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The effect of demand response on purchase intention of distributed generation: Evidence from Japan

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HIGHLIGHTS

- Studies the effect of demand response on purchase intention of PV.
- Uses originally collected Internet Japanese household survey data in 2015.
- Finds that time-of-use (TOU) plan has positive effect on PV purchase intentions.
- Calculates latent TOU impacts on PV installations and emissions reduction targets.
- Discusses policy recommendations to increase participations in TOU programs.

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ABSTRACT

Participation in demand response (DR) may affect a consumer's electric consumption pattern through consumption load curtailment, a shift in the consumption timing or increasing the utilization of distributed generation (DG). This paper attempts to provide empirical evidence of DR's effect on DG adoption by household consumers. By using the original Internet survey data of 5442 household respondents in Japan conducted in January 2015, we focus on the effect of the time-of-use (TOU) tariff on the purchasing intention of photovoltaic systems (PV). The empirical results show the following: 1) current TOU plan users have stronger PV purchase intentions than the other plan users, 2) respondents who are familiar with the DR program have relatively higher purchase intentions compared with their counterparts, and 3) when the respondents are requested to assume participation in the virtual TOU plan designed for the survey, which resembles plans currently available through major companies, 1.2% of the households have decided to purchase PV. In addition, we provide calculations of TOU's impacts on the official PV adoption and emissions reduction targets, and discuss policy recommendations to increase recognitions and participations in TOU programs.

1. Introduction

Demand response (DR) programs alter the patterns of electric consumption through both a change in electricity price and incentive payment designs and various DR programs are widely applied as a major tool of demand-side management in both the industrial and residential sectors to reduce the peak demand of electricity. Peak demand reduction can increase electricity reliability, induce energy conservation by increasing end-use efficiency of energy consumption and reduce costs for electric utilities and consumers by decreasing the generation of peak time electricity and decreasing costly infrastructure investments (Kim and Shcherbakova, 2011; Sezgen et al., 2007). Participation in DR may affect the electric consumption patterns by various means, such as the reduction of energy consumption through load curtailment or a shift in the timing of energy consumption and an increase in the use of on-site standby-generated energy, which limits the dependence on the main grid electricity (Siano, 2014). Previous experimental studies have focused on the effect of DR on electric consumption patterns, particularly in reducing and shifting peak demand (Bartusch et al., 2011; Thorsnes et al., 2012; see also Faruqui and Sergici, 2010). However, minimal effort has been made to understand the effect of DR on the utilization of on-site generation among households. Thus, in this paper, we quantitatively analyze the effect of DR on consumers' incentive to install on-site generation, also known as distributed generation (DG), using an original survey of Japanese residential consumers. The diffusion of DG contributes to emission reduction and improves the diversification

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of the energy supply while reducing the reliance on energy imports (Allan et al., 2015). Furthermore, because DR and DG are important factors of a smart grid (Siano, 2014), a better understanding of their relation would lead to more effective smart grid applications in the future. To analyze the effect of DR on DG adoption, we focus on the effect of the time-of-use (TOU) tariff on the purchase intention of photovoltaic systems (PV). In the TOU plan, the electricity price varies during the day; in addition, utility companies have been increasing the opportunity for residential consumers to participate in TOU plans (Kim and Shcherbakova, 2011). In Japan, major electric power companies offer a TOU plan, although it is not highly advertised, and consumers with a TOU plan are in the minority. We also target PV, which is one of the most popular DG systems among households. We estimate the effect of the TOU plan on the purchase intention of PV using data from an original Internet survey conducted in January 2015. Previous studies do not provide strong evidence to link respondents' claimed purchase intention and actual purchase behavior (Arts et al., 2011; Heberlein, 2012). Although we agree that the most accurate results and future predictions would be obtained if we were able to collect a large enough data on actual changes in PV purchase behaviors caused by implemented experimental TOU plans, such data collection is extremely difficult and costly, as we would have to recruit suppliers and consumers to cooperate with such experiment. However, there is some evidence that may support the link for PV purchase intention and actual purchasing behavior. Morwitz et al. (2007) found that purchase intentions are comparatively positively correlated with actual purchases for existing products than new products and for durable goods than non-durable goods. We study PV, which is already available in the market and can also safely be considered a durable good. Thus, although our results are based on the purchase intentions of consumers and not on actual purchasing behavior, it may still shed the light on the relationship between DR and DG and provide useful policy implications. We find the following results: 1) current TOU plan users have stronger PV purchase intentions than other plan users; 2) familiarity with the DR program increases PV purchase intention; and 3) when the respondents are asked to assume participation in the author-designed TOU plan, which is consistent with the plans currently available through major companies, 1.2% of the households have claimed that they would purchase PV. The remainder of this paper is structured as follows. Section 2 describes the situation of DR programs and PV in Japan. Section 3 presents the literature review regarding the effect of DR on electricity consumption behaviors and the purchasing factors of PV. Section 4 provides the details of the data and the variables used in the estimation models. Section 5 provides the descriptive statistics. Section 6 presents the empirical models and estimation results. Section 7 provides a discussion, and Section 8 concludes with policy recommendations.

2. TOU and PV in Japan

The power supply system in the post-World War II era in Japan has been regulated by a regional monopoly. In 1995, The Electric Utility Industry Law in Japan was revised, resulting in the gradual deregulation of electricity market. The revised regulation also allowed electric power companies to provide various electricity plans to promote load-leveling (Ohira, 2007). For example, Tokyo Electric Power Company provides TOU plans, which differ in the time frames in which cheaper prices are applied (from 1 a.m. to 9 a.m., from 9 p.m. to 5 a.m. and from 9 p.m. to 9 a.m.).[1] These TOU plans are recommended for households who use relatively small amount of electricity during the daytime hours. With some distinctions in prices and time frames in which energy charges vary, other main electric power companies offer TOU plans as well as seasonal pricing plans.

Although TOU plans are technically available for all households, according to the Agency for Natural Resources and Energy in Japan, the share of household contracts with non-fixed price plans accounts for approximately 7.3% of all contracts held by the 10 main regional electric power companies in 2012.[2] The government report commented that the time-varying pricing system "has not fully taken hold in the general consumer market". To prompt the participation in DR programs, the government is making efforts to place smart meters in all households by the early 2020s.[3] The smart meter allows us to measure the effect of DR program in households and helps raise consumers' awareness about their electric usage patterns (Ito, 2012). According to the results of a survey conducted by Goto and Saegusa (2012), one of the main reasons for customers not adopting a TOU plan is the lack of information about their own electric consumption pattern; the authors suggest that smart meters would help provide information to household users that would induce the popularization of TOU plans in Japan.

In addition, Japanese government will deregulate retailing of electric power in the residential sector by April 2016. Through these policies, it is expected that electricity will be priced in a more effective and diverse way, thus making it possible to control electricity demand during peak hours to a significant degree.[4] In short, we expect that DR would be more recognized and diffused widely in the future in Japan. This means that the evaluation of the potential of DR is increasingly significant in terms of policy implications.

Moreover, the current rate of residential PV installation is approximately 3.2% in 2013,[5] and currently, approximately 1.6 million households in Japan have PV installed. However, the government prediction is to increase the number of residential PV installation to 7.4 million households by 2030.[6] Thus, there is a gap between the present situation and the goal. Further, the evaluations of the potential of DR focus on peak reduction or peak shift behaviors even in Japan (e.g., Yamaguchi and Takayama, 2011),[7] which means that there is a lack of perspective connecting DR and usage of PV, as explained in Section 1. Our study focuses on the effect of DR on purchase intention of PV, which helps evaluate the potential of DR and estimate how large the effect would be if we assume that DR were widely diffused in Japan. It may contribute to the discussion about the potential of DR and the penetration of DG and provide some policy implications.

[1] Refer to the website of the Tokyo Electric Power Company.

(*footnote continued*)
⟨http://www.tepco.co.jp/en/index-e.html⟩ accessed on 18/01/2016.

[2] Refer to the report by the Agency for Natural Resources and Energy in Japan. ⟨http://www.enecho.meti.go.jp/category/electricity_and_gas/electric/summary/trend/pdf/1.pdf⟩ accessed on 18/01/2016.

[3] Refer to the Basic Energy Plan in 2014 reported by the Agency for Natural Resources and Energy in Japan. ⟨http://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/4th_strategic_energy_plan.pdf⟩ accessed on 18/01/2016.

[4] Refer to the Basic Energy Plan in 2014 reported by the Agency for Natural Resources and Energy in Japan. ⟨http://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/4th_strategic_energy_plan.pdf⟩ accessed on 18/01/2016.

[5] Refer to the report by the Statistic Bureau in Japan at ⟨http://www.stat.go.jp/info/wadai/pdf/018.pdf⟩, accessed on 18/01/2016.

[6] Refer to the report by the Ministry of the Environment in Japan at ⟨https://www.env.go.jp/earth/report/h26-01/chpt04.pdf⟩, accessed on 18/01/2016.

[7] See also the report by the Climate Change Policy Headquarters of Yokohama city in Japan. ⟨http://www.city.yokohama.lg.jp/ondan/press/h25/131023press.pdf⟩ accessed on 18/01/2016.