DISSECTING DR: A QUANTILE ANALYSIS OF RESPONSIVENESS IN A BELGIAN ELECTRICITY DEMAND RESPONSETRIAL

Aman Srivastava, University of Antwerp, +3232654788, Aman.Srivastava@UAntwerpen.be
Steven Van Passel, University of Antwerp, +3232654895, Steven.VanPassel@UAntwerpen.be
Erik Laes, VITO, + 3232867458, Erik.Laes@VITO.be

Overview

Demand response (DR) programs modify the demand for electricity by encouraging use during peak generation and discouraging its use at times when the load on the grid is highest. This modification of demand is typically achieved through the dynamic pricing of electricity based on time of use, or through the external control of appliances [1].

DR is being promoted through policy frameworks and trials in several European countries [2]. Belgium has also witnessed a number of DR trials, meant to test the feasibility of a broader DR rollout in the future. Notable among these trials has been Linear. Linear was a smart grid project that ran until 2014, and included a field trial among approximately 240 families in Flanders. Of these, 55 were subjected to time-of-use electricity pricing, and the remaining 185 were provided with smart appliances and received a capacity fee for the flexibility they offered [3].

The overall response to time-based pricing was found to be weak, while the acceptance of smart appliances turned out to be much higher. The results of the field test are captured and analyzed in the final Linear report, and these estimate that a full Belgian DR rollout among only white good appliances could lead to 2GW of flexibility [3].

This field test was complemented by user surveys conducted both before and after the project. These concerned the acceptance of, and expectations with regard to, smart appliances in a residential environment. The results of the surveys are captured in an unpublished user acceptance report. This report provided findings useful to understand user perceptions of the various aspects of demand response based on aggregate descriptive statistics, and concluded that user enthusiasm before the start of the field trial shifted to a more nuanced, yet still positive, opinion about the appliances by the end of the trial.

This paper builds upon and complements the findings of the user acceptance report through a deeper analysis of participants' perceptions and behaviors. In a first, it employs the technique of quantile regressions to disaggregate participant responses to the trial and identify whether varying responsiveness was associated with different perceptions of and concerns with the project. Through this approach, this paper provides in-depth recommendations, coming out of an actual trial, for a wider demand response rollout in the future.

Methods

The standard ordinary least squares (OLS) regression model has a few inherent limitations, despite its ease of use and its provision of unconditional estimates. It summarizes the response across an entire dataset – assuming that one model is appropriate for the whole data – and cannot be customized to noncentral locations, which are often more interesting in a sample distribution than the central locations. Second, the model assumptions are often not realistic; for instance, sample distributions are often not normal. Thus, the OLS model can be heavily influenced by the presence of a few outliers in the sample [4][5].

Quantile regression (QR) modeling replaces least squares estimation with least absolutely distance estimation for a specific quantile of the response distribution. While the linear regression model specifies the change in the conditional mean of the dependent variable, subject to a change in the covariates, the QR model specifies changes in the conditional quantile. Since multiple quantiles can be modeled, it is possible to get a more complete understanding of the response distribution. QR estimates are not sensitive to outliers [4][5].

The data from the Linear field test was provided by VITO, the Flemish Institute for Technological Research, which conducted the trial. This data included (1) participant demographics such as age and gender, (2) participation details such as whether the participants were given smart appliances or ToU tariffs and smart meters, (3) responses to the surveys, and (4) responses to the field test in terms of hours of flexibility and bonuses awarded, among others. After cleaning, the processed sample included data on 191 households.

This analysis focused on the smart appliance users, which comprised 155 of these 191 households, and thus the response variable used was the total hours of flexibility that were achieved per household across appliances. The model with the best fit – both in terms of adjusted R-squared for OLS and pseudo R-squared for QR – included 7 predictors listed below.

Question	Type	Levels
Respondent age	Continuous	
To what extent do you agree with, 'The use of smart appliances seems to have no benefits'	Categorical	5
To what extent do you agree with, 'The use of smart appliances makes me work more efficiently'	Categorical	5
To what extent do you agree with, 'I made use of my smart appliances'	Categorical	5
Would subsidies play a role in deciding to buy smart appliances?	Categorical	5
Would the ability to operate appliances remotely play a role in deciding to buy smart appliances?	Categorical	5
To what extent do you agree with, 'Our behavior changed as the field test progressed'	Categorical	5

Results

The results broadly show that among respondents who claimed that their behavior didn't change, greater flexibility was associated with decreasing coefficients, suggesting that they were less likely to be among the most flexible. Among respondents who were neutral to or agreeable on the behavior change, the flexibility decreased towards the middle quantiles and increased rapidly towards the higher quantiles, suggesting that these respondents primarily populated the highest quantiles.

Across the sample, participants were less likely to offer flexibility if they perceived less of a benefit to using smart appliances. At higher quantiles, the coefficients became more negative; i.e. among participants who offered the most flexibility, a negative perception of the benefits of smart appliances reduced flexibility more – especially among those with the most negative perceptions – than among those that offered less flexibility. Thus negative perceptions of the benefits of smart appliances are a challenge, particularly among those who are likely to be more responsive.

Most respondents agreed that subsidies would indeed influence their decision to buy smart appliances. Respondents who were more likely to be influenced by subsidies were also likely to offer less flexibility in general. Thus among the least responsive participants, financial considerations were more clearly inversely related with flexibility than among the most responsive.

The quantile analysis also shows that respondent age doesn't greatly affect response among the least flexible participants, but that there is a large negative relationship between age and flexibility among the highest quantiles, i.e. being younger substantially increases response even among the most flexible respondents. This suggests that other concerns play a more significant role among the least responsive, rather than just their ages.

Conclusions

This paper conducted a quantile regression analysis on a recent Flemish demand response trial, in order to dissect participants' responses and better understand perceptions and concerns at different levels of response. Its findings suggest that for future DR programs to be successful, policymakers should target ways to encourage subtle – not excessive – behavior change. In order to aid such changes, DR implementation should be enabled by functional technologies and should be accompanied by awareness campaigns - among more responsive groups - on the benefits of smart appliances. Uptake of such programs among less flexible groups may be increased through financial incentives, or by demonstrating the financial benefits of such programs. Lastly, while younger respondents may represent low-hanging fruit to realize some benefits of DR, in the longer term, efforts should be invested into getting older audiences involved in such programs. Among less responsive groups, age was not as significant, suggesting that these segments have other concerns that might be better addressed by the steps outlined above.