An Analysis of Time of Use Pricing in Electricity Supply Chains

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Firms in the electricity industry recently gained access to data about their end-consumers in unprecedented volume, velocity and variety. Perhaps, the single most important tool that facilitates such benefits is the smart meter. The smart meters empower consumers to make more informed and real-time decisions regarding the timing as well as the quantity of their consumption. This is often referred to as the demand side management (DSM). It is estimated that DSM can lead to $59 billion increase in social welfare by 2019 (Federal Energy Regulatory Commission (FERC), 2009).

DSM programs generally focus on two main activities: Load shifting and reducing the overall energy consumption. The former shifts demand during peak periods, and flattens the aggregate demand curve, allowing more electricity to be provided by the cost-efficient base load plants. This could also reduce the need to build additional generation capacity to meet future peak demand. A potential unintended consequence is an increase carbon emissions because of the difference in the carbon footprints of the base and peak load power plants. On the other hand, the energy conservation programs incentivize customers to reduce their energy usage (Davito et al. 2010).

Reaping the aforementioned benefits of the DSM programs hinges on the utility companies' ability to develop easy-to-understand programs to give residential consumers the tools and the incentives to better manage their energy usage. Furthermore, the regulators must design a framework and appropriate incentives to encourage the utilities to test and use DSM programs more effectively. FERC (2009) estimates that 60% of the DSM programs' benefits will be due to different pricing strategies to manage consumer demand. Therefore, it is important to quantify the impact of different pricing strategies on the various customer segments, the peak load reduction, energy conservation as well as the impact of these pricing strategies on the usage mix of the generators with heterogeneous carbon footprint, hence, the environment. Therefore, in this research project we explore the following research questions:

- Is time of use (TOU) pricing effective in load shifting, energy conservation, and energy bill reduction? How does it compare to flat rate pricing or real time pricing (RTP)?
- How does the regulatory environment affect the response to DSM activities? Is TOU pricing more effective under regulated or competitive electricity markets?
- What are the implications of alternative pricing strategies on the firm and consumer welfare?
- What is the impact of alternative pricing strategies on the dispatch of electricity generators with heterogonous carbon footprint, hence, the environment?

We empirically investigate the residential electricity demand and supply equilibrium. On the demand side, we use a dataset consisting of the half-hourly electricity consumption and demographic data of over three thousand households collected through a field experiment, which exposes residential consumers to several TOU tariffs. Assuming utility maximizing agents, we empirically recover the parameters of consumer demand. On the supply side, we model the pricing problem of a social planner, a monopolist electricity provider, and utility maximizing firms under competition. Using the data about the half-hourly system load and wholesale electricity market prices, we find the optimal pricing schemes under these electricity market structures and alternative tariffs, i.e, flat rate, TOU pricing and RTP. Finally, we use the dispatch data of the generators to estimate the environmental impact of such pricing schemes. Our counterfactual analyses show that:

- TOU pricing schemes flatten the electricity demand curve. The peak consumption shifts to off-peak hours, while the total demand slightly increases. While the electricity providers can benefit from the decreasing capacity investment costs due to load shifting, TOU pricing may not be as beneficial to support the energy conservation efforts.
- The demand response to TOU pricing is stronger under the competitive electricity market as the prices reflect the wholesale electricity costs more closely compared to that of the regulated market.

- RTP, which is passing the wholesale costs directly onto the end-consumers, is the most effective pricing scheme in demand flattening. We show that seasonally varying TOU tariffs, which are relatively simple to implement for the utilities and easy to comprehend for the consumers, can capture most of the additional benefit of RTP.
- TOU tariff results in lower unit energy charge for the consumers compared to the flat rate. However, the consumers end up with slightly higher energy bills due to the increase in their off-peak consumption. RTP, however, also lowers the consumers' total energy bills since wholesale costs are passed on to the consumer effectively, and the off-peak consumption does not increase as much.
- Flat rate is better than the RTP in terms of consumer's utility and welfare because under RTP, consumers lose some of their valuable peak demand. TOU pricing does not have this detrimental effect, and consumers recover the lost utility from peak hours during the less costly off-peak hours. From a welfare standpoint, seasonally changing TOU rates are more preferable to constant TOU rates, since they effectively flatten the demand curve without negatively impacting the consumer welfare.
- The conventional wisdom suggests that keeping the total consumption the same, TOU pricing can have a detrimental effect on the environment: The base electricity load is typically covered by carbon intensive (and cost efficient) power plants such as coal-fired power plants whereas the peak load is covered by more environmentally friendly (and expensive) power plants such as peaker natural gas power plants, etc. The flattening of the demand curve may lead to the base power plants supplying more while the “greener" plants supplying less. In the electricity market under study, the base load and peak load plants have approximately the same emissions intensity and therefore, TOU tariff does not have a significant detrimental impact on the environment. However, as RTP flattens the demand curve more than TOU tariffs, it increases the carbon emissions more significantly.

References:

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