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Real-time pricing when some consumers resist in saving electricity

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HIGHLIGHTS

- We model consumers switching from uniform to real-time electricity pricing (RTP).
- Half the consumer population is pro-RTP and half resists saving electricity.
- Efficient RTP is feasible but is incompatible with mass adoption.

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ABSTRACT

Successful real-time electricity pricing depends firstly upon consumers' willingness to subscribe to such terms and, secondly, on their ability to curb consumption levels. The present paper addresses both issues by considering consumers differentiated by their electricity saving costs, half of whom resist saving electricity. We demonstrate that when consumers are free to adopt real-time prices, producers prefer charging inefficient prices and, in so doing, discriminate against that portion of the consumer population which faces no saving costs. We also find that efficient marginal cost pricing is feasible, but is incompatible with mass adoption of real-time prices.

1. Introduction

Given the increasing demand for electricity, environmental concerns such as global warming and related uncertainty with regard to fuel prices, consumers are being urged to conserve energy resources (Neumann et al., 2006). Some structural strategies have therefore been implemented in a bid to make energy conservation more attractive. Governments in Europe and indeed most countries, have favored two main strategies. These entail increasing the cost of energy through taxes on fossil fuel consumption and offering a combination of labeling and fee-rebates for energy-efficient appliances, for example (Brown and Cameron, 2000, pp. 30–31; David Suzuki Foundation, 2007). A newer strand of strategies focuses on the opportunities afforded by digital communication technologies when combined with dynamic pricing (Wall and Crosbie, 2009; Kiesling, 2007). One generally accepted pricing strategy is real-time pricing (RTP), whose efficiency has been demonstrated in many studies. From a theoretical perspective, RTP's advantage is that it reflects demand variation and current marginal costs, instead of only expected marginal costs as would be the case with fixed-price schemes (Aubin et al., 1995).

Advocates of RTP have often argued that the transaction costs of implementing them are now reasonable (Aubin et al., 1995, p. 173). In a recent paper, Faruqui et al. (2010) expressed a mixed view on this, asserting that time-variable pricing notably creates transaction costs for customers who must track price changes and respond accordingly. As yet, none of the existing studies on RTP actually incorporate such costs. The present paper offers a model in which these costs are explicitly accounted for in a consumer's decision to switch to RTP. We use the stylized model put forward by Chao (2010) as a framework in which we consider a simple demand response (DR, hereafter) program, whereby producers can offer consumers a single discount payment in return for switching to RTP. We show how saving costs affect marginal cost pricing when a producer's main objective is to induce customers to conserve energy.

To our knowledge, Bernard and Roland (2000) represents a first step in that direction. However the authors' model considers the effect of a single transaction cost on consumer participation in a self-rationing program, not an RTP program. Unlike Bernard and Roland (2000), our analysis assumes a continuum of consumers differentiated with respect to their ability to save electricity. Our approach is also similar in spirit to that of Brennan (2010) who relies on horizontal differentiation to model the plight of consumers who fail to take advantage of energy efficiency investment because of incomplete information or inability to translate that information into beneficial action. The main difference with

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Brennan (2010) is that our model does not include physical energy-efficient investment. Moreover, in our model the barrier to saving electricity is represented as a change in utility that is proportional to the amount saved with unit saving cost as multiplying factor. This has as implication that a consumer's marginal willingness to pay is a function of the saving cost. Salies (2010) introduced this approach in a one-period framework with unit demands. The present paper offers an extension of his model to the case where there are two time periods and consumers have continuous demand functions.

This way of modeling consumer saving costs has several appealing features. Firstly, it offers the opportunity to separate out the effect of specific barriers to the adoption of RTP from the standard own-price elasticity effect of electricity demand. Secondly, this approach allows for heterogeneous consumers, that is, consumers who differ with respect to their demand for electricity at a given price. In other words, switchers who face higher saving costs not only consume more but also are less responsive to real-time prices. A central finding in the paper is that a second-best DR program exists where only a tiny fraction of consumers with positive saving costs switch to RTP. Moreover, unlike what was asserted in Rochlin (2009), we show that electricity producers, through the DR program, may not be willing to pay consumers to reduce their electricity use for short periods of time. If they are allowed to earn as much profit as under fixed uniform pricing (FUP, hereafter), they prefer to price discriminate against pro-environment switchers thereby charging all switchers lower-than-efficient peak prices thus using the DR program as a penalty (negative discount payment).

The rest of the paper is organized as follows: Section 2 supports the assumption that switching to real-time pricing involves transaction and other behavioral costs; Section 3 details our model; and Section 4 discusses the policy implications of the results and possible directions for future research.

2. Barriers to switching to RTP

None of the studies on DR programs, even the most recent (Orans et al., 2010; Chao, 2010), have actually provided theoretical underpinnings to explain the empirical evidence that consumers do not bother to take advantage of tariffs that are potentially energy saving. Quoting Neumann et al. (2006), p. 27, “[g]iven the significant size of the [DR] resource and its cost-effectiveness, why aren't we seeing more [DR] deployment when emergencies occur?” As previously noted in literature (Train et al., 1987), however, a consumer's decision to switch to a time-variable rate depends not only on the cost differential between this and standard rates, but also on that consumer's ability and willingness to change consumption patterns in response to a change in marginal electricity prices. As Train (1994) asserted, efforts to optimize under different tariffs essentially represent the time and cost of learning about a tariff. For Aubin et al. (1995), p. 175, a crucial obstacle to real-time pricing “is the capacity of consumers to use [sophisticated price] signals, that is their capacity to reduce peak consumption and to defer consumption from peaks to other periods”. This idea is also suggested in Bernard and Roland (2000), p. 162 who assert that “frequent price changes lead to substantial transaction and adjustment costs for the consumers, mainly due to the need to get information on price changes and to react rapidly to them.” More recently, Horowitz and Woo (2006) go further, arguing that except for large industrial customers there is little evidence to support the assumption that small consumers understand real-time pricing and can make informed consumption decisions.[1] As suggested by Faruqui et al. (2010) customers going for time-variable rates would tend to be risk takers and have load shape flexibility, which is not realistic for most households.

Under-saving in energy can be modeled as resulting from a transaction/saving cost of switching between two tariffs that are in all other respects the same (Salies, 2010).[2] This switching cost has more to do with “lock-in” practices in daily energy consumption in the sense that households who have been accustomed to uniform pricing for a long time may indeed have already adapted their consumption habits. This point is supported by empirical evidence from Japan showing that most customers do not care a great deal about their electricity expenses because its use is an everyday activity (Yamamoto et al., 2008). In the market for gas, Leth-Petersen (2007) also finds support of habit formation from gas consumption, conditional on the technology that provides the energy derived service. The rationale for transaction costs is that different tariffs require specific investments in terms of how to adapt demand to them (learning costs), more particularly when they involve different pricing structures. A consequence is that once a consumer adopts one retailer's tariff, he or she may have no incentive to switch to an alternative tariff supplied by that retailer, thus discarding potentially energy-saving ones.

The existence of saving costs not only raises doubt about the allocative efficiency of imposing DR programs to all clients, but it may also explain why utilities often do not have incentives to induce their customers to reduce electricity use through time differentiated tariffs. It is this assumption that distinguishes our model from that of Chao and from the literature on fostering electricity DR where the existence of barriers to electricity saving have been suggested but not formally considered.

3. Efficiency of a simple DR program when some consumers resist in saving electricity

3.1. Model assumptions

Following Chao (2010), we consider a power system that has a peak load period of 6 h and an off-peak period of 18 h. The model characterizes customers by an hourly direct demand function for electricity, that is $q_h(p) = 22,000 - 20p$ for the peak period and $q_l(p) = 11,000 - 10p$ for the off-peak period. The corresponding inverse demand functions are $p_h(q) = 1100 - 0.05q$ and $p_l(q) = 1100 - 0.1q$. Each type of demand (peak and off-peak) is associated with an underlying utility function (denoted by U_h and U_l, respectively), where $U_x(q_x) = \int_0^{q_x} p_x(q)dq$, for $x = h, l$. These functions will be used here for calculating the changes in consumer surplus that result from switching to RTP. The marginal cost of producing electricity for peak and off-peak periods is given by the function $c(q) = -40 + q$ or $s(p) = 4000 + 100p$. Another key assumption is that consumers cannot engage in resale. This weak assumption for electricity markets stems mainly from the fact that electricity is used at the very instant it is transmitted. Stronger assumptions are used for expository purposes. They are given in Chao (2010), p. 12. Note that under these assumptions, wholesale customers are absent from the model (see also Rochlin (2009) on this point).

[1] Another reason might be that electricity is invisible for most households, meaning that consumers do not know when they are using a lot of it (Thaler and Sustein, 2009, p. 206).

[2] RTP and the fixed rate are homogenous because the electricity consumed in either case is an identical product, irrespective of the applicable pricing structure. The sole element of differentiation in the model is consumer heterogeneity with respect to the saving cost.