The Impacts of Special Environmental Events on Electricity-Saving Behaviors: Evidence from High-frequency Smart Meter Data of Residential and Non-residential Consumers

Xingchi Shen, School of Public Policy, University of Maryland College Park, xcshen@umd.edu
Yueming Qiu, School of Public Policy, University of Maryland College Park, yqiu16@umd.edu
Ling Luo, State Grid Shanghai Electric Power Research Institute of China, luol@sh.sgcc.com.cn
Xiaohao Zheng, Jiangsu Trans Universe Power Co. Ltd of China, zhengxiaohao@jstue.com

Overview

Academics and policymakers are increasingly interested in using "nudges" – such as information provision, social comparisons, and persuasion (Allcott, 2017; Hansen and Jespersen, 2013) – to alter consumer behaviors. Nudges are typically inexpensive compared to price-based approaches. For example, in 2019 Shanghai Development and Reform Commission of China required government institutions at various levels to organize publicity campaigns on the day of special environmental events to improve citizens' environmental protection and energy conservation awareness. This paper aims to investigate the impacts of special environmental events on consumers' electricity consumption behaviors. Specifically, we examine three popular events in China and around the world: Earth Hour, World Environment Day, and Chinese National Energy-Saving Publicity Week.

A growing list of studies provides evidence that nudges can change human behaviors, in the context of charitable giving (e.g. Bartke et al., 2017), exercise (e.g. Woodend et al., 2015), food choice (e.g. Stämpfli et al. 2017), and energy conservation (e.g. Allcott and Rogers, 2014). There are also debates about the effectiveness of nudges (e.g. Rayner and Lang, 2017). Our study provides the first empirical evidence of the effect of the special environmental events on both residential and non-residential consumers and also explores the mechanisms behind the effect.

This paper has four main research objectives. Firstly, we estimate the effect of the special environmental events on electricity consumption behaviors. Secondly, we estimate the share of commercial users who significantly reduced electricity usage under the influence of the events. Thirdly, we investigate the intraday time-based heterogeneity of treatment effects. Lastly, we analyze the mechanisms behind the effect in order to explain the heterogeneity of the estimated effects of different events.

Methods

(1) Treatment effect estimation based on econometric analysis: In order to construct our econometric model to estimate the effect of the events on electricity consumption, we make use of two datasets on commercial & residential individual electricity usage and hourly weather. (a) Individual electricity use data. We obtained the individual commercial electricity use data (at 15 minutes' level) and the individual residential electricity use data (at daily level) from The State Grid Corporation (SGC). This forms a panel data that covers 684 commercial consumers and 1780 residential consumers randomly drawn from all the smart-metered consumers in Pudong, Shanghai over an about one-year period from 01/01/2017 to 02/28/2018. (b) Hourly weather data. We obtain the weather data from a local weather station in Putong, Shanghai from the National Meteorological Information Center of China. The hourly weather data include the highest pressure (hPa), maximum wind speed (m/s), hourly average temperature (℃), relative humidity (%), and hourly precipitation (mm).

We adopt a two-step local linear method to control for confounding factors. In the first stage, we fit a panel regression model using global data to estimate the effect of weather, seasonality, day-of-week, and time-invariant consumer-specific factors on electricity consumption. Then we save the residuals which have excluded the influences of these confounding factors. In the second stage, we regress the residuals on the special environmental event variables within a narrow time bandwidth. The high-frequency data enables us to obtain enough observations within a narrow time bandwidth to further eliminate the influence of other confounding factors.

Stage 1:

$$kWh_{it} = \beta_0 + \sum \beta_{1j} f_j(Tempeture_t) + \beta_2 AirPressure_t + \beta_3 Humidity_t + \beta_4 WindSpeed_t + \beta_5 Precipitation_t + \text{Multiple time fixed effects} + Individual\ fixed\ effects + Rsdisuals_{it}$$

Stage 2:

$$Residuals_{it} = \beta_0 + \beta_1 \cdot Event\ Dummy + \varepsilon_{it}$$

(2) Mechanism analysis: In order to conduct our mechanism analysis, we make use of two datasets on policy documents and social media. (a) Policy document data. We sort out 10 Chinese policy documents which are related to the special environmental events. (b) Social media data. We web-scraped 19,182 tweets from Weibo including the key words of "Earth Hour", "World Environment Day", "Energy Saving Publicity Week", and "Energy Saving" from Weibo users located in Shanghai published during the time around the events (from 03-15-2017 to 06-26-2017). We reviewed all the related policy documents and web-scraped social media tweets, and summarized all the activities related to the events.

Results

We find that the World Environment Day and the National Energy Saving Publicity Week caused commercial users to reduce their electricity consumption by 0.3 kWh/hour and 0.4 kWh/hour in the short run, around 4% and 5% reduction, respectively. However, the impacts caused by the two events decayed rapidly once the events ended, and the influence sphere of the two events is also limited. We find an obvious "rebound effect" on electricity consumption for both residential and commercial users after the Earth Hour. Most activities adopted (as evidenced by the tweets and policy documents) during the first two events were related to actual knowledge and useful skills of energy saving, while most activities during the Earth Hour were symbolic behaviors like turning off lights and running. We also explore a possible mechanism to explain the "rebound effect" of Earth Hour. Turning off lights from 20:00 to 21:00 caused employees to be unable to work at that time given a fact that a considerable part of employees has to work until 21:00 in Shanghai. We provide simple evidence by showing that there is a significant increase in electricity consumption during off-hours on the first day after the day of Earth Hour, which demonstrates that more employees might work overtime on that day. Moreover, we find consumers tend to save electricity during peak times.

Conclusions

Our results are valuable for policy makers. The Earth Hour event should adopt more activities that are directly related to the knowledge and skills of environmental protection and energy saving, although its inimitable symbolic activity caused great public attention. Moreover, more attention should be paid to residential users and valley times.

Policymakers and environmental communities should continue to support the special environmental events. Although the short-run energy-saving effect caused by the events decayed rapidly, we should acknowledge that short-run behavior change reflects a change in people's awareness. Only the change in awareness can determine people's long-run behavior. A short-run change is the beginning of a long-run change. The government should continue organizing special environmental events to improve people's energy conservation and environmental protection awareness.

Selected References

Allcott, H. (2011). Social norms and energy conservation. Journal of Public Economics, 95(9-10), 1082-1095.

Allcott, H., & Rogers, T. (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. American Economic Review, 104(10), 3003-37.

Hausman, C., & Rapson, D. S. (2018). Regression discontinuity in time: Considerations for empirical applications. Annual Review of Resource Economics, 10, 533-552.