Electricity demand response in Japan: Experimental evidence from a residential photovoltaic power-generation system

Takanori Ida[1]
Graduate School of Economics, Kyoto University, Japan
Kayo Murakami[2]
Chikushi Jogakuen University, Japan
Makoto Tanaka[3]
National Graduate Institute for Policy Studies, Japan

Executive Summary

In recent years, renewable energy and demand-side resources have been key issues as Japan attempts to tackle the dilemma of securing its energy supply without further increasing its environmental footprint; these challenges have become particularly acute after the energy crisis. The Japanese government seeks to double the share of renewable energy in national consumption to reach 24% in 2030 while increasing nuclear power to about 20%, still below the pre-Fukushima level. Although there is little scope for increasing hydroelectric power (9%) in Japan, the government envisages the share of solar photovoltaic (PV) power rising to 7% in 2030; 5% is expected to come from biomass, 2% from wind power, and 1% from geothermal power. Specifically, PV power generation capacity is expected to increase from 13GW in 2013 to 64GW in 2030, a fivefold increase.

Considering demand-side management, the Japanese government expects 17% energy savings compared to the reference case. One key target is to improve efficiency in residential energy management. Most Japanese residential consumers are

1 Yoshida, Sakyo-ku, Kyoto 606-8501, Japan. E-mail: ida@econ.kyoto-u.ac.jp

2 2-12-1 Ishizaga, Dazaifu City, Fukuoka 818-0192, Japan. E-mail: murakamikayo@gmail.com

3 7-22-1 Roppongi, Minato-ku, Tokyo 106-8677, Japan. E-mail: mtanaka@grips.ac.jp

currently charged flat-rate tariffs for electricity using conventional analog electric meters, but the government plans to install digital smart meters in all households (about 50 million) in Japan by 2024. Along with smart meters and possibly home energy management system (HEMS), dynamic pricing schemes, such as critical peak pricing (CPP), are expected to induce residential consumers to use electricity more efficiently.

The past decade has seen a growing body of literature reporting on field experiments with electricity demand response; we will briefly survey these in the next section, with a focus on the Japanese case. However, we are not aware of any study documenting a large-scale field experiment investigating demand response among households with rooftop PV generation systems. A household with a PV generation system can be regarded as a "prosumer" (i.e., a combination of a producer and a consumer). A PV prosumer can generate electricity using a solar panel and sell it to power companies while also consuming electricity in the home. This prosumer can be a net buyer or seller of electricity, depending on weather conditions and the solar panel's capacity. As discussed above, significant increases in both PV generation and demand-side resources are expected by 2030 in Japan. Given this, it is useful to understand the impact of dynamic pricing on PV prosumers' behavior.

In this paper, we use a randomized controlled trial (RCT) to examine the effect of dynamic pricing, specifically CPP, when applied to households with rooftop PV generation systems. In 2013, a randomized field experiment with about 1,200 households was conducted in Yokohama City of Kanagawa prefecture (near Tokyo), but the present paper is the first to use a large-scale field experiment to investigate the effectiveness of dynamic pricing among households with PV generation capabilities. The study thus sheds new light on how PV prosumers react to price changes. Furthermore, our field experiment utilized an RCT to divide households into control and treatment groups. Meanwhile, the energy crisis led to substantial demand-reduction measures, which affected both groups. As such, our field experiment should have adequately measured the effectiveness of CPP.