Economics Bulletin

Volume 30, Issue 2

Penalizing Consumers for Saving Electricity

Evens Salies
Observatoire Français des Conjonctures Economiques, Sciences Po

Abstract

In response to climate change, many electric utilities introduce pricing schemes to induce their customers to consume less electricity. When a significant portion of the consumer population finds it more costly to economize electricity, one would expect utilities to offer incentives in return for lower usage of electricity. The model put forward in this paper enhances understanding of why a typical electric utility may instead prefer to increase prices, in so doing discriminating against environmentally conscious customers. This result holds even when the utility is charged for its greenhouse gas emissions. But in this case the price increase is sufficiently small to induce energy savings also from customers for whom there is a net cost in doing so.

The author is grateful to the referee for extremely helpful comments. Acknowledgements go to Ben Davies, Ian McAvinchey, Alex Kemp, John Skåtun and other participants to the "Firms and Markets Workshops" seminar of Aberdeen University Business School (Scotland) where an earlier version of this paper was presented. I also thank Thierry Pénard for its insightful suggestions and participants to the "Applied Economics Seminar" of University of Rennes 1 (France).

Citation: Evens Salies, (2010) "Penalizing Consumers for Saving Electricity", *Economics Bulletin*, Vol. 30 no.2 pp. 1144-1153.
Submitted: Mar 25 2010.   **Published:** May 03, 2010.

1. Introduction

In line with general concerns about climate change, consumers are being urged to save energy resources. Many studies confirm that appropriate incentives need to take into account not only households' financial constraints but also demand inertia (Department of Energy & Climate Change, 2009). Some structural strategies have therefore been implemented in a bid to make energy conservation more attractive to households (Steg, 2008). One strand of the literature focuses on the opportunities afforded by digital communication technologies and time-variable tariffs (Wall and Crosbie, 2009; Kiesling, 2008). Another strategy is to increase the cost of energy through taxes on household consumption of fossil fuels, yet consumption rates remain controversial as evidenced in the current debate in France (Kanter and Saltmarch, 2009). Finally, many governments have policies to promote more efficient product choices, such as a combination of labeling and fee-rebates offered in relation to energy-efficient appliances (David Suzuki Foundation, 2007).

In this paper we focus on price-oriented mechanisms via which electricity utilities introduce new tariffs aimed at reducing electricity use. In this respect, one concrete example deserves some comment. When the French residential electricity market was opened to competition, new entrant retailer Poweo introduced an innovative time-of-use tariff with discounted running charges for new customers provided they did not consume more than a contracted amount. Yet two years or so later, Poweo removed this attractive scheme. This decision suggests either that Poweo's tariff was merely a means of attracting customers or that its new customers spent more on electricity than they had budgeted for, despite their apparent desire to control electricity use.

Reversing the pricing practice leads to an increase in the electricity price at higher consumption levels. To mention a few examples, in 2008 one Canadian utility (BC Hydro, 2008) introduced a block-inclining tariff (overall revenue-neutral), similar to that faced by most Californian electricity consumers (Reiss and White, 2005). Such tariffs also exist in Japan, where Tokyo Electric Power Company's customers subscribe to the monthly Meter-Rate Lighting tariff. Households are thus charged the first 120 kWh at ¥17.87/kWh (nearly 20 cents at January 2010's exchange rates), increasing 23% up to 300 kWh, and a further 5% above that level. This tends to suggest that penalizing pricing structures could be an efficient tool for inducing energy conservation. For example, Thaler and Sustein (2009, p. 40) assert that energy conservation methods framed in terms of losses are effective nudges because most people are loss averse.

Overall, these pricing strategies suggest that the structure of electricity tariffs must inevitably adapt to the need to induce consumers to reduce their electricity use. There are several reasons to believe that traditional structures such as flat rates (the amount paid is strictly proportional to consumption), simple two-part tariffs (the amount decreases with consumption) and block-declining rates do not seem appropriate to inciting consumers to control their electricity consumption behavior.

The present paper puts forward a theoretical model for analyzing the pricing policy of an independent electric utility when its objective is to induce customers to conserve energy. Our analysis assumes that there is a continuum of consumers whose differentiated attitudes towards electricity saving decision may be likened to the cost of switching between two brands (Chen, 1997; Klemperer, 1987). A central finding here is that a “first-best” optimum exists whereby only those consumers who attach a ‘positive’ value to environmental protection are charged for energy conservation. This result holds even when the firm is charged directly for its greenhouse gas emissions. In this case, the firm charges a lower penalty so as to induce energy saving from that fraction of its customers for whom there is a net cost in doing so.

The rest of the paper is organized as follows: section 2 supports the assumption that reducing energy consumption involves behavioral costs; section 3 provides our model; while section 4 discusses the policy implications of the results and possible directions for future research.

2. Barriers to household energy saving

Environmental economics literature is replete with empirical studies looking at the barriers to investment in demand-reducing equipment, such as Banfi *et al.* (2008) for residential building, and Wall and Crosbie (2009) for electricity demand reduction in lighting. Though not directly related to energy saving, Taylor (1975) provides an earlier reference where habit formation is suggested as an explanation for the small value of own-price elasticity estimates in the short run. More recently, Maréchal (2009) surveys the energy economics literature concerning habits as an important factor explaining the limited effectiveness of policy-driven energy saving incentives. This 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). Even in the longer run, purchases of energy-efficient appliances may not lead to a reduction in energy demand. One mechanism underlying this effect is called the “direct rebound effect”. It is such that “[i]mproved energy efficiency for a particular energy service will decrease the effective price of that service [which] leads to an increase in consumption of that service.” (Sorrell and Dimitropoulos, 2008, p. 637).

Few of the studies however provide a theoretical framework to underpin the empirical evidence. Brennan (2009) considers the plight of consumers who do not bother to take advantage of energy efficiency investment because of incomplete information or inability to translate that information into beneficial action (supporting evidence of such barriers is found in Banfi *et al.*, 2008). In Brennan’s model, a fraction of consumers chooses not to invest despite the fact that they would be better off doing so. One rationale for this may be consumers’ low awareness of the energy efficiency of electricity-using appliances (Yamamoto et al, 2008; Steg, 2008 and see the references therein). Another reason might be that electricity is invisible, meaning that consumers do not know when they are using a lot of it (Thaler and

Sustein, 2009, p. 206). Although we concur with these factors, here we take a different approach to that of Brennan who considers transport rather than switching costs.

In the following model, 'under-saving' in energy may simply reflect a transaction cost akin to the cost of switching between two identical products. One reason for this kind of inertia could be people's desire to reduce cognitive dissonance or the psychic 'cost' of being exposed to information which undermines the logic of maintaining current consumption behaviors (see Akerlof and Dickens, 1982 who seem to be the earliest reference importing this kind of psychological in the economics literature). For example, it is likely that consumers who discard a potentially energy-saving tariff and tend to go along with their default tariff simply want to avoid the discomfort of learning how much they could have saved on their bill. Another possible barrier to energy saving is the existence of efforts of optimizing under different tariffs (Train, 1994). As that author asserted, such efforts essentially represent the time and cost of learning about a tariff.

3. Pricing policy when consumers have different attitudes towards the environment

Rather than attempting to consider the potential for energy savings via investment in energy-efficient technologies or via technology substitution, we instead try to focus on electricity waste reduction. We assume identical customers who use an amount of electricity equal to $(1+\delta)q^*$, where $\delta/(1+\delta)$ is the fraction of electricity used that is wasted. Wastefulness in this model arises from the related assumption that consumers only derive a satisfaction from the services they actually use. Therefore, the utility of consuming $(1+\delta)q^*$ is equal to that of consuming q^*. Formally, there is a reference-level utility each consumer derives from consuming the services she actually uses. It is constant and denote by U^*.

Consumers are in a continuum of measure 1, each of whom and is characterized by the cost of reducing his or her consumption from $(1+\delta)q^*$ to q^*. Here, the cost of reducing electricity consumption is a fixed cost per unit of electricity saved, akin to the cost of switching between brands of products that are in all other respects undifferentiated. As suggested in Klemperer (1987, footnote 6, p. 378), in our single-period model, the role of consumer switching cost is quite similar to horizontal product differentiation. We prefer to consider those 'transportation costs' (as per Klemperer), as wasted and non wasted electricity are exactly the same products. However, unlike Choe and Fraser (1999) and almost all papers on consumer switching costs, this cost can be negative. We denote it by s. The rationale for our weaker assumption is that s is a gross cost of spending time or effort in saving energy less the value attached to protection of the environment. This 'net cost' could be for example the psychological cost of turning off the lights in unoccupied rooms less the value attached to such action. For consumers who have a negative attitude towards the environment, the difference is positive whereas it is negative for environmentally conscious consumers. This assumption borrows from Green (2000) who models competition between electricity retailers when consumers face switching costs. He distinguishes between the consumer's cost of switching from the incumbent and the added value of buying from a new entrant. But the difference between them is assumed to be always positive in Green's model. s is thus an independent realization of a random variable S that is uniformly distributed on $[-\theta, \theta]$ for convenience, where $\theta > 0$ and greater than p. We further consider that as electricity is used at the very instant it is transmitted to consumers, they cannot engage in resale.

Let p and f denote the unit and standing charges of the old tariff. The firm introduces an optional tariff $(p, f - m)$, where m is a discount payment offered to customers who switch to this optional tariff provided they reduce their consumption to the level q^*. In the remaining of the paper we set $f \equiv 0$ as this variable does not enter into any of the results.[1] By introducing this new tariff, the firm can price discriminate between customers who will sort themselves depending on the costs faced in saving electricity. U^*, p and s are in monetary terms and we assume that $U^* > \theta\delta q^*$. To capture universal service in electricity, we finally assume that market size is given and equal to 2θ.

Case 1 (all consumers switch). A first interesting solution is to determine the discount payment m^* such that all customers reduce their consumption to q^*. Let us first write the consumer program. A consumer is indifferent as between switching to the new energy-saving tariff and continuing to waste electricity if s is such that $U^* - pq^* + m - s\delta q^* = U^* - p(1+\delta)q^*$, which leads to $s = p + m/\delta q^* \equiv \tilde{s}(m)$. As a consequence, all consumers whose switching cost is higher than $\tilde{s}$ stay on the old tariff. We can see immediately that the number of switchers increases with the discount payment. In the remainder of this section we shall calculate the discount payment and the corresponding fraction of energy savers in various situations. Note that adding the switching cost $s\delta q^*$ at the right-hand side of the previous inequality changes the interpretation without changing the value of $\tilde{s}(m)$. $s\delta q^*$ would be interpreted as the extra utility of not having to make effort to reduce consumption to q^*.

To make all consumers switching to the electricity saving tariff, the firm should set its discount such that $\tilde{s}(m^*) = \theta$, which leads to $m^* = (\theta - p)\delta q^*$. This situation is efficient for consumers since all win in the program, more particularly those for whom $s > 0$. The net utility of a consumer of type s is $U^* - p(1+\delta)q^* + (\theta - s)\delta q^*$ that is strictly greater than $U^* - p(1+\delta)q^*$ for all s. The firm's profit takes the simple form $pq^* - m$ that is equal to $p(1+\delta)q^* - \theta\delta q^*$, namely the profit before it introduced its new tariff, less the amount $\theta\delta q^*$. As we can see, unless it is subsidized, the firm will not offer m^*.

Case 2 (monopoly). Let us now consider the case in which the firm behaves as a monopoly that wields some power over its customers. We denote by α the share of customers who stay on the old tariff and $1 - \alpha$ as the fraction of consumers who opt for the energy-saving tariff. The share α of consumers who stay on the old tariff is given by:

$$\int_{\tilde{s}}^{\theta} \frac{1}{2\theta} ds = \frac{1}{2} - \frac{1}{2\theta}\left(p + \frac{m}{\delta q^*}\right) \tag{2}$$

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[1] I thank the referee for suggesting this simplifying assumption.

provided $\theta \geq p + m/\delta q^*$. Since the firm serves all its customers, then $1-\alpha$ is equal to 1 minus the above expression. These shares will depend on the value of m and p set by the firm. As suggested in the introduction, the own-price elasticity of electricity demand is generally small in the short run. Furthermore, given our assumption that U^* is constant (all consumers derive a satisfaction from the quantity they actually use, q^*), it is reasonable to assume that the monopolist maximizes its profit with respect to m where its profit is given by:[2]

$$\alpha p(1+\delta)q^* + (1-\alpha)(pq^* - m). \tag{3}$$

The first order condition for profit maximization leads to:

$$m^* = -\left(p + \frac{\theta}{2}\right)\delta q^*. \tag{4}$$

The discount payment is negative, meaning that consumers who switch to the new tariff are charged more. As $\tilde{s}(m^*) = -\theta/2$, it follows that only those consumers who attach a high value to energy-saving will switch to the energy saving tariff. As the population of consumers is distributed on the interval $[-\theta, \theta]$ we can easily deduce that these consumers represent only one fourth of the total. One can also verify that the change in the firm's profit is $\theta\delta q^*/8$. Thus, the firm can make profit by inducing only a small fraction of its consumers to save electricity. Taken together, these results would suggest that in the presence of pro-environmental consumers, penalizing pricing structures may be more robust than rewarding ones in decentralized markets. Note that when switching costs approach zero, $m^* \uparrow -p\delta q^*$, and $\tilde{s}(m^*) \uparrow 0$. The extra charge applied to switchers approaches the levels of revenue lost on them, that is the monetary value of the electricity no longer wasted, $p\delta q^*$.

We shall examine two further cases. The former (*Case 3*) is inspired by the 2008 decision by Canadian utility BC Hydro to introduce an energy-saving tariff that, as mentioned in our introduction, was revenue-neutral to it. Then we consider revenue-neutrality assuming the firm is emitting greenhouse gases, for which it is charged (*Case 4*).

Case 3 (revenue-neutrality). Setting (3) equal to $p(1+\delta)q^*$ leads to $m^* = -p\delta q^*$. In this situation, half the consumers adopt the new tariff ($\tilde{s}(m^*) = 0$). It transpires that this situation is also Pareto Optimal in that the discount payment maximizes the sum of consumers' surplus and firm profit. Note that the result we obtain under revenue-neutrality is not only optimal but also distribution free in that it does not depend on the distribution that specifies the cost to consumers to save electricity. This qualitative result is similar to that found in Choe and Fraser (1999). However, in that paper all households make a positive waste reduction effort, implying that a first-best can only be achieved applying environmental tax and a waste collection charge to the firm. The optimal aspect of revenue-neutrality invites us to ask what would be the value of the optimal discount payment in the more realistic situation whereby the firm faces a cost for emitting greenhouse gases.

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[2] In the concluding section, we discuss some implication of relaxing this assumption.

Case 4 (revenue-neutrality with a charge for greenhouse gas emissions). Let us therefore assume that δq^*, the amount of waste before the introduction of the new tariff, produces a quantity $\beta\delta q^*$ ($\beta < 1$) of greenhouse gas emissions. And, denote c the corresponding per unit price ($c < p < \theta$) which is exogenous. A rationale for considering δq^* as the only source of externalities is that this quantity is mostly produced from fossil-fuel plants, whereas q^* is produced from say, nuclear plants. The firm's profit is now:

$$\alpha[p(1+\delta)q^* - c\beta\delta q^*] + (1-\alpha)(pq^* - m).$$

Under the constraint that the firm keeps its revenue equal to $p(1+\delta)q^* - c\beta\delta q^*$, we obtain $m^* = (c\beta - p)\delta q^*$. The discount payment is still negative but it leads to more energy conservation ($\tilde{s} = c\beta > 0$). This shows that when the utility has to pay for its greenhouse gas emissions, its discount payment is still negative, but it is sufficiently low to induce a fraction of consumers who attach a negative value to the environment to save energy. We can compare this result with the effect of a charge for emissions when the firm behaves as a monopoly. The discount payment would increase and the marginal consumer would be $\tilde{s} = (c\beta - \theta)/2$, the value of which depends on the magnitude of c.[3]

4. Conclusion: discussion and extension

The first policy implication relates to the rewarding-penalizing debate we introduced at the beginning of this paper. When mandatory to all customers (*Case 1*), rewarding tariffs compensate the deadweight loss of consumers who have to make an effort to use less electricity. Pro-environmental consumers on the other hand, win 'twice' under such programs, which may explain why profit-maximizing firms show some reluctance to use such tariffs. Unless firms attach a high positive value to the environment or are subsidized, which we have not considered here, this strategy is not sustainable.

We considered neither entry by a new firm nor the cost to consumers to switch the incumbent. Regarding the decision of Poweo to introduce a discounted tariff provided consumers do not consume more than a contracted amount, our result suggest that this firm underestimated the effort consumers have to make to have control over their electricity consumption. In fact, in a decentralized environment and when the firm can perfectly discriminate between its customers (*Case 2*), it is optimal for it to penalize its environmentally-conscious customers, thus sacrificing environmental protection since only one-fourth of the consumers reduce their consumption. As we have shown in *Case 4*,

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[3] As it is also the case in most countries that fossil-fuel power plants are a source of base load generation, more realism could be achieved by assuming that a fraction $\gamma \in (0,1)$ of $c\beta\delta q^*$ is attributable to non-savers, while $(1-\gamma)$ to electricity savers. Solving the unconstrained-revenue monopolist problem in this case leads to different solutions: $m^* = \left(\frac{c\beta-\theta}{2} - p - (1-\gamma)c\beta\right)\delta q^*$ and $\tilde{s} = (c\beta(2\gamma-1)-\theta)/2$. This reflects a lower incentive to the firm to attract its customers to the energy saving tariff.

however, charging the firm for its greenhouse gas emissions can improve the situation, for the introduction of such a charge forces the firm to induce a fraction of consumers to make positive efforts to conserve energy. But now there would be a trade-off between consumption efficiency and the deadweight loss due to switching, from those consumers who have to pay a cost to use less electricity.

These results also lead us to discuss the usual assertion that measures designed to protect the environment imply sacrifices of one's comfort (Hansla *et al.*, 2008). The present model started with the reasonable assumption of a population of consumers, half of whom consider electricity saving as a sacrifice. Except in *Case 4* there is no consumer sacrifice in the model, since consumers who reduce their electricity consumption are always those who attach a positive value (negative switching costs) to doing so. In this respect, our result in *Case 3* is undoubtedly the most interesting as revenue-neutrality is both Pareto optimal and optimal to the firm. This suggests that having a high fraction of environmentally conscious consumers can make electricity saving possible. In policy implication terms this result argues in favor of increasing the share of environmentally conscious consumers by converting the others to switch to environment-friendly ways of using electricity. This undoubtedly requires changes in preferences as asserted by Stern (2008). This kind of psychological strategy is precisely what governments in many countries have been trying to achieve through conservation campaigns ". . . aimed at changing people's knowledge, perceptions, motivations, cognitions and norms related to energy use and conservation." (Steg, 2008, p. 4450; see also Banfi *et al.*, 2008, p. 515).

The results of our model have relied on a one-period framework and a simple pricing structure. To assess their general application one could assume that U is a continuous function. If consumption is made up to the point where marginal willingness to pay is equal to price, then the optimal consumption level, q^{**}, would be such that $U(q) - pq - f + s(q - q^{*})$ reaches a maximum, with q^{*} the level of electricity consumption when $s \leq 0$. Ignoring further constraints, the first order condition is $U'(q^{**}) = p - s$. It is worth noting that this point corresponds to a lower slope than the point q^{*}. Thus assuming a disutility to saving energy straight in the utility function can provide a simple explanation of why consumers resist saving electricity. We note however that for consumers whose effort to save electricity is high, marginal utility could be negative. The implication of this is left for future researches. Second, one could design a more sophisticated model with several competing firms that set the optimal level for more sophisticated tariff than that we have considered here. But, a further inertia that would then have to be considered is brand switching.

Finally, one could consider a full contractual framework of the effort made by households to reduce electricity consumption. The problem could be one of hidden information where households keep their attitudes towards the environment secret. Moral hazard (hidden action) could also be an important issue here, although with today's enabling technologies the firm can have at its disposal all the information regarding the volume of electricity used by its consumers. There is one item of information unlikely to be available to policy makers, and that should be hard to contract for, namely electricity wastage which is set to remain a genuine impediment to energy conservation.

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