[*HOURLY PRICE ELASTICITIES OF HOUSEHOLD ELECTRICITY DEMAND USING HIGH-FREQUENCY METERING AND SURVEY DATA*]

[Minwoo Hyun, KAIST, +82-10-3360-6423, minwoo.hyun@kaist.ac.kr]
[Jiyong Eom, KAIST, +82-10-8612-1606, eomjiyong@kaist.ac.kr]

Overview

We explore the hourly electricity price response of Korean households under an increasing block rate, using high-frequency electricity usage data and extensive on-site surveys collected from a total of 1,177 households in February 2017. To our best knowledge, no previous studies examined hour-level price elasticities of electricity demand for residential customers. A discrete-continuous choice (DCC) model has been constructed to represent the households' decision making for electricity consumption in every hour over the course of the billing period, while addressing the possible price endogeneity issue inherent under the block pricing. Our results from a system of equations of hourly electricity demand show relatively low price elasticities at the hourly level compared to annual or monthly residential demand examined in previous literature. Our study also indicates that the households remain most price-responsive after working hours.

Methods

We begin by constructing a measure of expected marginal electricity price perceived by the households under the increasing block tariff, so as to obtain consistent estimates for price elasticities. The expected marginal price is calculated based on the average of each block's marginal price weighted by the logit choice probability of the households placed in the block over the course of the billing month. A seemingly unrelated regression (SUR) approach is then employed to estimate own price elasticities for each hour along with those for the other hours of the day to account for possible contemporaneous effect across error terms:

$$log(q_{idh}) = \alpha_h + \beta_h log(\bar{p}_{idh}) + \gamma_h hdh6_{idh} + \theta_h D_{weekend} + \zeta_h Z_i + \delta_h\, log(income_i) + \eta_h appliances_i + \varepsilon_{idh}$$

where q_{idh} is the consumption of electricity in hour h of household i with billing date d, $hdh6$ is the heating degree hours (six-hour moving average), and Z_i is for various building and household characteristics. In an attempt to identify the sources of price responsiveness, we also estimate the model while interacting the expected marginal price with various dummy variables including the household-level ownership of electric appliances.

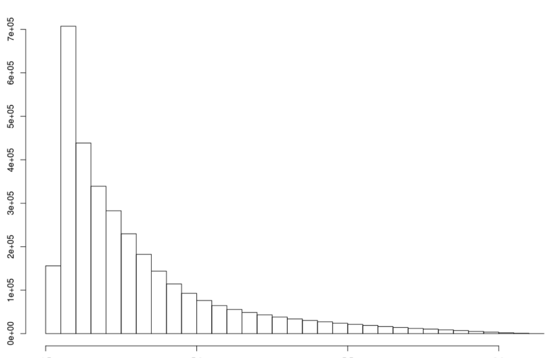

Figure 1: Histogram of Expected Marginal Price

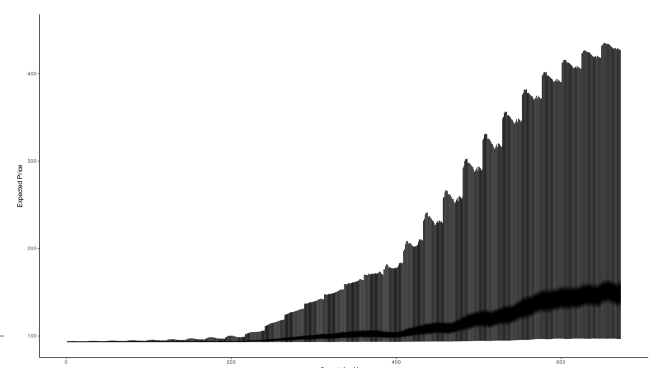

Figure 2: Expected Marginal Price vs. Cumulative Hours

Results

Our SUR estimation approach provides a rich set of robust results. It indicates that the hourly own price elasticity ranges from -0.03 to -0.11 in a statistically significant manner in all hours except daybreak and lunch hours. Note that the households exhibit greater price responsiveness during non-working hours, in particular before and after the typical commute time. Most of other covariates are consistent with our expectation: parameter estimates for weather variables (heating degree hours) remain positive and significant, and so does household income, building floor area, and the size of households. Our early results also indicate that the households modify their utilization of appliances depending upon their socioeconomic characteristics and hours of the day.

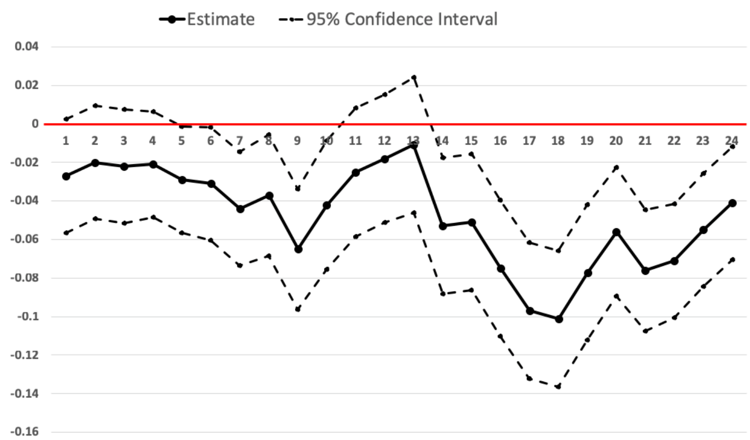

Figure 3: Within-Day Price Elasticities of Electricity

Conclusions

This study makes two major contributions to existing literature on the characterization of household electricity demand. It first sheds light on the sources of the households' price elasticities by leveraging their appliance ownership survey data and high-freqency metering data. The second contribution is the novel approach taken to identify hourly price elasticities, which employs the two-step discrete-continuous choice model with expected marginal price that the households perceive over the course of the billing period. Our hourly demand estimation shows that the households remain relatively price-inelastic under the current increasing block tariff with the most pronounced response shown in the typical winter peak hours, which suggests opportunities for price-based load management. Our future work would investigate the impacts that appliance ownership has on hourly price elasticitity, suggesting implications for the development of price-based programs and appliance-level curtailment contracts for demand-side management of the electricity market.

References

Allcott, H. (2011). Rethinking real-time electricity pricing. *Resource and energy economics, 33*(4), 820-842.

Hanemann, W. M. (1984). Discrete/continuous models of consumer demand. *Econometrica*, 541-561.

Hewitt, J. A., & Hanemann, W. M. (1995). A discrete/continuous choice approach to residential water demand under block rate pricing. *Land Economics*, 173-192.

Hirst, E., Goeltz, R., & Carney, J. (1982). Residential energy use: Analysis of disaggregate data. *Energy Economics, 4*(2), 74-82.

Labandeira, X., Labeaga, J. M., & López-Otero, X. (2012). Estimation of elasticity price of electricity with incomplete information. *Energy Economics, 34*(3), 627-633.

Lijesen, M. G. (2007). The real-time price elasticity of electricity. *Energy Economics, 29*(2), 249-258.

Olmstead, S. M. (2009). Reduced-form versus structural models of water demand under nonlinear prices. *Journal of Business & Economic Statistics, 27*(1), 84-94.

Silva, S., Soares, I., & Pinho, C. (2017). Electricity demand response to price changes: The Portuguese case taking into account income differences. *Energy Economics, 65*, 335-342.

Taylor, T. N., Schwarz, P. M., & Cochell, J. E. (2005). 24/7 hourly response to electricity real-time pricing with up to eight summers of experience. *Journal of regulatory economics, 27*(3), 235-262.

Vesterberg, M. (2016). The hourly income elasticity of electricity. *Energy Economics, 59*, 188-197.

Zhang, Z., Cai, W., & Feng, X. (2017). How do urban households in China respond to increasing block pricing in electricity? Evidence from a fuzzy regression discontinuity approach. *Energy Policy, 105*, 161-172.