The effects of a national energy saving urge on residential electricity consumption

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1 Introduction

For electrical grid system operators, the ultimate goal is to run their system stably. A recent trend toward incorporating renewable sources of electricity into the grid system magnifies the importance of the fundamental goal because of the eco-friendly energy sources' intermittency stemming from their temporal and weather dependency. Higher volatility in electricity demand due to increasing unusual weather events (e.g., cold and heat waves) in the current climate emergency also intensifies the operators' difficulty in the stable operation of the grid system.

Eastern Japan was expecting an electricity shortage between March 22 and 23 mainly for two reasons: 1) high electricity demand due to unusually low temperatures; and 2) low electricity supply caused by power plant shutdowns for earthquake-inducing maintenance. To avoid blackouts, the Japanese government issued the first-ever warnings in a row from March 21 to 23, calling on an electricity consumption reduction in households and companies within the service areas of Tokyo Electric Power Company (TEPCO) and Tohoku Electric Power Company.

In this paper, we examine the impact of government warnings of blackouts on household electricity consumption to understand how households adjusted their consumption behavior as a reaction to the warnings. In our empirical analysis, focusing on residential consumers, we estimate not only the aggregate change in residential electricity consumption but also their dynamic responses to the warnings over time.

2 Research Design and Data

We exploit a geographic boundary of electric utility companies' service areas for identification. The Fuji River, which runs through Shizuoka Prefecture, determines the service areas of TEPCO and Chubu Electric Power Company (Figure 1). Because the government warnings aimed to reduce the demand for electricity in areas served by TEPCO, it is intuitive that the river naturally determines the treatment status. And it is unlikely that households on each side of the river show significantly different patterns of electricity consumption. Therefore, it is reasonable to suppose that the only difference between the two groups of households is whether or not they were the target group that used TEPCO-supplying electricity.

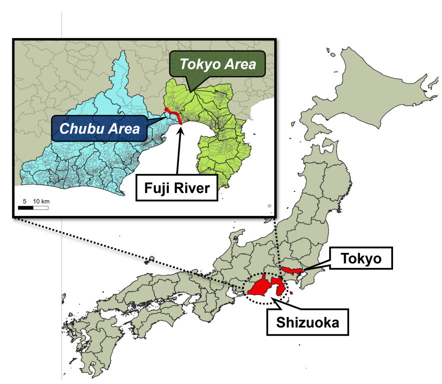

Figure 1: Identification

For our empirical analysis, we utilize hourly meter reads from 737 households in Shizuoka Prefecture, whose distance from the river is less than 20 km. In addition, using the zip code of each household in our sample, we collect weather data, including temperatures, from the closest weather station and exploit it in our analysis.

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3 Preliminary Results

We first estimate the average treatment effects by the two-way fixed effects difference in difference specification. Outcome in this estimation is hourly electricity consumption $e_{i,t}$ for household i in time period t. Let $D_{i,t}$ denote a binary variable that is equal to 1 if households live in the Tokyo area and if t is on March 22 or March 23. We specify the estimation model as follows:

$$\ln(e_{i,t}) = \tau D_{i,t} + \gamma X_{i,t} + \alpha_i + \delta_t + \varepsilon_{i,t}, \tag{1}$$

where $X_{i,t}$ is the vector of household and weather variables, α_i is household fixed effects, and $\varepsilon_{i,t}$ is a mean-zero unobservable. The coefficient τ captures the average treatment effects. The estimation results show that on average, the urge has the limited effects on household electricity consumption. The estimate is -0.2% and statistically indistinguishable from zero.

We next estimate the dynamic treatment effects in an event-study framework to consider households' dynamic responses. We consider the following two-way fixed effects specification:

$$\ln(e_{i,t}) = \sum_{k \neq -1} \tau_k \mathbb{1}[t = k] + \gamma X_{i,t} + \alpha_i + \delta_t + \varepsilon_{i,t}, \tag{2}$$

where $t = 0$ corresponds to the first urge issued at 8 pm on March 21, which was a precautionary measure to save electricity the next day. We aggregate the hourly data at the 4-hour interval for the ease of interpretation. The results are summarized in Figure 2. The estimates show that households reduce electricity consumption by around 7% immediately after the minister's press conference at 2:45 pm on March 22 (the third vertical line). However, we find null results in the other time slots, including the slots after the second warning at 11:30 am on March 22 (the second vertical line) and third warning at 11 pm on March 22 (the fourth vertical line). We also fine no increase after the warning was lifted (the fifth vertical line).

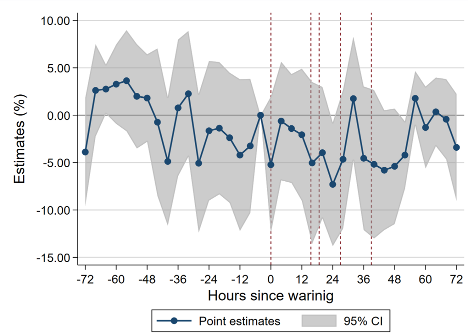

Figure 2: Estimation Results

4 Conclusion

Using hourly data on household electricity consumption and exploiting the geographic boundary of utilities' service areas, we estimate the causal effects of the government's electricity-saving urge on residential electricity consumption in target areas. We find no meaningful effect on average, but a marginal reduction immediately after the minister's press conference. These results could highlight the importance of finding effective ways to provide targeting individuals with information stimulating desired behavioral changes.

For further analysis, we will measure the gap between the actual and predicted electricity consumption at household level, and then identify the heterogeneity in household responses to the warnings across household characteristics (e.g., the correlation between households' average electricity consumption and the resulting reduction in electricity consumption) and regions (e.g., the difference in response to the warnings between prefectures relevant to the risk of blackouts and prefectures irrelevant to it).