Strategic Demand Response to Dynamic Pricing: A Lab Experiment for the Electricity Market

Ayse Tugba Atasoy[1] Marjolein Harmsen - van Hout[2] Reinhard Madlener[3]

[1,2,3] Institute for Future Energy Consumer Needs and Behavior (FCN), School of Business and Economics/E.ON Energy Research Center, RWTH Aachen University, Aachen, Germany

[1] +492418049836, TAtasoy@eonerc.rwth-aachen.de,

[2] +492418049835, MHarmsen@eonerc.rwth-aachen.de,

[3] +492418049820, RMadlener@eonerc.rwth-aachen.de.

1 Overview

Dynamic pricing in the electricity market allows for passing the marginal production costs on to consumers and therefore facilitates demand-side response and management. It provides consumers financial incentives to change their consumption pattern as to mitigate network congestion and flatten the load curve. Several field studies investigate whether dynamic electricity pricing proves effective in shifting electricity consumption from peak to off-peak periods (e.g., Faruqui and Sergici, 2010; Wolak, 2011). We make two observations from reviewing this literature: (i) there is a consensus that financial incentives are effective in this context; however, the size of the effect varies significantly among studies, (ii) there seems to be no systematic research examining the behavioral mechanism underlying the observed demand response.

Our study fills this gap by capturing the core decision problem in a simple experimental design. Thus, we develop a laboratory tool, which grants us a high degree of control and cost-effectiveness to investigate influences on consumer demand compared to the aforementioned field studies. As a baseline treatment, we replicate a setting introduced by Mak et al. (2014), which constitutes a two-period 'wait-or-buy' game with an exogenous first period, an automated supplier, and twenty subject buyers. While the seller offers a fixed number of products in the market, consumers decide on purchasing a product immediately or waiting until the next period, taking (i) price uncertainty and (ii) inventory risk into account. This treatment captures demand response in the retail market with scarce products. Further, we design an additional treatment by removing the inventory constraint and implementing a devaluation rule between the purchasing periods – mimicking the demand response in the electricity market. We find that in both retail and electricity market treatments, while on average consumers play the equilibrium predictions and buy strategically, a considerable share of consumers systematically deviates from rationality, i.e., buying too soon and waiting too long. Our results have important policy implications. For example, automation of the demand side management would potentially benefit consumers, since we observe significant systematic deviations from rationality.

2 Methods

For the baseline treatment, we consider a monopolist who sells a fixed inventory to twenty consumers over two different periods t_1 and t_2 between which the consumer payoff is discounted. At the beginning of each first period (t_1), the seller announces a price P_1, which is exogenous. The price in the second period, P_2, is not determined exogenously, but optimized by the seller, whose objective is to maximize

his profit in period 2. While we think that the price uncertainty is a relevant constraint in the electricity market, the inventory risk is not relevant in this context, as no risk is posed by running out of electricity. Therefore, we have a treatment design without an inventory constraint, but where only price uncertainty is introduced. We adjust the discounting rule by a devaluation rule between the two periods – making our treatment comparable to *peak* and *base* periods in which the valuation for consuming electricity differs substantially (e.g., day-/night time). The experimental design aims to capture the equilibrium behavior for strategic buying in both markets. Our experimental setup constitutes a between-subjects design for the two market treatments. We tested our setting in the laboratory for economic research at RWTH Aachen University using a computerized experiment. Subjects were enrolled students of the university. We conducted 5 sessions for the baseline and 7 sessions for the electricity treatment. Each session consisted of 20 participants and 60 two-period rounds with randomized valuations and P_1 prices.

3 Results

First, we analyze in how far the consumers act as strategic buyers. We do this by quantifying the individual deviations from the sub-game perfect equilibrium solution. Our preliminary findings suggest that consumers on average act as fully strategic buyers both in the retail (confirming the results by Mak et al., 2014) and in the electricity market settings.

We further categorize the deviations from the equilibrium behavior into two main consumer segments; individuals who buy too soon (myopic) and individuals who wait too long (irrational waiting). We find the deviations in two groups to be statistically significantly different from each other and observe systematic deviations from strategic behavior. We explain these deviations from different margins, such as, risk aversion and time preferences. We find a statistically significant negative correlation between risk aversion and irrational waiting. Further, we find that the deviation from the equilibrium strategy becomes systematically smaller over the rounds of the game, suggesting a potential learning effect.

4 Conclusions

We observe that individual deviations from the equilibrium strategy occur systematically over the rounds in specific consumer segments. Our results have important policy implications in favor of automation of the demand side management, as individuals are found to deviate systematically from rationality even in a simple decision framework. Our findings also potentially suggest that specific consumer segments might especially benefit from the demand side management.

References

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