Load Shifting Behavior Under Dynamic Electricity Pricing and The Role of Information Feedback

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Overview

Recent retail market deregulation and ICT-based technological innovation brings new opportunities to dynamic electricity pricing, which is regarded as a promising instrument to manage peak-time electricity demand and to promote allocative efficiency in the retail market. The residential sector in particular has received much attention not only for its relatively economically inefficient use of electricity, but also for its increasing share of national energy system. In the U.S., nearly half of residential consumers are reported to have already installed smart-meters by the end of 2016 (EIA, 2017) and majority of utilities operate any type of residential dynamic pricing program in the form of default or opt-in rate (Faruqui, Hledik, & Lessem, 2014). In attempts to promote the adoption of residential dynamic pricing, utilities have conducted a large number of pricing pilots to test consumer responsiveness and program effectiveness.

Dynamic pricing programs are often assessed based on the extent to which peak load is reduced—*load foregoing*— or shifted to off-peak hours—*load shifting*—in response to price signals. Among the two behavioral responses, although not clearly distinguishable, promoting load shifting instead of simple load foregoing could help consumers continue to enjoy energy services they forego during the peak in different time of the day and thereby bear lower, or even negative costs of adopting the programs. Thus, load shifting, if successfully induced, can not only promote the political acceptance of residential dynamic pricing programs but may also encourage them to alter energy consumption patterns even more aggressively. Previous studies report that households indeed repond to dynamic pricing, but they mostly do so by cutting electricity usage in peak hours with very limited load shifting, often resulting in a net reduction of overall electricity usage (Allcott, 2009; Faruqui, Sergici, & Akaba, 2013; Jessoe & Rapson, 2014).

To the best of our knowledge, little is known about how load shifting behaviour can be instigated and what it would result under residential dynamic pricing. We conducted a controlled field experiment for 320 Korean residential electricity consumers to test whether and how the provision of load-shifting relevant information influences their electricity consumption decisions in a dynamic pricing setting. Specifically, our load-shifting information consists of two parts, alternatives for load-shifting choices and their expected payoffs, which we hypothesize would help complete the consumers' decision basis (Howard, 1988).

There are two interrelated reasons that residential consumers under dynamic pricing may not engage in load shifting behaviour. First, the consumers may not be aware of any alternative, load-shifting way of energy consumption probably due to the absence of relevant information, or they may recognize the load-shifting option but do not know its exact payoffs to motivate such behaviour. These in combination are expected to result decision ambiguity, rendering potentially attractive load shifting options go unexercised. Second, more generally, the complex nature of decision making with relatively small financial stakes makes the consumers behave differently from what the utility-based rational choice theory might predict (Frederiks et al., 2015). It is well known that although electricity consumption involves many small decisions, their precise costs are hard to identify as they are revealed ex-post and intermittently (Gilbert & Zivin, 2014), and not salient either as their sum only account for 2~3% of household spending in general. As a consequence, residential consumers are likely to make only boundedly rational decisions. The decision making may follow so-called 'satisficing heuristics' (Simon, 1997), such as load foregoing or inefficient energy conservation, which would constitute a default set of choices guaranteeing known payoffs, rather than bothering to explore other alternatives that might improve their payoffs further.

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Acknowledgement: This work has been supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government (MSIP) (No. 2017R1A2B4002170) and also by the Korean Ministry of Science, ICT, and Future Planning through the Graduate School of Green Growth at KAIST College of Business.

Experimental Design

Our experiment employs a panel of 320 households recruited to receive participation incentives and smart meter installation in return for participating "Smart Energy Campaign" during the winter of 2017. The participants were randomly assigned into three groups varying in the types of electricity prices and SMS-based information feedbacks: Control (n=100), Treat1 (n=110, peak reminder only), and Treat2 (n=110, peak reminder plus load-shifting information). Control group remained under the current flat rate and is not exposed to any intervention. Treat1 and Treat2 groups were all subjected to a de facto TOU tariff characterized by a peak-time rate of KRW700 (=$0.65) on top of the flat rate only during 5-8 pm on weekdays. While Treat1 group received peak-time reminder everyday and weekly reports on individual performance, Treat2 group received additional load-shifting information about choice alternatives and their expected individualized payoffs everyday. The TOU tariff has been operationalized as follows: each participants in Treat1 and Treat2 was given with the initial incentive balance of KRW50,000 (=$46.7) with the start of the experiment; and the initial balance decreased at the rate of KRW700 (=$0.65) per each kWh usage in peak hours until it reaches the minimum balance of KRW10,000 (=$9.3) under which no futher deduction was made. Control group received KRW20,000 (=$18.7) as a participation incentive at the end of the experiment.

Results

We find Treat1 group reduced its peak usage on average by 3.4% and Treat2 by 4.8% (in both cases, p-value<0.001), which inicates households given with load shifting information were more responsive to the increased rate than those without. In terms of daily usage, while Treat1 reduced daily usage by approximately 2.3% compared to its pre-experiment usage, Treat2 exhibited no statistically significant change. The implication is that load-shifting relevant information indeed promoted the consumers to curtail their peak-time consumption even further by inducing meaningful load shifting from peak to off-peak hours.

Several other findings are worth to note. First, the two treatment groups exhibited different usage pattern over the course of the pricing experiment. For Treat1, the peak-time load impact gradually increased over the weeks, which points to the exsistence of possible learning effect for the households in dealing with the dynamic pricing. Treat2 group, however, exhibited relatively large and constant peak-time reduction from the first stage of the experiment. Second, the two groups also differed in daily load pattern, in which Treat2 group responded more to the dynamic pricing than Treat1 in most of hours of the day with the former exhibiting particularly pronounced increase in electricity consumption in early morning period (5~7 AM). That is, Treat2 tended to exercise more distant, aggressive load-shifting options which would have gone unnoticed without the load-shifting information. In summary, our experiment suggests that the provision of information that helps complete the decision basis of households can promote them to undertake more instantaneous and aggressive actions under dynamic pricing than the case without.

Conclusions and Implications

We examined the effect on price response of the provision of information on load-shifting alternatives and their payoffs in a residential TOU setting. Unlike previous studies mainly on the performance of various pecuniary incentives or non-pecuniary interventions (e.g., information feedbacks), our controlled field experiment systematically investigated the role that information on decision alternatives might play in inducing the change in energy behaviour and the process by the change occurs. Our study provides an indirect evidence that residential electricity consumers may remain boundedly rational at least for some period of time in the search for individually efficient price response, unless more concrete, decision-relevant information is provided. The implication is that utility regulators implementing a new dynamic pricing plan are better positioned to ensure that load-shifting information is clearly and effectively communicated, so that the households may adapt to and respond to the plan more efficiently, which may also eventually improve the program's performance.

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