The price is not right! Energy demand, time of use tariffs, values and social practices

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The price is not right! Energy demand, Time of Use tariffs, values and social practices

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Abstract
Several governments are opting to move from flat electricity tariffs to Time of Use pricing in an effort to curb peak electricity demand. However, despite the fact that numerous trial studies looking to quantify the effectiveness of pricing schemes have been carried out, these have produced mixed results, and in most cases, the observed temporal shifts in demand in response to the introduction of time-varying pricing are marginal at best. If changes in the timing of energy demand should be of substantial magnitude, marginal behavioural shifts in electricity consumption will not be sufficient. This prompts conceptual efforts to research what constitutes an (in)effective price-driven demand management intervention, and what their implementation may mean for energy demand. Most failures in price-driven interventions have been interpreted by energy economists in terms of setting the wrong price, which for time-varying tariffs translates into inadequate price ratios between peak and off-peak periods. This view is rooted in principles of economic rational choice theories that assume people will always respond to changes in the price of goods or services in a rational, predictable manner. However, this fails to consider the fact that price is only one of many factors at play when it comes to making decisions that will result in demand for energy. This paper suggests that more radical reductions in demand for energy and associated carbon emissions can be achieved through approaches that aim to find a better alignment of time-varying pricing and the (value of) social practices which constitute everyday life. The paper concludes by suggesting ways to integrate concepts explaining ToU pricing effects and the timing of electricity demand with methodologies which disaggregate price elasticity, and offer alternatives to the estimation of market and non-market values of practices and time.

Introduction
Time-varying tariffs are increasingly being introduced in European countries as a means to mitigate peaks in electricity demand. To date, 17 EU member states have implemented some form of energy tariff with intra-day/weekdays/weekend price differentiation; real-time or hourly energy pricing contracts are available in eight of those countries (ACER, 2018). Even though the most commonly applied type of Time of Use (ToU) tariff structure is a day/night, peak/off peak differentiation. However, in some countries, the number of time periods considered in these ToU tariffs ranges from 3 (e.g. Italy) all the way to 24 in countries such as Estonia and Spain where between 25% and 50% of all households are charged for energy based on hourly pricing.

The widespread adoption of ToU tariffs as demand management mechanisms has sparked considerable interest in their effectiveness, and numerous studies have been carried out with a view to assessing the impact of the implementation of such tariffs. However, the results on demand shifting and reductions differ immensely, ranging all the way from 0% to 60% (Faruqui et al., 2017). As pointed out by Öhrlund (2020), most discrepancies in the effectiveness of such pricing interventions have been attributed by energy economists to 'having set the wrong price', which for time-varying tariffs translates into inadequate price ratios between peak and off-peak periods. This view, however, shows a complete disregard for the temporal dynamics that give rise to the observed daily demand loads and periods of peak demand. Consequently, it offers a very simplistic explanation as to why imposing a new tariff structure doesn't always translate into reductions or shifting of energy demand loads.

This paper explores the shortcomings of purely price-driven demand management interventions, as well as potential alternative approaches that pay closer attention to the timing of energy demand and its relation to the timing of energy-consuming practices and price differentials. The analysis presented in this paper is underpinned by the following three observations. Firstly, the measurement of the direct relationship between price and demand matters. Metrics which are commonly used to quantify the effects of ToU tariffs on electricity demand – such as price elasticity – should be considered carefully as they can directly point to the successes and failures of price-driven interventions. Secondly, there is great uncertainty around how individuals respond to changes in price in the short-term and this is because of the emphasis on behavioural shifts in response to marginal price changes. If changes in the timing of energy demand should be of substantial magnitude, marginal behavioural shifts in electricity consumption will not be sufficient. Hence, the role of individual consumers' behaviour in response to ToU tariffs cannot be dissociated from the timing of demand. Thirdly, given the conspicuous relation between energy demand and people's doings, perhaps a more effective approach would entail focusing on people's doings and considering how these interact with time-varying prices. In principle, time-varying pricing structures, like ToU tariffs, could be reconciled with broader interpretations of how everyday life is socially shaped. If this were the case, theories of social practice and their applications to develop a deeper understanding of the timing of energy demand can represent an alternative lens through which the potential effects of ToU tariffs can be examined.

This paper presents a preliminary effort to introduce alternative approaches and techniques which are not currently in use in time-varying pricing studies. Three tentative approaches, namely disaggregating demand elasticity, integrating non-market techniques for valuing time, and market valuation of practices, are presented below with a view to widen the perspective on ToU tariffs. As a starting point, the paper offers brief descriptions of contextual topics such as price elasticity of demand, behavioural economic approaches and social practices, as well as their relevant concepts that are key to understand the relationship between ToU tariffs and the timing of electricity demand. This is followed by a brief review of recent studies on short-term price elasticity of demand, behaviour and social practices in relation to ToU pricing. Finally, applications of the proposed approaches in the realm of time-varying energy pricing are discussed, and we offer our concluding remarks.

Understanding the relationship between Time of Use tariffs and the timing of electricity demand: key concepts

Price elasticity of demand

Price elasticity of demand is generally understood in energy economics as a direct measurement of the relationship between price and quantity of energy demanded over a period of time. Elasticity measurements vary according to different temporal scales with very short-term elasticity focusing on how changes in time-varying tariffs (for instance, critical peak pricing or ToU tariffs) trigger changes in energy consumption (Labandeira et al., 2017).

The 1970s oil crises triggered attempts to reduce growing demand for electricity and negative environmental impacts. The high costs of producing electricity in the late 1970s meant that several utilities started developing programmes aimed at reducing the final price of electricity with a view to ensure that demand would not collapse. Concepts associated with the price elasticity of energy demand relate to input-cost effect, i.e. one of the most extensively explored theories on the direct effects of oil price shocks. According to this approach, higher energy costs lower usage of oil, which in turn lowers productivity of capital and labour. The input-cost effect theory is generally paired with income-effect theories, (i.e. higher costs of imported oil reduce disposable income of households). The cost context of that historical period, combined with the regulatory framework compelled utilities to actively tame the final price of electricity to prevent the elastic effects which were experienced by the automobile industry: during oil crises the automobile industry was devastated by the collapse of consumer demand for low fuel efficiency full-size cars (Lee & Ni, 2002).

Price elasticity has been widely criticised as a concept too closely connected with the standard decision-making model in neoclassical economics, which portrays people as ideal decision-makers with complete rationality, perfect access to information, and consistent, self-interested goals, and will always attempt to maximize their utility for both monetary and non-monetary gains (Stern, 1986). However, price elasticity is to date the main metric for measuring the effectiveness of time-varying pricing interventions, such as ToU tariffs in both academic and policy domains. For instance, price ratios between peak and off-peak tariffs are in trials and empirical studies the main variable for analysing demand responses.

In the empirical energy economics literature, the evidence on which studies on elasticity draw varies. Years of empirical research have failed to provide conclusive evidence of the relationship between short-term changes in price and demand. For instance, Al Faris (2002) finds short-term demand elasticities ranging from -0.04 to -0.18 in countries such as Saudi Arabia, Kuwait, Oman, UAE, and Qatar. Other studies such as Holtedahl and Loutz (2004), and Jones (1995) obtain estimates roughly within the same range. However, several other studies find somewhat or much higher price elasticities, such as Filippini and Pachuari (2002) and Hesse and Tarkka (1986).

In the past couple of decades, several other studies on the effects of ToU pricing of electricity have been published, with the aim to shed some light on the effect of price differentials between peak and off-peak periods on overall demand loads. For instance, Bartusch et al. (2011) and Bartusch and Alvehag (2014) find that the change in peak to off-peak demand ratio relative to the pre-tariff period is approximately 2.5 %, compared with the change in the price differential between peak and off-peak hours relative to the pre-tariff period, which was approximately 160%. While these studies do not explicitly estimate the price elasticity of electricity demand, the reported findings imply an elasticity of around -0.017. The results for load shifting under other types of pricing schemes such as 'real-time' pricing also appear to indicate a weak response, with even lower price elasticities in the range of -0.0014 to -0.0043 (Lijesen, 2007; Allcott, 2011).

As pointed out by Öhrlund (2020) in his critical analysis of summarising studies on the effects of price-based demand response programs — "The variability in the reported effects of time-varying rates on peak electricity demand (with and without enabling technologies) is immense—ranging from about 0-60% for residential users" (Öhrlund, 2020, p. 5). Claims have been made that "much of this variability can be explained by differences in the peak to offpeak price ratio of the rates as well as the use of enabling technologies" (Öhrlund, 2020, p. 5). However, Öhrlund (2020) and Öhrlund and Schultzberg (2022) both show in various ways that the analyses underpinning these claims are theoretically and methodologically flawed. A study summarising 30 time-varying rate trials in the residential sector found that "the size of the difference between peak and off-peak prices does not fully explain the variation in the size of the consumer response across studies" (Frontier Economics, 2012). In another study where the methodology known as risk-of-bias, developed in the field of medicine to correct for common sources of biases in trials (such as selection, allocation and detection biases) on the effects of time-varying rates suggested that the bias-corrected figure for peak reduction was 2.5% instead of 6.9% (Davis et al., 2013).

Behavioural economic approaches

Along with existing legislative frameworks, economics has been a major tool by which governments have sought to steer people's behaviour. However, the rational choice theory that sits at the basis of neoclassical economic thinking implies that one can count on individuals behaving consistently in ways that are meant to benefit them. This has led to the traditional approach to economic interventions which assumes that setting the 'right' price and providing better information are sufficient for people to make the 'right' decisions. Over the last decades, however, a plethora of studies from the field of cognitive psychology have shown time and again that people do not always make strictly rational decisions, hence deviating from the expected rational economic decision-making which results in market behaviours that are at odds with the traditional economic models' expected outcomes (EIA, 2014).

In recent years, there has been an increasing interest in applying these insights and theories from the field of psychology to the study of these departures of the traditionally expected 'economic rationality', which has given rise to what has come to be known as Behavioural Economics (Chatterton, 2011). The basic premise of Behavioural Economics is that, rather than making extensive calculations regarding the utility of every option available to us, our brains are hardwired to make a range of mental shortcuts or heuristics, and researchers in this field have identified a host of behaviours that are counter to rational choice theory and can generally be classified under the umbrellas of cognitive bias and bounded rationality (EIA, 2014). It is, therefore, reasonable to expect that behavioural economic theories can shed some new light on individual choices and how people respond to different types of *stimuli*, including time-varying price.

Behavioural determinants that influence energy consumption are shaped by internal factors (such as individual attitudes, beliefs, values, personal norms) as well as external factors (such as regulations, institutional constraints and consumption practices) (Stern 2000). One of the key principles underpinning behaviour applied to time-varying pricing is that direct feedback can improve end-users' awareness as well as incentivise a more active engagement with time-varying tariffs. The effects of direct feedback are based on psychological theory of feedback, which dates back to the 1930s, with Skinner's (1938) model of operant conditioning: behaviours which produce a positive outcome are more likely to be repeated than those which produce a negative outcome. For instance, research on the impact of energy consumption feedback has shown that households that received reports regarding their consumption relative to neighbours were demonstrated to cut their usage by 2.5 percent, in a sustained manner (EIA, 2014). Time-varying pricing can induce either negative or positive feedback and bring about behavioural change (Vallacher & Wegner, 1987). At the empirical level, over a hundred empirical studies of energy feedback have been conducted over the past 40 years and over 200 articles have been published about energy consumption feedback during that time (Karlin et al, 2014). The general conclusions of behavioural studies on ToU pricing are that there are large, but unexplained, variations in responsiveness to ToU tariffs across consumers, which could (at least partially) be attributed to the fact that consumers are largely inattentive to complex pricing structures, including changes in dynamic marginal electricity price.

Social practices

Theoretical approaches to the study of social practices offer a viable alternative to behavioural economic approaches thanks to their focus on people's doings and the rhythms of everyday life. By placing the social ordering of people's activities at the centre of the study of social life, social practice theory offers a consistent ground for investigating issues relating to the timing of energy demand (Southerton, 2006).

Approaches based on social practices view the timing of energy demand as the result of the socio-temporal organisation of daily practices (Shove & Walker, 2014). Such approaches diminish the role of price in its most normative sense and shift the focus to multiple values of time. The nominal price of energy, i.e. the amount of money consumers pay for a unit of electricity, does not alter the essence of practices themselves, but may have some influence over the space-time in which practices are performed.

Practice theoretical approaches take two predominant views of their subject of study: practices as performances and practices as entities. A practice-as-performance takes place at a particular time and space when understandings, technologies, practitioners and activities come together in a specific way (Schatzki, 1996). For example, in the summer, doing the laundry could be postponed from a day to the next because of the sunny weather or brought forward by an hour to take advantage of an off-peak tariff. Even if laundering practices are carried out at regular intervals (say, once a week), this activity precludes an exact duplication and may not take place at exactly the same time and in exactly the same order. While the analysis of the practice-as-performance is interested in the moments of integration that occur when practices are in action, the analysis of the practice-as-entity focuses on the structured organisation of the practice. That is, the practice of doing the laundry comprises multiple non-dependent and recognisable actions (such as pulling out clothes from the basket, placing them in the washing machine, etc.), which together form the entity of 'doing the laundry'.

Understanding changes in the timing of energy demand through practice theoretical lenses involves studying social practices in terms of changes in the way they intertwine and how this unfolds over time. However, social practice theories – unlike individualistic behavioural approaches and their "attitude-behaviour-choice" paradigm – do not lend themselves easily to establishing a direct relationship with price-driven interventions. Previous work has looked at conceptualising time-varying pricing schemes such as ToU tariffs as 'disruptions' to everyday practices that throw some routines into a state of negotiation that is likely to result in some kind of change (Nicholls & Strengers, 2015). However, based on their comparative analysis of smart energy systems pilots in Norway, Austria, and Denmark, Christensen et al. (2020) conclude that, while time-varying prices matter when it comes to (re)shaping practices in the home, they should not be analysed in isolation as people's response to the (dis)incentives communicated through time-varying pricing "will always be closely interlinked with other elements of engagement, devices, and competences that are decisive for the actual effect of the pricing scheme".

Another observation relevant to the further elaboration of the practice-theoretical understanding of price is that financial incentives also play a role in making some practices more meaningful relative to others, and therefore more likely to be widely adopted (Christensen et al., 2020). It is clear, however, that this does not happen in the calculating and utility-maximising way implied by the rational economic choice model but through more general 'sense-making'. For instance, time-varying pricing can be seen as a tool to be used in an effort to increase awareness of the importance of electricity for those practices enabled by it (i.e. electricity-consuming practices). In turn, this increased awareness of the impact of certain practices on electricity (or energy) consumption could serve as the basis for incentivising the adoption of alternative practices or the acquisition of new skills that allow for making use of energy in more efficient ways (Strengers, 2011).

Other practice theoretical concepts closely related to energy consumption are the so-called 'hot-spots' and 'cold-spots'. The terms '*cold spots'* and '*hot spots*' are meant to capture the idea that activities are not evenly spread in everyday life and are constrained by collective and institutional rhythms (Southerton, 2003). Everyday life phenomena such as the existence of rush- or peak-hours are due to the existence of such practice 'hot-spots'. Since these peak hours are (more or less) predictable, it follows that time-varying pricing also has the potential to be used a tool for incentivising (temporal) shifts in demand or creating cold-spots when the normal everyday practices are temporarily suspended in favour of, say, family time (Southerton, 2003). In this view, while high social loads (i.e. hot-spots) do not always correlate perfectly with peak energy demand loads, by making electricity more 'visible' through price, so that it matters more, social and environmental circumstances can then influence and disrupt everyday activities that consume electricity in favour of less energy-intensive ones.

A brief review of studies on the relationship between Time of Use tariffs and the timing of electricity demand

Studies on ToU tariffs, behaviour and short-term price elasticity of demand

When it comes to empirical studies on price elasticity of demand for electricity, a distinction is usually made between long-term elasticities, short-term elasticities, elasticities from ToU pricing studies, and so-called 'real-time' elasticities. However, most current literature on price elasticities focuses on analyses of annual or quarterly data, or on elasticities of ToU pricing trials, with only a couple of examples of studies on real-time elasticities.
Behavioural approaches imply that normative values are attributed to consumption. People would be willing to pay for consuming electricity provided the price is right for them. In the context of time-variable pricing, changes to prices at specific times of day would prompt consumers to change the timing of demand (Nicolson et al., 2017; Yu et al., 2020). The comparison which every consumer (or household) would be faced with is between the price dictated by the energy retailer and their willingness to pay, for instance, to get the laundry done at the desired time of day. In parallel, consumers are willing to accept a premium for price changes and shift consumption when it is less convenient provided the disruption is worth the financial return associated with an off-peak price offering. The normative time-varying price is therefore confronted with consumers' values which can vary depending on factors such as social norms (Delmas et al., 2013), convenience (Öhrlund et al., 2019) and quality of life (Ozaki, 2018). The resulting demand elasticity to price is framed as an average outcome of a mix of (often conflicting) values. Figure 1 provides a summary of trials in Great Britain, Northern Ireland, and Ireland. The average reduction in peak demand is between 5%-10% and discrepancies are very significant.

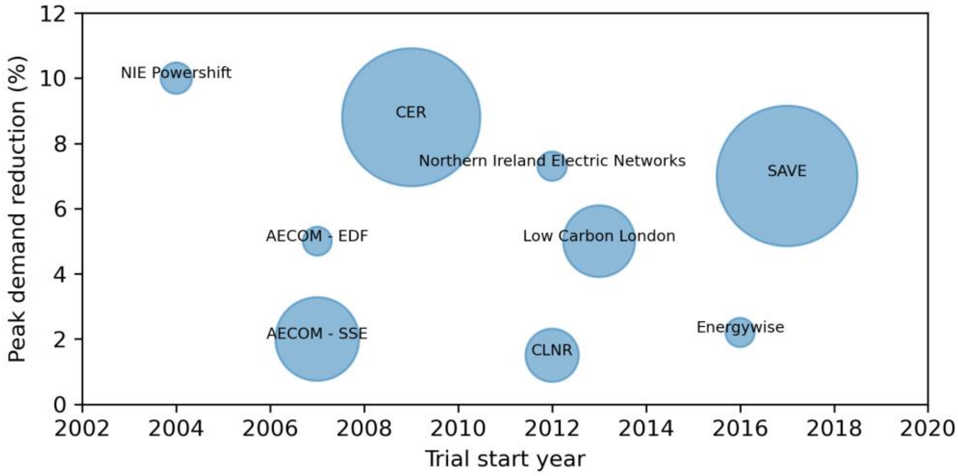

Figure 1 – Graphic summary of the discrepancies across ToU tariff trials' findings. The size of the bubble corresponding to each trial is proportional to the sample size of each trial (min: Energywise [n=173]; max: SAVE [n > 4000]).

Studies on ToU pricing and social practices

In an attempt to overcome an excessive emphasis on price and behaviour, whilst integrating everyday life aspects of energy demand, a growing body of work points to specific practices or activities' temporal shifts in response to ToU pricing. According to such studies, understanding the dynamics of energy demand and the variation which occurs in association with ToU pricing is a matter of studying the ordering of social practices. Price is inferred to have the power to flex individual practices. Hence, an output (change in the timing of an individual practice) corresponds to an input (differential pricing between peak and off-peak).

Powells et al. (2014) analyse the flexibility of individual practices during peak hours in response to ToU pricing. They find that flexible practices (i.e. practices performed differently as a result of Time of Use tariffs) include laundry, household chores and dishwashing. Domestic cleaning practices, such as laundering, are considered to be relatively flexible in time in other studies (Jack, 2016). Smale et al. (2017) group practices in relation to the appliances involved and issues around time. They show that, in terms of energy end-uses, timing is critical for lighting, heating and cooling spaces; in terms of practices, cooking, eating and leisure activities are time critical, whereas domestic cleaning is not seen as time critical. In general, households changed the performance of a number of practices only if these were not specifically tied to socially conventional times (e.g. mealtimes). In a Swedish study, practices which were regularly shifted from peak to off-peak hours included dishwashing and laundry (Öhrlund et al., 2019). Other practices such as showering, tumble drying, vacuum cleaning, bubble bathing and sauna bathing were also shifted from peak to off-peak hours on several occasions (though not as regularly as dishwashing and laundry).

Conversely, and following perfect parallelism, practices are identified as inflexible if they are not performed differently as a result of the introduction of ToU tariffs. For instance, practices such as cooking and watching TV are considered inflexible according to Powells et al. (2014). Practices specifically tied to socially conventional times constrain their temporal flexibility. Lighting, heating and cooling of spaces are grouped as inflexible practices as they relate to comfort (Friis and Christensen, 2016). According to these studies, seasonality affects the daily rhythms of lighting and heating, which are otherwise considered highly inflexible. Light and warmth are seen as 'necessary' services. Cooking, eating and leisure activities tend to be clustered together. Food and entertainment are also considered to play an important role in shaping and maintaining social bonds between members of a household. Two explanations are presented for the inflexibility of eating practices. First, bodily needs and temporality seem to be more strictly defined when it comes to eating. Second, decisions around the timing of food preparation and eating (as well as entertainment) practices often have an added (albeit rather hidden) layer of complexity due to the coordination between household members required when it comes to organising family meals (Higginson, 2014). Electricity-intensive forms of entertainment like watching TV and videogaming are two more examples of inflexible practices during which people relax and are typically less reflexive of energy issues (Smale et al., 2017).

A common trait that these studies investigating the flexibility of practices share is that flexible practices are treated in isolation. For instance, cooking practices might be inflexible either because of social conventions around meals (Murtagh, et al., 2014) or because they are strongly connected to the temporal organisation of other practices such as going to work, taking children to school, doing homework, watching television, etc. (Nicholls & Strengers, 2015).

The main lesson learned from the empirical literature on ToU pricing and flexible practices is that price does not exert the same effect on all practices. An approach focusing on the flexibility of individual practices necessarily decouples practice from their relationships to other practices and de-historicises those relationships. Changes in the interaction between practices and price or value are not necessarily understood solely in terms of flexible practices and other lines of enquiry are needed to widen perspectives and integrate approaches and methodologies which value time as explained in the following section.

Widening perspectives on Time of Use tariffs

The concepts reviewed in the previous section attempt to connect ToU tariffs with energy demand and yet do not engage critically with how time is valued in relation to varying prices. At the expense of oversimplifying, Figure 2 illustrates the direction that studies on price elasticity, behaviour and social practices would need to undertake in order to widen their perspectives on the effects of ToU tariffs on energy demand.

This section presents a preliminary effort to introduce alternative approaches and techniques which are not currently in use in ToU studies. Applications in the realm of time-varying energy pricing are discussed with a view to widen the perspective on ToU tariffs. Three tentative approaches are presented below.

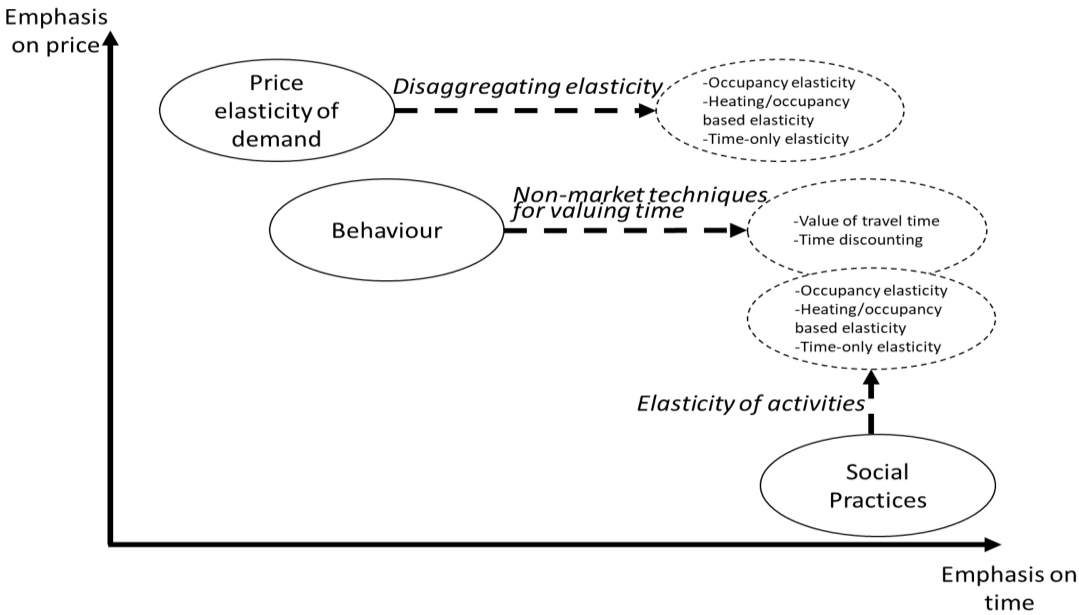

Figure 2 – The location of concepts relevant to understanding the impact of ToU tariffs on energy demand in the price-time 'emphasis space' and the direction they would need to pursue along these dimensions in order to widen our perspectives.

Disaggregating elasticity

The term 'price elasticity of demand for energy' would appear to indicate that price is the most important – if not the only one – factor when it comes to measuring changes in demand. However, by disaggregating this demand elasticity into components which closely relate to the temporal and spatial elements of human activities, a more precise representation of their interaction with ToU tariffs could be reached. For instance, one suggestion is that considering other variables in addition to price would help provide a better account of observed changes in demand. Three possible examples of such variables are: (i) occupancy elasticity, (ii) heating and occupancy-based elasticity; and (iii) time-only elasticity.

For instance, occupancy elasticity could be defined and measured as the variation of the level of energy demand given changes in occupancy over time. Occupancy elasticity starts from absolute inelasticity for unoccupied households (i.e. nothing can change if nobody is home), and increases with occupancy (i.e. the more people at home, the more possible scenarios and outcomes). However, this is not to say that more people equals more elasticity as, crucially, this is also a function of time. For instance, at peak time, where energy demand increases more than occupancy rates, there might be high inelasticity of energy demand.

Taking as a starting point the suggestion that heating varies according to temperature and occupancy, the elasticity of heating demand could be based on changes in temperatures and occupancy (rather than price). A heating and occupancy-based measure of elasticity would determine: (i) whether changes in temperatures have a higher weight than occupancy as regards changes in heating demand or (ii) whether changes in occupancy have a higher weight than temperatures as regards changes in heating demand.

A time-only version of elasticity could simply describe how the activities that people engage in change over different periods of clock-time, (e.g. from one 10-minute period to the next) and how these changes affect energy demand.

There are, no doubt, other routes to take. And further analyses of alternatives to 'pure' price elasticity might provide some clues as to the direction that unconventional approaches to temporality and energy demand might follow. For the time being, however, the works cited below are examples of studies that could be used to establish the foundations for further research into the proposed alternatives.

With regards to non-averaged price elasticity, a recent study by a group of Swedish researchers looks at elasticity changes during the day for lighting, cooking and, to a lesser extent, heating (Broberg & Persson, 2016). The approach used in this study entails a move away from typical average elasticities in an attempt to incorporate the time of day and aspects of space within the household into price elasticity calculations.

With reference to occupancy elasticity, Torriti (2012) looks at daily occupancy levels of single-person households in 15 different European countries. This work measures how occupancy varies within 10-minute intervals based on time use data. Changes in occupancy throughout the day vary significantly across countries. For instance, in Southern European countries occupancy is generally higher later in the evening and, correspondingly, peaks in residential electricity demand take place later in the day.

Regarding time-only elasticity, some research in this direction was carried out as part of quantitatively estimating the clock-time dependence of household practices (Torriti, 2017). An analysis of UK time use data shows that washing has the highest value on the time dependence metric; using computers is the least time-dependent practice; Tuesdays, Wednesdays and Thursdays have the highest time dependence for all practices; and certain energy-related practices have higher seasonal dependence than others.

Non-market techniques for valuing time

For decades, the economics literature has utilised techniques to provide monetary values to time. In essence, the principle of time as a finite resource and the utility associated with it constitute the basis for most of the valuation techniques, including travel time and time discounting. These include contingency valuations, human capital approaches and other methods which intend to estimate society's willingness to pay (or accept) for specific changes in people's lives where monetary values do not exist. Life itself is an example of what gets monetised as part of these techniques through 'value of statistical life' estimates typically utilised for policy appraisals where saving lives is compared with other benefits and costs. Whilst some techniques, like in insurance practice, make assumptions around duration and frequency of activities, others more explicitly value time in monetary terms. For instance, the medical cost assessment is a technique which provides a monetary value for reducing the time of hospitalisation.

The value of travel time can be defined as the price people are willing to pay to acquire an additional unit of time. This value can often be determined by estimating mode choice models and evaluating marginal rate of substitution between the cost and travel time of the alternative modes. Values of travel time savings vary depending on journey purposes, the characteristics of the journeys being made and the preferences of individual travellers (HM Treasury, 2016). Journey purposes may consist of commuting (to/from a usual place of work), employer's business (i.e. journeys made in the course of work), and other non-work-related trips (i.e. all other trips such as shopping, leisure and personal trips). For non-work-related trips, the value of travel time savings represents the value travellers place on the activities they are able to engage it thanks to the time savings. For instance, in response to a quicker commute a traveller could choose to spend more time at home with their families or move to a bigger house further away from work. Under this approach, the time valuations differ depending on certain conditions. For instance, saving walking or waiting time has a higher perceived value than time spent in a vehicle. Valuations of travel time have recently been applied in the realm of Electric Vehicle charging, where travel time is generally negatively correlated with Electric Vehicle driver utility, especially when additional charging stops are required due to an insufficient state of charge at the time of departure (Fridgen et al., 2021).

Time discounting is the process of attributing higher value to actions happening in the present relative to those actions scheduled in the future. This is based on what economists refer to as 'pure time preference' and is separate from the concept of rate discounting (Torriti and Ikpe, 2015), which is typically applied to off-peak periods as part of time-varying tariffs. Time discounting has implications for prioritising preferences in the short term compared with those happening further into the future. This means that, in essence, the returns associated with ToU tariffs could be diminished if they took place chronologically after other returns. For instance, because of pure time preference, the nominal market price of 'doing the laundry' at peak times will be immediately higher than that of doing the laundry during off-peak periods the following day. Yet, the non-market value of doing the laundry when it's deemed necessary might be higher than that of the alternative (e.g. waiting for the off-peak period to do the laundry), even if that means incurring in a higher economic cost.

Elasticity of activities

Studies focusing on individual activities take the nominal ToU price at market value. For activities which are likely to involve using electricity, such as preparing food, washing dishes, washing bodies, cleaning, washing clothes, watching television and listening to the radio, often using various appliances and devices, there is a nominal price associated with the amount of electricity consumed. What could be the monetary value of performing these activities and their corresponding price elasticity? These activities themselves do not feature a nominal price unless they are commodified in the form of a market relationship between those performing the chores (e.g. a cleaner) and those commissioning them (e.g. a tenant or homeowner). For this particular example, the duration and intensity of cleaning determines how the commodification of the chores translates into monetary values. Bonke (1992) focuses on how to best evaluate the time dedicated to household duties, whether by a market-price or an opportunity-cost approach. According to the former approach, the hourly wages of outside collaborators recruited from the labour market can be translated into a valuation of the time needed to be spent by household members on the practice itself. With regards to the latter approach, time spent on household duties by each subject is subtracted from the total time available for engaging in paid work in the market (i.e. time spent in 'house work' is time that cannot be spend in remunerated activities).

Table 1 illustrates an example of household activities and corresponding nominal price of electricity use as derived from equivalent hourly wages for jobs performing those tasks, the electricity appliances employed, the average electrical loads of these appliances, the nominal price of electricity consumption and the corresponding nominal price of electricity use. This classification is presented here for illustrative purposes only. As mentioned above, the practices cannot be confined to market values of the time associated with those performing them and nominal price of electricity of the appliances used in the household. However, studies focusing on individual activities could in principle be expanded to integrate elasticity estimates.

The alternatives presented by the two approaches discussed above are 'low-hanging fruits' that could be used as the basis for more complex valuation analyses of the great diversity of practices people engage in in their everyday lives. And then, there is the issue of estimating the corresponding price elasticity of such practices. There are only so many hours in a day, and most people spend roughly a third of these sleeping. Those who are economically active also have to factor in their contractual hours. Similarly, there are many other time commitments that need to be taken into account (e.g. time needed for commuting). Therefore, there is only so much room for shifting other activities in time within the time budget allocated to them. Inevitably, this also raises questions around differences in these time budgets and the additional constraints that 'time-poor' individuals would be subject to.

Other relevant questions are, for instance, how does the elasticity depend on how specific activities hang together with other (sets of) household practices? Do we run the risk of decontextualising said activities by valuating them in this manner? And how do considerations of price and (different forms of) elasticity provide room to consider societal differentiation in terms of ability (or willingness) to provide flexibility? Providing an answer to these questions falls beyond the scope of this paper, but perhaps there is still value in asking them here as they point to the potential avenues for further research into these issues.

Table 1- Example of household activities and corresponding nominal price of electricity use (in GBP).

Practice	Monetary value of the activity	Electricity appliances	Average electrical load (kW)	Nominal price of electricity use (p/kWh*)
Preparing food	Y (£8/hour, based on average wage of a cook in UK restaurants)	Hob	2.4	39.1
		Oven	2.13	34.7
		Microwave	1.25	20.4
		Kettle	2	32.6
Washing dishes	Y (£6/hour, based on average wage of a dishwasher in UK restaurants)	Dish washer	1.13	18.4
Washing	N	Electric shower	9	146.7
		Central heating pump	0.6	9.8
Cleaning	Y (£12/hour, based on average wage of a cleaner in UK)	Vacuum	2	32.6
Washing clothes	Y (£9/hour, based on average wage of a launderette attendant in UK)	Tumble dryer	2.5	40.8
		Washing machine	0.41	6.7
		Washer dryer	0.79	12.9
		Iron	1	16.3
Watching TV and listening to the radio	N	TV	0.12	2.0
		TV receiver box	0.03	0.5
		Radio	n/a	n/a
Using computer for leisure	N	Personal computer/console	0.14	2.3
Using computer for work	Y (£14/hour, based on average wage of a £30k yearly salary)	Personal computer/console	0.14	2.3

* In Britain, energy tariffs are usually expressed in terms of pence (p) per kWh (i.e. p/kWh); 1 p = £0.01

Conclusion

As countries all over the world increasingly expand the implementation of ToU tariffs, not only trials, but also market applications of such tariffs will increase researchers' access to data. It is critical that analyses on the effects of ToU pricing do not continue to be limited to simple price/demand equations, on the one hand, and constrained by disciplinary – primarily economic – views on the role of price and time, on the other hand.

For decades the energy economics literature has been investigating the relationship between time-varying tariffs and energy demand. In the case of ToU tariffs, such attempts can be summarised in the form of short-term price elasticity of demand. Behavioural studies often offer a more nuanced approach to explaining non-financial reasons as to why individuals respond to price *stimuli* with emphasis on individual attitudes, beliefs, values, personal norms as well as regulations and institutional constraints. Conversely, approaches based on social practices have provided a foundation for understanding variation in the timing of energy demand but have fallen short of developing convincing accounts around the relationship between price and energy demand. In its attempt to move away from the traditional emphasis on getting the price right, the paper puts forward three specific contributions to widen perspectives on the relationship between ToU pricing and energy demand.

First, this paper argues that price elasticity of demand metrics would benefit from the inclusion of additional variables which better represent the time and space in which ToU tariffs and energy demand interact. Tentative applications involve occupancy elasticity, heating and occupancy-based elasticity; and time-only elasticity.
Second, behavioural studies on the impacts of ToU pricing would profit from the integration of techniques which enhance both how time is represented and how price is integrated with the timing of energy demand. In essence, the paper suggests the integration of non-market valuation techniques such as travel time and time discounting to behavioural studies on ToU pricing effects.

Third, those social practice studies on ToU pricing focusing on individual activities would benefit from analytical efforts to incorporate techniques which estimate the elasticity of activities. This is an extremely challenging endeavour and the example in Table 1 on nominal prices for individual activities is far from a definitive market valuation. The purpose of that exercise is merely to ignite scholarly conversations around how social practice theories can engage with ToU behaviour and pricing.

We conclude that 'setting the right price' for ToU tariffs is a matter of (substantially) enhancing our knowledge and understanding of the dynamics of energy consumption and the links between price and demand for energy. Metrics which are enriched by non-price information can pave the way towards more radical approaches to demand (and carbon emissions) reductions through better alignment of time-varying pricing and people's everyday life. It is also clear that, in order for any of these price-driven approaches to demand management to be truly effective, it is necessary to raise awareness of what higher (or lower) electricity prices mean, and remove the stigma around higher prices which are typically seen as unwarranted punishments. Ultimately, it all comes down to making electricity 'visible', which is a drastic departure from the paradigm of the last century, where consumers are seen as a passive component of the energy systems whose only purpose is to pay for their bills. There is much to gain by bringing the role of energy, as well as the impacts of consumption, into the collective forefront. On the one hand, we would be better able to appraise the role of energy (services) for the attainment of wellbeing; on the other hand, we would also be able to develop more effective strategies for incentivising energy demand reductions without negatively impacting on wellbeing. Undoubtedly, there is much to be done, but we certainly hope that the proposals put forward in this paper will spark some much needed further debate and research into these issues.

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