Household Preference for Electricity Service Plans: the Role of Enabling Technology and Risk Preference

Jaewoong Lee, KAIST College of Business, +82-10-3422-8606, jwlee86@business.kaist.ac.kr
Soyoung Yoo, KAIST College of Business, +010-6620-9039, jessyoo@business.kaist.ac.kr
Jiyong Eom, KAIST College of Business, +82-10-8612-1606, eomjiyong@business.kaist.ac.kr

Overview

As a price-based approach toward electricity demand response (DR), dynamic pricing (DP) has been experimented at the pilot scale in several countries for residential and small commercial customers, not to mention its broader implementation for large commercial and industrial facilities. Given that residential customers are allowed to choose any from alternative DP plans, such as Peak Time Rebate (PTR), Time-of-Use (TOU), Critical Peak Pricing (CPP), and Real Time Pricing (RTP), or to remain with their existing ones, electricity service providers would have to run the risk of revenue loss or overrun (Borenstein, 2012) unless the customers' preference for the DP plans and their demand response are correctly identified in association with the enabling technologies. Another complication in revenue management emerges also from the enrolled customers provided with other types of services, such as (1) monetary information (e.g. current marginal price and expected monthly bill) or nonpecuniary information appealing to social norm (Allcott, 2011; Jessoe & Rapson, 2014) via advanced metering infrastructures (AMIs) and in-home displays (IHDs) and (2) automated load shifting enabled by the programmable and controllable thermostat (PCT).

We notice that surprisingly little is known about the customers' preference for various DP plans and how the ongoing development and deployment of the enabling technologies might affect the residential adoption of those plans, although considerable investments in metering infrastructure has to be made by utilities or municipal governments in order to implement electricity demand response. Previous pricing pilot studies based on randomized controlled trial (RCT) have shown the peak reducing or shifting effect of the DP (Faruqui et al. 2013). Although only a small subset of the studies demonstrated that the presence of AMIs or IHDs can promote the consumers' price elasticities, the results remain inconclusive with regard to whose elasticities would increase, how long such demand response would be sustained (Allcott & Rogers, 2014), and whether the customers under the DP might be made better off with the enabling technologies. Such limitations may be attributable to the experimental setting in the RCT studies that the participants are forced into the same set of electricity services and/or enabling technology packages, without the opportunity of choosing from alternative service options being taken into account.

We instead have designed a discrete choice experiment (DCE) consisting of 17 situations of choosing from electricity service plans (ESP), each of which is a form of TOU tariff bundled with either of the two types of information service, AMI or PCT. The experiment was administered to about 2,000 Korean households via an online survey provider. The risk preference of the individual households as expressed by the constant relative risk aversion (CRRA) has also been identified through a series of comparison questions to address the potential source of heterogeneity regarding the adoption of a new product, which in this study is the enabling technology. Interestingly, our results indicate that the households given with AMIs or PCTs tend to adopt TOU tariffs featuring higher peak-to-off-peak ratio, although they on average are not willing to pay for the technologies *a priori*. Our major findings are twofold. First, considerable household heterogeneity exists regarding the preference for ESPs, which in some cases runs counter to our expectations. Second, the households' risk preference as well as other sociodemographic variables can explain a part of such heterogeneity, but not all.

Methods

The discrete choice experiments (DCEs) are commonly used in characterizing consumer preference for different product attributes in a discrete choice context—see, for example, Rebelt & Train (2000), Abdullah & Mariel (2010) and Huh et al. (2015) for cleaner and reliable electricity services, Tanaka et al. (2014) for EVs, Newell & Siikamaki (2014) for energy durables, and Neenan et al. (2015) for TOU and fixed bills. Each of our 17 experiments offers one outside option (current time-invariant tariff in Korea) *and* a subset of 34 alternative residential electricity service plans (ESP). The ESPs combine three TOU attributes (peak/off-peak rates and their durations) and one technology service attribute (usage and cost feedback by AMIs versus automatic load control by PCTs), the latter of which incurs different upfront costs for the households (Table 1).

Table 1. Attributes and levels of TOU structure and attendant technology services in ESP alternatives

ESP attributes	#Attributes	Levels				
Peak duration (in hours)	5	2 (morning/afternoon)		4 (afternoon)	6 (morning/afternoon)	
Off-peak price (KRW/kWh)*	3	110	90	70	-	-
Technology cost (KRW)	3	0	30,000	300,000	-	-

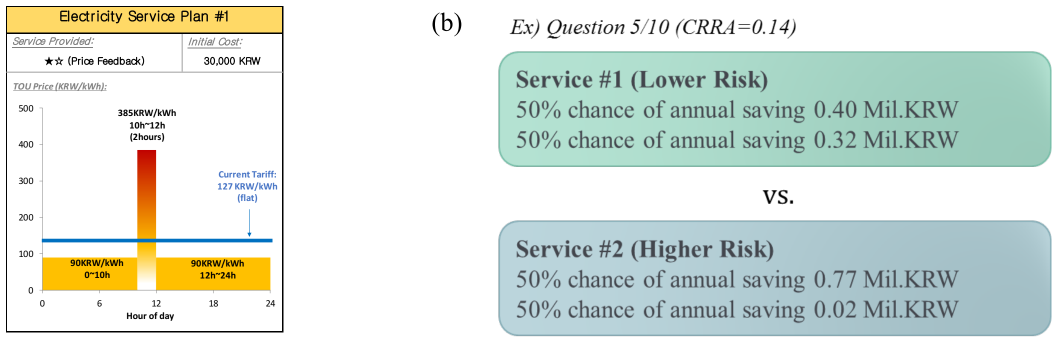
* The level of peak prices accounts for its peak duration and off-peak price level in the spirit of revenue neutrality.

The entire survey consists of three different parts: (1) the survey of residential and household characteristics, (2) DCE questions about ESPs, and (3) 10 questions to assess risk preference (CRRA). Regarding the second part, each of the participants (each either householder or housewive above 20s) were asked to answer all of 17 DCE questions (see Figure 1a for an example of ESP options). The last part provided the 10 binomial choice questions to estimate the CRRA, adapted from Holt & Laury (2002) and Qiu et al. (2014) (see Figure 1b for an example).

Figure 1. Examples of (a) energy service plan option and (b) risk preference (CRRA) question

(a)

(b)



To capture the heterogeneity in consumer preference, we used a mixed logit model capable of representing a range of willingness-to-pay (WTP) as a function of socio-demographic variables, following Newell & Siikamaki (2014):

$$U_{ij} = \lambda_i \left[Cost_{ij} + \gamma_i \frac{p_{Peak}}{p_{OP}} + \alpha_i d_{AMI} + \beta_i d_{PCT} + \eta_i X_j \right] + \varepsilon_{ij}$$

$$\lambda_i = \tilde{\lambda}_0 + \sum_{k=1}^{K} \tilde{\lambda}_k Z_{ik}, \quad \tilde{\lambda}_0 \sim LN^{-}(\mu_\lambda, \sigma_\lambda^2)$$

where U_{ij} is consumer i's utility obtained from subscribing ESP j, $Cost_{ij}$ is income-normalized upfront cost of enabling technology packaged in ESP j, p_{Peak}/p_{OP} is the peak-to-off-peak price ratio (≥ 1), d_{AMI} and d_{PCT} are dummy variables for the enabling technologies bundled, X_j are dummy variables representing peak-time duration (2, 4 or 6 hours) and its time zone (morning versus afternoon) of ESP j, and Z_{ik} is k th socio-demographic variable for consumer i $(k = 1, \ldots, K)$. Also, as a separate model, we tested interaction between the demeaned peak-to-off-peak price ratio and the technology dummies. We have conducted an econometric estimation using the Hierarchycal Bayes (HB) procedure to yield the estimates for the two types of individual-level coefficients: (1) the WTP of consumer i regarding a one unit increase in the peak-to-off-peak price ratio, γ_i and (2) the WTPs to the services provided by AMI and PCT, α_i and β_i, respectively.

Results

Our analysis indicates that the customers on average do not prefer to have the feature of technologies which incur private costs: only a 27.4% of the households are shown to have positive WTPs regarding AMI with nearly all of them presenting negative WTPs regarding PCT. Also, those with positive WTPs do not seek more risk than the others. However, the striking result is that the households on average are more willing to accept ESPs featuring higher peak-to-off-peak ratio if the technology services come along; 91.8% and 72.9% of the households exhibited positive estimates for interaction effect terms between peak-to-off-peak ratio and AMI or PCT, respectively. It was also found that risk preference comes into play to an extent: risk seekers are likely to be male and relatively affluent, exhibiting significantly higher preference for peak-to-off-peak ratio in the presence of enabling technology.

Conclusions

Our analysis based on a discrete choice experiment, which has been administered to 2,000 Korean households, demonstrates considerable heterogeneity regarding technology-enabled dynamic pricing plans. The results suggests that, although the households on average might not be willing to pay to AMI and PCT *a priori*, most of them can be made better off under electricity dynamic pricing (DP) when it comes with the enabling technologies. We suggest that utilities or energy service providers should be prepared to provide AMI or PCTs without initial upfront costs incurred to their consumers and deliver more dynamic tariff options, but not *vice versa*. In addition, given the sizeable financial risk currently perceived by the customers, pilot test programs can be implemented beforehand to reduce unnecessary concerns related to the adoption of enabling technologies that would in turn affect the preference for the energy service plans in a more desirable way. From the perspective of policy making, utilities or municipalities are better positioned to develop a data-based decision support system in their pursuit of electricity dynamic pricing which involves substantial fixed investments. More comprehensive analysis is underway, and the implications for consumer surplus and policy simulations will follow.