8:00, and 19.01 yen per kWh otherwise. The data obtained from the experiments are the electricity consumption of each household, measured in 30-min intervals, and attributes of the housing and households. Fig. 1 shows the electricity price schedules.

[2] This CPP experiment was conducted during 2012–2014. For the purposes of this article, we use the data collected during 2013, because that year produced the most reliable data. A nationwide campaign for electricity saving during 2012, in response to a power shortage after the 2011 nuclear disaster in Fukushima, may have affected the behavior of our respondents. Results from both a treatment group and a control group are required for the analysis, but the 2014 experiment did not organize a control group. Therefore, 2012 and 2014 data are less reliable than 2013 data.