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Consumer demand for time of use electricity tariffs: A systematized review of the empirical evidence

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ABSTRACT

Time of use (TOU) tariffs, if widely adopted, could help make electricity more secure, clean and affordable. However, quite little is known about whether consumers will switch to a TOU tariff or what might increase uptake if switching rates are lower than required. This paper presents the results of a systematized review and meta-analysis combining the results of 66 measures of uptake to a variety of TOU tariffs across 27 studies conducted in six countries. It provides the first robust estimate of consumer demand and correlates of demand for TOU tariffs that is not based on the results from just a single study or tariff. Four main conclusions emerge. First, if consumers are left to opt-in to TOU tariffs, uptake could be as low as 1% unless efforts are made to close the intention-action gap, otherwise enrolment could reach 43%. Second, if enrolment is opt-out, uptake could approach 100%. Third, whilst national surveys indicate the potential appetite for TOU tariffs in a population, they are insufficient for predicting future TOU tariff adoption rates; the median proportion of domestic energy bill payers who say they would be willing to switch to a TOU tariff in national surveys is five times higher than the median enrolment rate to TOU tariffs offered by utilities. Fourth, real-time pricing tariffs, in which the price of electricity varies freely throughout the day, are less popular than static TOU tariffs which have fixed peak and off-peak rates. This paper discusses the limitations of opt-out enrolment for TOU tariffs and presents results suggesting that small upfront payments, bill protection and automation are promising alternative methods of increasing opt-in enrolment. Policymakers and researchers should now consider how recruitment will be performed, weighing up the benefits to society as a whole against the distributional impacts for individuals and groups.

1. Introduction

Encouraging domestic consumers to change the time of day at which they use electricity is a key part of many governments' plans to ensure national energy supplies are secure and affordable in the transition towards greater penetration of intermittent renewable energy sources and the electrification of heat and transport [1]. One way in which consumers will be incentivised to change their consumption patterns is through price signals delivered via time of use (TOU) electricity tariffs, in which the price of electricity varies depending on factors such as electricity network constraints and the wholesale price of electricity. A large body of literature demonstrates that consumers will alter their consumption patterns in response to a range of TOU tariffs, with an average reduction in peak time energy consumption of around 15% depending on the tariff design [2], see also [3,4] and, in particular, [5] which reviews 30 trials on the impact of TOU tariffs on electricity demand. An underlying assumption of many of these studies, including government decarbonisation strategies, is that consumers will voluntarily sign up to a TOU tariff in the first place. However, the evidence on level of consumer demand for TOU tariffs is far less clear.

Whilst TOU electricity pricing has been an established part of grid management strategies involving large industrial and commercial users for many years, domestic TOU programmes remain restricted to relatively basic legacy options such as Economy 7 tariffs [6] in Great Britain (GB), or the Tempo Tariff in France [7]. Aside from the United States, where more modern TOU tariffs are now commercially available, there

Abbreviations: CPP, Critical peak pricing; CPR, Critical peak rebate; DP, Dynamic pricing; EU, European Union; GB, Great Britain; OECD, Organisation for Economic Co-operation and Development; OLS, Ordinary Least Squares; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RTP, Real-time pricing; TOU, Time of use; UK, United Kingdom; US, United States

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is therefore no useful measure of current commercial consumer demand for TOU tariffs.[1] Alternative sources of evidence on consumer demand for TOUs include recruitment rates into TOU field trials and measures of stated demand elicited from survey participants. However, to our knowledge, there has been no attempt to synthesise the evidence from this wide range of sources to provide an overall estimate of the likely uptake of TOUs amongst domestic energy bill payers.

Further, if consumer uptake is lower than required – as our initial analysis of consumer behavior in the energy market suggests it could be – evidence is also required on what recruitment strategies and enabling technologies are likely to be most effective at increasing uptake. For example, in the behavioural science literature, a large body of research documents the way in which enrolment rates to various services and products are higher when people are enrolled automatically, with the option to unenroll ('opt-out'), as opposed to when people must take active steps to sign up ('opt-in'). Notable examples are workplace pension schemes, green energy tariffs and organ donor registration [8–11]. Some TOU tariff field trials enrolled participants onto TOU tariffs by default, unless consumers opted-out, whereas others relied on consumers actively deciding to opt-in, presenting an opportunity to understand which method may be more successful at stimulating uptake. In addition, some studies provided participants with assistive technologies, usually smart thermostats that customers could programme to lower set-points during the higher peak time price periods. Such technologies may also make TOU tariffs more, or even less, desirable, depending on how these technologies are perceived. Moreover, there are many different types of tariffs for which the price of electricity varies throughout the day, and some tariff designs may be more appealing to consumers than others. Five key time-varying tariff designs are:

- Static TOU. Prices vary during the day in a fixed and regular way, for example by having a peak price between 4 and 8 p.m. on weekdays, and an off-peak price at other times.
- Dynamic TOU (DP). Price points are fixed, but the times at which they apply vary from day to day. For example, there may be low, medium, and high price periods, and customers are notified in advance between which times those prices will apply,
- Real-time pricing (RTP). Prices vary in real-time (e.g. to the hour or half hour) depending on the current wholesale cost of electricity.
- Critical peak pricing (CPP). Pricing is mostly flat, but there are occasional high price 'events' of which customers are notified in advance.
- Critical peak rebates (CPR), also known as peak time rebates. Pricing is flat, but at certain times (notifiable in advance) customers are rewarded for reducing their electricity demand compared to some agreed amount.

For simplicity, this paper adopts the convention of using the term 'time of use' tariff (here, abbreviated to TOU tariff) as a generic term to refer to a whole spectrum of time-varying tariffs, including both static and dynamic pricing options.[2]

This paper presents the design and results of a systematized literature review [12] aimed at answering five main review questions:

- How much domestic consumer demand is there for TOU tariffs?
- Does domestic consumer demand for TOU tariffs vary by tariff design?
- Does domestic consumer demand for TOU tariffs vary according to the presence of automation technologies?
- Does domestic consumer demand for TOU tariffs vary by the way in which the tariff is framed to consumers, such as whether the choice is opt-in rather than opt-out?
- Is there cross-country variation in demand for TOU tariffs?

This systematized review uses methods from a systematic review, including the use of a review protocol in which the search strategy, inclusion/exclusion criteria and extraction methods are determined in advance. However, like a rapid review, the completeness of searching was determined by resource constraints [12]. This review also includes a meta-analysis, "which statistically combines the results of quantitative studies to provide a more precise estimate of the results" [12], p. 94 to answer the research questions above. The review provides evidence from six countries, covering Australia, France, Norway, Netherlands, United Kingdom and the United States.

The rest of this paper is structured as follows. Section 2 outlines the method used to conduct the systematized review, including the search strategy and screening criteria as well as the extraction and synthesis of the uptake measures. Section 3 presents the results of the search and synthesis used to obtain a measure of overall uptake and uptake by country, tariff design, framing etc. in a meta-analysis. Section 4 discusses the strength of the evidence for consumer demand for TOU tariffs in light of the limitations of the original study designs and the review-level limitations (e.g. incomplete retrieval of relevant research) before concluding, in Section 5, with an overall recommended 'best' estimate of consumer demand for TOU tariffs and the key research gaps. The reporting of the design and results follows the PRISMA check-list [13] for reporting items for systematic reviews (mostly used in medical research) as closely as possible.

2. Method – a systematized review

2.1. Criteria for considering studies for this review

A review protocol was prepared in advance of conducting the review (see additional online material). We included studies written in the English language that document empirical, quantitative findings on switching rates to commercially available tariffs or hypothetical sign up rates, elicited in surveys, to TOU tariffs amongst domestic energy consumers in Organisation for Economic Co-operation and Development (OECD) countries.

The following types of report were excluded:

- Studies that documented qualitative findings only, because these types of studies could not be used to provide a quantitative measure of uptake.
- Studies that did not report empirical results (e.g. include only modelled uptake), because these studies would either be reliant on an empirical measure which our inclusion criteria would capture or would be based on targets or estimated optimum uptake levels, neither of which are equivalent to actual consumer demand.
- Studies that did not report research including a TOU (e.g. which focused only on direct load control or other non price-based demand-side response).
- Studies focused exclusively on the non-domestic sector.
- Studies reporting work conducted in non-OECD countries, because it was judged that such countries may have different priorities and concerns related to electricity usage (e.g. in developing countries, particularly energy access) that would make such research better suited to a separate review.

Studies reporting uptake measures based only on study recruitment

[1] We exclude countries such as Italy which have made time of use tariffs mandatory since mandatory enrolment rates do not provide evidence of consumer demand.

[2] Although this is a conventional use of the terminology, sometimes the term 'time of use' tariff (here, abbreviated to TOU tariff) is used to refer to a specific type of time-varying tariff design that has a peak and off-peak price at the same time of the day or week; following the conventions in the literature on demand-side response, we refer to this sub-group of TOU tariffs as a static TOU tariff (see bulleted list).