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Smart choices? An experimental study of smart meters and time-of-use tariffs in Ireland

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Abstract

The introduction of smart technology and dynamic tariffs (such as time-of-use tariffs) provides multiple potential benefits for electricity markets. However, time-of-use tariffs represent an additional complexity for consumer tariff choices in electricity markets. How well consumers may choose between different types of tariffs, and whether certain tools can improve these choices, are therefore important questions for energy regulators and policy makers. This paper presents the results of an exploratory study that used experimental behavioural science to explore the issue of consumer choice in electricity markets for time-of-use tariffs. A representative sample of consumers (*n*= 145) were given information about smart meters and time-of-use tariffs. Attitudes towards smart meters and comprehension and choice quality between different types of electricity tariffs (judged against participants' own perceptions of their electricity usage) was measured through a sequence of experimental tasks. Findings suggest that a general aversion to time-of-use tariffs may lead to sub-optimal choices between different types of tariffs. Participants were also asked to choose between different priced time-of-use tariffs via an experimental price comparison site. Tools which facilitate personalised estimated costs were shown to significantly improve decision-making between such tariffs. Potential policy implications, in light of these findings, are discussed.

Keywords: Smart meter; time-of-use tariff; consumer choice; behavioural economics

JEL Codes: C91, D12, Q41

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1. Introduction

The introduction of smart technology in electricity markets may be important for improving the efficiency, reliability and cost effectiveness of future electricity supply (e.g. Faruqui *et al*., 2010a, Faruqui *et al*., 2010b, Faruqui and Palmer, 2012). Primary aspects are the ongoing global roll-out of smart meters and the introduction of dynamic electricity tariffs, such as time-of-use (ToU) tariffs. ToU tariffs charge different prices for electricity at different times of day, providing price signals to consumers to shift usage from peak to off-peak times. Smart meters and ToU tariffs are increasingly available to domestic electricity consumers across North America, Australasia and Europe. A 2009 European Union directive aims for at least 80% of consumers in participating countries to install smart meters in their homes by 2020 (European Parliament, 2009). For this infrastructural change to be cost effective, however, consumers need actually to take-up and engage with these products at levels greater than previously seen (Faruqui *et al*., 2010a).

The present study was prompted by the forthcoming roll-out of smart meters and ToU tariffs in Ireland. It was conducted in collaboration with Ireland's energy regulator, the Commission for Regulation of Utilities (CRU). The aim was to employ experimental behavioural science to investigate consumer attitudes, comprehension and decision-making towards smart meters and ToU tariffs. We undertook an exploratory laboratory study. Its four stages were designed to observe consumer decisions at four key points in the roll-out process of smart meters and ToU tariffs. Each stage addressed a specific research question, using tasks and experimental manipulations informed by the existing behavioural science literature. However, while designing the experiment it became apparent that previous research (see below) has focussed overwhelmingly on demand for different ToU tariffs without considering the capability of consumers to understand their own usage and to match it to an appropriate tariff. In experimentally assessing these capabilities, we address a gap in extant literature.

The primary contribution of the paper is, therefore, to provide insights into consumer responses to the introduction of smart meters and ToU tariffs. By identifying and investigating some key psychological mechanisms underlying ToU tariff choice, the study provides evidence of relevance to energy regulation and policy, not only in Ireland but across international markets. Thus, a secondary contribution is to demonstrate how behavioural experiments can support empirically informed regulation (Sunstein, 2011).

Research questions were identified in collaboration with CRU. First, given that consumer engagement with and adoption of smart meters is likely to depend on initial sentiment, an initial research question was:

1) *What are consumers' general attitudes towards smart meters?*

Three further research questions were linked to plans for the roll-out in Ireland. ToU tariffs are to be introduced in addition to existing flat rate tariffs[1]. Suppliers will also be required to offer a static ToU tariff[2] with time periods determined by CRU but prices permitted to vary across suppliers (henceforth the *standard* ToU tariff). Importantly, suppliers will be able to offer additional static ToU tariffs that differ in both time periods and prices (Commission for Regulation of Utilities, 2018a). Thus, consumer choice between tariffs is likely to have an important bearing on the success of the policy. Testable research questions were:

2) *Does the framing of a "standard ToU tariff" alter its attractiveness?*
3) *What information can help consumers choose between ToU tariffs based on their energy usage?*
4) *How does the presentation of ToU tariffs affect the understanding and appeal of these tariffs?*

Consumer decision making capability cannot be taken for granted. It is a well-established finding that consumers often choose sub-optimally even among conventional flat rate electricity tariffs (Wilson and Waddams Price, 2010). In Ireland, consumers could have saved €1,146 on their electricity bills by switching to the optimal supplier over the 2013-2017 period (Commission for Regulation of Utilities, 2018b). Undeniably, ToU tariffs introduce additional complexity to consumer choices. Increased choice complexity can reduce decision quality and lead some to avoid choosing altogether (Mogilner *et al*., 2008, Dowding and John, 2009). Consequently, it is important to understand how well consumers can choose among these innovative, but more complex tariffs, and to ascertain whether certain tools might be deployed to help consumers to make good choices.

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[1] The Irish market does contain day/night tariffs that operate via separate meters. The proportion of consumers on these tariffs is low, however, so they were not considered sufficiently important to feature substantially in the present study.

[2] A static ToU tariff is one in which the time periods for different rates are known and fixed. Other types of dynamic tariffs available in other countries include dynamic ToU, critical peak pricing and real time pricing (see Nicolson *et al*., 2018, for definitions of these).

Laboratory experiments are increasingly used to inform public policy and in social science more generally (Falk and Heckman, 2009). Although hypothetical measures of preference and (perhaps especially) willingness to pay can be subject to "hypothetical bias" (Harrison and Rutström, 2008), measures of capability are likely to be more reliable and can be incentivised (Lunn and Ní Choisdealbha, 2018). Exploratory designs that assess the accuracy of decision making at different stages of purchase have been successful in providing a wide range of insights in other public policy domains, for example in the regulation of car finance (McElvaney *et al*., 2018). For present purposes, we designed an exploratory laboratory experiment to record consumer decisions between ToU tariffs in a controlled environment. The novel design required participants to estimate their electricity usage across a week, and measured tariff choice quality based on this estimate.

The rest of the paper proceeds as follows. Section 2 draws from the existing relevant literature to motivate our approach, which is outlined in Section 3. Section 4 provides the results and section 5 discusses these findings, considers policy implications, and highlights scope for future work. Section 6 concludes.

2. Existing Literature

2.1. Smart Meters

One of the potential benefits of smart metering is that consumers can engage with their electricity usage more immediately (Sintov and Schultz, 2015). Although billing information has traditionally exposed consumers to infrequent periodic electricity usage (for example at monthly or bi-monthly intervals), smart meters record electricity usage periodically throughout each day. Feeding this directly to providers removes the need for physical meter readings. For consumers, electricity can be an invisible or abstract consumption good (Fischer, 2008), but smart meters in tandem with technology, such as in-home displays (devices to display real-time electricity usage information), allow consumers to observe current electricity use and potentially alter usage. Previous research has investigated how smart meters and in-home displays influence electricity usage, especially when linked to dynamic electricity tariffs. Smart meters and feedback mechanisms have the potential to reduce usage by 2.5% - 12% (Fischer, 2008, Faruqui *et al*., 2010b, Faruqui and Palmer, 2012, Commission for Energy Regulation, 2011, Bager and Mundaca, 2017).

Regulators in Ireland have surveyed attitudes towards smart meters, finding that 43% of consumers would be willing to have one installed (Commission for Regulation of Utilities, 2018b), a figure broadly consistent with other countries, including the UK (39%, Department of Energy and Climate Change, 2014). However, responses are typically gathered within a wider survey where respondents do not receive information about the potential benefits of smart meters, such as monetary gain and environmental improvement. Framing benefits in terms of environmental gains rather than monetary gains can increase acceptance of energy saving measures (Schwartz *et al*., 2015) or reduce actual usage (Asensio and Delmas, 2015), although others have found no such difference (Steinhorst *et al*., 2015).

2.2. ToU Tariff Demand

Research into ToU tariff acceptance has recorded substantial variation across countries and studies (Nicolson *et al*., 2018). Many studies have compared consumer attitudes to different dynamic electricity tariffs, including, but not limited to the static ToU tariffs to be introduced in Ireland. Typically, flat rate tariffs are preferred to any and all ToU tariffs (Dütschke and Paetz, 2013, Stenner *et al*., 2015), but different types of dynamic tariffs may be judged more or less appealing (Fell *et al*., 2015, Nicolson *et al*., 2018).

Hobman *et al*. (2016) suggest that various mechanisms from behavioural science could influence attitudes and behaviour towards adopting ToU tariffs. Loss aversion (Nicolson *et al*., 2017) and risk aversion (Qiu *et al*., 2017) can inhibit ToU tariff demand. Nicolson *et al*. (2018) show that opt-out policies are more effective than opt-in policies at inducing take-up, confirming the presence of default effects or status quo bias (e.g. Samuelson and Zeckhauser, 1988). However, they also highlight the potential difficulty (and associated ethical question) of implementing an opt-out policy for ToU tariffs (p.287), suggesting “softer” approaches might be more appropriate.

Far less research effort has investigated how consumers choose between ToU tariffs. In a meta-analysis of ToU tariff demand by Nicolson *et al*. (2018), no study investigated consumers’ choices when faced with the same types of tariffs but with different time or pricing structures. Although experimental survey data has been used to study consumer choices between different types of dynamic pricing, this is fundamentally different to choices between different price points and time periods for the same type of tariff. In previous field studies investigating consumer response to ToU tariffs in Ireland (e.g. Commission for Energy Regulation[3], 2011) and the USA (e.g. Cappers and Sheer, 2016, for a review of studies), sample populations were randomly assigned to control or intervention groups. Typically in such studies, consumers in the control group remain on a conventional flat rate tariff, while those in the intervention group are arbitrarily assigned to a ToU tariff. This is a methodological construct to minimise selection bias when measuring subsequent behaviour, but it by definition does not consider consumer choice among tariffs as a factor. Yet, in reality, these are choices that consumers will have to make and which may have a strong bearing on the ultimate impact of smart meter installation. The lack of investigation of consumer choice therefore constitutes a gap in the literature.

Research in other domains finds evidence of primacy effects: alternatives that are viewed first are evaluated more favourably than alternatives viewed later (e.g. Bruce and Papay, 1970, Belton and Sugden, 2018). The order in which tariff options are presented may thus influence choices. Additionally, when preferences are uncertain, individuals may look to expert opinion to help inform decision making (Beshears *et al*., 2008). Signalling to consumers that a particular tariff from a range is the "standard" may encourage take up of that tariff. Yet Hledik *et al*. (2017) failed to find a significant positive impact of promotional marketing messages in a binary switching task for energy tariffs, although the potential salience of an accreditation signal may increase when comparisons are made against multiple choice options.

The presentation of ToU tariffs may affect both their attractiveness and consumers' understanding of them. ToU tariffs are commonly presented in "traffic-light" colour-coding (e.g. Commission for Energy Regulation, 2011, BE Works, 2014). Research in other domains, such as food labelling, finds that such colour-coding can improve the comprehension of key information (Littlewood *et al*., 2016). Linearization of time (presenting a 24-hour clock in a linear, horizontal format) could also improve comprehension of ToU tariffs (BE Works, 2014).

A challenge when deploying surveys and experiments rather than field trials is to define objective criteria for the quality of respondents' decisions. In the present study, efforts were made to provide an appropriate benchmark for assessing the quality of tariff choices. In the absence of real usage data, other studies have relied on self-reports of when household appliances are used (Buryk *et al*., 2015) or whether most usage is during peak times (Qiu *et al*., 2017). Here, we go further by asking participants to estimate their proportional electricity usage

[3] The Commission for Energy Regulation preceded the current energy regulator, the Commission for Regulation of Utilities, in Ireland.

across the different time periods of a ToU tariff. From these estimates, costs may be compared for different tariffs and so quality of tariff choice can be assessed. This approach rests on the premise that to choose a good tariff consumers must generate some kind of internal representation or estimate of their own usage. Although an individual's beliefs about when they use electricity throughout the day may differ from their actual usage, these initial beliefs will influence their initial perceptions of or engagement with ToU tariffs.

The ability of consumers to choose an optimal electricity tariff given their current usage is only part of the decision of consumers. An additional important aspect of ToU tariffs is their role in encouraging energy behaviour change. However, the quality of consumer choice is likely be influenced by their initial perceptions of what constitutes a good tariff for them at present, and identifying potential for behaviour change (as well as accurately predicting the likelihood to follow through with the intended behaviour change) represents an additional complexity in tariff choice. It is first then an important empirical question to measure the effect of tariff choice without considering this additional complexity.

A general advantage of behavioural laboratory studies such as this present study is that they enable complete control of the experimental environment (Lunn and Ní Choisdealbha, 2018). Because we were primarily interested in consumers' ability to match their usage pattern to a tariff, the study was designed to control for anticipated future behaviour change as a rationale for tariff choice. Descriptions of how this was achieved are provided in the experimental designs for the relevant stages (found in sections 3.2 and 3.4).

3. Experimental Design

This study utilised an exploratory experimental methodology involving multiple stages. The advantage of exploratory studies, especially in domains relevant to policy, is that they allow for a sequence of research questions to be tested in a single study. A necessary trade-off is the need to simplify the experimental design at each stage. The stages in this study employed a combination of choice tasks, which were designed to mimic the consumer experience of the introduction of smart meters and ToU tariffs, and judgement tasks, which presented a series of multiple choice questions (MCQs) about the features of certain ToU tariffs. The choice tasks were: (1) Smart Meter Letter task, (2) Tariff Choice task, (4) ToU Price Comparison Site task. The judgement task was: (3) ToU Tariff MCQ task. The introduction of smart meters and ToU tariffs presents three key issues for consumers to consider:

1) *Do I get a smart meter installed?*

2) *Do I choose a ToU tariff?*

3) *What tools can help me choose between different ToU tariffs?*

Figure 1 below shows how the stages in this experiment were designed to provide insight into each of these three questions.

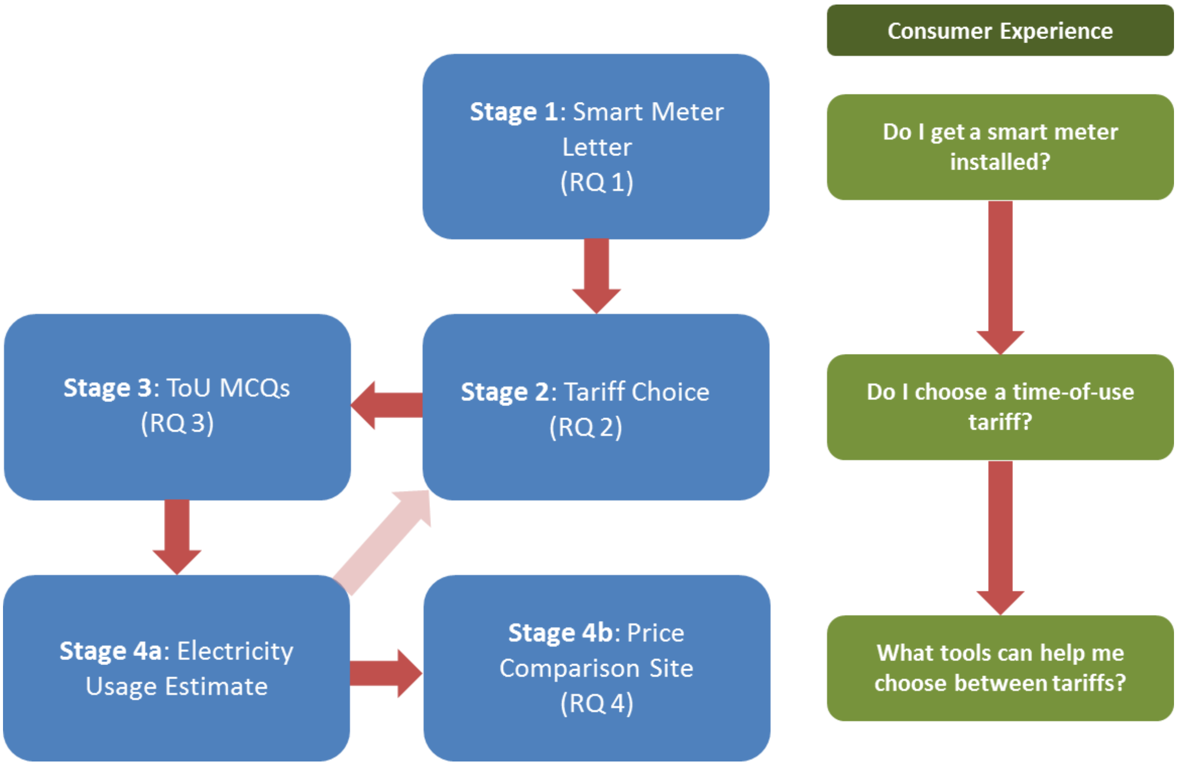

Figure 1. Experimental walkthrough of stages and consumer experience

3.1. Smart Meter Letter task

In this initial stage, participants were shown a letter from a fictional electricity supplier offering to fit a free smart meter in their homes. After reading the letter, participants were asked whether they would agree to the installation if they received that letter. In addition to basic information about smart meters and installation times, the letter contained information about the potential benefits of smart meters and future ToU tariffs, and the content of this was manipulated across participants in a 2 x 2 between-subject design[4]. The two manipulations were:

[4] Full templates of the letters, and differences between formats can be found in Appendix A.

Benefits Framing: Half the letters contained potential environmental and infrastructural benefits of smart meters and ToU tariffs (the 'Environment' condition) and half contained potential monetary benefits (the 'Money' condition). The differences in benefit framings within the two types of letters can be seen *italicised* below:

Environment

..."*Smart meters can help each of us to do our bit for the environment by providing real time usage information and showing you how much electricity you are using at any given time. This can help you to cut out wasteful electricity use."*...

..."[Time-of-use tariffs] *help address the issues of demand on electricity supply, by charging more when demand is higher and less when demand is lower. This helps to make electricity supply more reliable and can reduce the risk of power outages.*"...

Money

..."*Smart meters can help to make electricity billing simpler by providing real time electricity usage. This removes the need for estimated bills and so means you only ever pay for the electricity you use.*"...

..." [Time-of-use tariffs] *may allow some customers to save money on their electricity bills by shifting their electricity usage to times of the day when electricity is cheaper. This can give customers more control over their electricity costs.*"...

Roll-Out Information: Half the letters contained a statement informing them that, since smart meter roll-out was a government objective, those who did not agree to installation may be contacted again in the future. This information was omitted in the other half of letters. The content of this roll-out information is below:

"*The government is committed to rolling out smart meters in every household by 2024. This means that if you do not arrange a smart meter installation now, we will get in touch to try and arrange installation at another time.*"

This task was not the main aim of the study, and within the task itself, the main aim was to observe consumer attitudes towards smart meter installation in the presence of general information about smart meters and their benefits. Given a relatively small sample size (n= 145), a 2 x 2 between-subject design meant any effect sizes would need to be substantial in order to detect an effect between the specific manipulations. Nevertheless, the presence of a large effect size following relatively small manipulations to the letter content could be of interest to policy makers in the design of communication material, and so we judged the above manipulations to be of interest.

3.2. Tariff Choice task

In the next stage, participants were asked to imagine that a smart meter had been installed in their home[5]. They were shown four tariffs and asked to choose the one they would prefer if they were making the decision in real life. They were not explicitly asked to consider their electricity usage patterns at this point. The four tariffs were:

Standard ToU (ToU): Four different tariff periods throughout a 24-hour period. This tariff was designed in collaboration with CRU and was the target tariff of interest.

Non-Standard (NS3) ToU: An alternative with three different tariff periods that might be made available in addition to the *Standard ToU* tariff.

Non-Standard (NS2) ToU: An alternative with only two different tariff periods – day and night – that might be made available in addition to the *Standard ToU* tariff.

Flat Rate: A conventional flat rate tariff where the price of electricity did not change throughout a 24-hour period[6].

The prices of these tariffs were designed such that the *Standard ToU* tariff was cheaper than the alternatives for all but those with highly unusual usage patterns – those consuming a substantial percentage of electricity during the most expensive period. This strategy enabled an estimation of the financial cost of any aversion to these ToU tariffs. Note that this stage imposed a forced choice, whereas in reality consumers might be able to avoid making a choice and simply remain on their current tariff. The forced choice was used to counter the potential

[5] In the instructions for Stage 2 the motivation for why a smart meter would be installed in their home differed according to their response in Stage 1.
[6] Details of the time periods of rates for each tariff are outlined in Appendix B.1.

for responses to be dominated by status quo bias. We were interested in how well individuals could identify an advantageous tariff when making an active choice. Given this, the proportion of participants opting for a ToU tariff will be an overestimate if in reality consumers are able to avoid making an active choice of tariff following the instalment of a smart meter.

This stage judged the quality of choices against consumers' perception of their own current consumption. It is theoretically possible that a participant would choose a tariff not because it was cheapest for their current usage pattern, but because it would be cheapest if they made certain changes to their electricity usage. However, we designed the options such that where the *Standard ToU Tariff* was cheapest given current usage, the only behaviour change that could make an alternative tariff relatively cheaper required an increase in consumption during peak times, i.e. the opposite of the intended effect of ToU tariffs. Thus, anticipated behaviour change should not explain choices in the Tariff Choice task.

In addition, this stage manipulated the salience of the *Standard ToU* tariff relative to other options, in a 2 x 2 between-subject design. The two manipulations were:

Order: For half of participants, the *Standard ToU* tariff was presented as the top of four tariff options. For the other half, the position of this tariff was determined by random selection from among the remaining orders.

Accreditation: For half of participants, the *Standard ToU* tariff was labelled as a "Standard Smart Tariff" via a simple accreditation button placed alongside. The button was plain and was simply intended to indicate that it had been accredited as a "standard" tariff option for smart meters. The other half of participants saw no indication that this tariff represented a benchmark of any kind.

3.3. ToU Tariff MCQ task

This stage tested whether different presentations of ToU tariffs improve participants' ability to recall and comprehend key information about these tariffs. Two different *Standard ToU* tariffs were presented to participants, who then answered a series of MCQs about them. The questions were separated into two types: Memory and Comprehension. Participants viewed information about the two tariffs for one minute before it disappeared. They were not explicitly told to memorise the information. Six MCQs probed how much information they could recall. The tariffs then reappeared onscreen and participants answered six comprehension questions. The full list of questions is provided in Appendix C.

The main manipulation was how the tariffs were presented. Half the participants saw a *Standard* format shown in Figure 2.a., which simply listed the different rates, times and prices. The other half saw an *Hourly Breakdown* format designed to potentially improve tariff understanding, based on existing literature. This was colour-coded in a "traffic light" format and presented graphically as a linearized 24-hour clock, as shown in Figure 2.b. For consistency, the format that each participant saw in this stage was the same in all other stages of the study. We were therefore also able to measure whether tariff format had any effect on decision-making in these other tasks.

Figure 2.a. Example *Standard ToU* tariff in *Standard* format (*top*)

Figure 2.b. Example *Standard ToU* tariff in *Hourly Breakdown* format (*bottom*)

3.4. ToU Price Comparison Site task

The final stage generated an objective measure of how well participants could choose between different ToU tariffs. Participants were first asked to estimate their own usage throughout a seven day week. Responses permitted us to assess consistency with choices made in the earlier Tariff Choice task, as well as providing us with a usage pattern against which subsequent decisions could be compared. These decisions were made via an online interface that mimicked a price comparison site for electricity tariffs.

For the estimates, participants were asked to provide a percentage breakdown of their electricity usage across the *Standard ToU* tariff time periods. They did this for the 24-hours of an average weekday, then for an average weekend day, and finally for an average day across the full seven days of a week (based on their responses for weekday and weekend information). They were informed that they would be reminded of this weekly estimate during subsequent decisions and that the programme had calculated their exact weekly usage based on their weekday and weekend responses[7].

For the decisions, participants were explicitly asked to choose the cheapest ToU tariff for them, based on their own perceptions of their current usage. Each one required a choice from among three different *Standard ToU* tariffs. There were six decisions. Relative prices of the three tariffs varied over the six decisions. Again, the design of this stage removed future changes to electricity usage behaviour as a potential explanation for responses. Although in reality consumers may choose a tariff that was not presently the cheapest, but would be if they made certain behaviour changes, it was made explicit to participants that the objectively correct choice was to minimise cost based on current usage.

Decisions were incentivised. Each time participants correctly chose the cheapest option based on the usage estimates they had supplied, they won an additional ticket for a lottery to win a €50 shopping voucher. They understood that one-in-ten participants would win and each correct answer increased their chances. This incentive structure was applied for two reasons: (1) this stage was the most cognitively demanding and we wanted participants to think carefully about decisions; (2) there were objectively correct responses in this stage such that performance could be measured. The incentive also ensured that there was equal motivation to answer correctly for each of the six decisions, irrespective of previous performance.

The design of the price comparison interface mimicked current practice. Although ToU tariffs in general are not available in Ireland, a few residential consumers are on day/night tariffs. Price comparison sites differ in the options available for these customers. Some calculate and display potential savings for a consumer who uses an average day/night usage split. Others allow the consumer to self-report their own day/night split. In the USA, some providers that offer ToU tariffs provide a bill calculator to help participants to compare tariffs (Cappers and Sheer, 2016). Consequently, this stage tested whether these different interfaces increase the likelihood of selecting the cheapest tariff. Participants were randomly assigned to use one of two interfaces:

[7] This weekly usage was calculated by the programme by weighting the responses to the weekday usage by 5/7 and weighting the responses to the weekend usage by 2/7. An example electricity usage calculation can be found in Appendix E.1. A comparison of estimated and exact usage patterns can be found in Appendix E.2.

Average Usage: Participants were shown costs for each tariff for a consumer with an average usage profile. This was calculated using an average annual total usage (4,000 kWh) and average profile. Participants were reminded that these costs were a guide and that they were to choose the cheapest tariff for their own usage.

Personal Usage: Participants could input their own usage profile across time periods into a personal calculator tool, which then calculated costs across the different *Standard ToU* tariffs. As a default, the usage pattern was set at the average, which participants adjusted.

4. Results

Participants were 145 Irish consumers aged 18-71 recruited by a market research company. The sample was representative of the Dublin population, balanced by gender (48.3% female) and age (mean= 39.5, *SD*= 14.27). The study itself was conducted one participant at a time and lasted approximately 40 minutes. Participants were paid €40 for taking part in this study and two other unrelated ones, with breaks and refreshments in between.

4.1. Smart Meter task

Overall, 76.6% of participants responded positively to the letter, stating that they would agree to a smart meter installation. More responded positively in the Environment condition (80.6%) than the Money condition (72.6%), and in the Roll-Out condition (80.6%) than the No Roll-Out condition (72.6%). Table 1 reports logistic regression models. A positive response is the dependent variable. Experimental manipulations and demographic information are independent variables.

Models 1 and 2 show that the differences between letter types were short of statistical significance, with no significant interaction between the manipulations. However, Model 3 highlights significant differences by individual background characteristics. Participants aged 18-40 were more likely to respond positively than participants aged over 40 (p= 0.048), while females responded positively more than males (p= 0.018). Model 4 finds no significant age-gender interaction. There was no significant difference by whether participants had a degree, nor by response time to the question.

Letter Response "Yes"	**Model 1** All	**Model 2** All	**Model 3** All	**Model 4** All
Environment	0.4606	0.3140	0.3413	0.2881
	(0.399)	*(0.527)*	*(0.568)*	*(0.568)*
Roll Out	0.4606	0.3140	0.2171	0.2464
	(0.399)	*(0.527)*	*(0.558)*	*(0.561)*
Environment * Roll Out	-------	0.3428	0.5653	0.4745
	-------	*(0.811)*	*(0.858)*	*(0.860)*
Age: 18 - 40	-------	-------	0.9286**	0.4728
	-------	-------	*(0.470)*	*(0.565)*
Female	-------	-------	1.0725**	0.5358
	-------	-------	*(0.454)*	*(0.577)*
18 – 40 * Female	-------	-------	-------	1.3853
	-------	-------	-------	*(1.002)*
Degree	-------	-------	-0.1784	-0.1143
	-------	-------	*(0.482)*	*(0.490)*
< Median Response Time	-------	-------	0.3893	0.4006
	-------	-------	*(0.433)*	*(0.436)*
Constant	0.7531**	0.8210**	-0.2190	-0.0007
	(0.320)	*(0.362)*	*(0.510)*	*(0.533)*
Observations	145	145	143	143

Standard errors in parentheses, coefficients reported as log odds
*** p<0.01, ** p<0.05, * p<0.1

Table 1. Logistic regression models of likelihood to respond positively to smart meter letter

4.2. Tariff Choice task

The *Standard ToU* tariff was selected by 37.9% of participants, while 28.3% selected the *Flat Rate* tariff, 25.5% the *NS2 ToU* tariff and 8.3% the *NS3 ToU* tariff. Participants who saw the *Standard ToU* tariff at the top (34.2%) in the Order condition were actually on average less likely to choose it than those who saw it elsewhere (41.7%), with little difference between those who saw the accreditation button (38.4%) than those who did not (37.5%). Table 2 reports logistic regression models with *Standard ToU* tariff choice as the dependent variable.

Models 1 and 2 finds no significant effect of "Order" and "Accreditation" manipulations, or their interaction, on choosing the *Standard ToU* tariff. Model 3 also reports no significant effect of whether a participant responded positively to the smart meter letter in Stage 1. Females were significantly more likely to choose the *Standard ToU* tariff than males (*p*= 0.033) and participants who took longer over the task were marginally more likely to choose it also.

***Standard ToU* Choice**	**Model 1** All	**Model 2** All	**Model 3** All
Order First	-0.3152	-0.2076	0.0697
	(0.344)	*(0.487)*	*(0.528)*
Accreditation	0.0300	0.1335	0.4484
	(0.343)	*(0.479)*	*(0.525)*
Order First * Accreditation	-------	-0.2136	-0.7571
	-------	*(0.688)*	*(0.761)*
Standard ToU Cheapest	-------	-------	0.6757
	-------	-------	*(0.481)*
Letter Response "Yes"	-------	-------	0.5355
	-------	-------	*(0.473)*
Hourly Breakdown	-------	-------	0.3498
	-------	-------	*(0.381)*
Age: 18 - 40	-------	-------	-0.6424
	-------	-------	*(0.420)*
Female	-------	-------	0.8593**
	-------	-------	*(0.402)*
Degree	-------	-------	0.5089
	-------	-------	*(0.423)*
< Median Response Time	-------	-------	-0.6801*
	-------	-------	*(0.390)*
Constant	-0.3519	-0.4055	-1.6598**
	(0.297)	*(0.345)*	(0.759)
Observations	145	145	143

Standard errors in parentheses, coefficients reported as log odds

Table 2. Logistic regression models of likelihood to choose the *Standard ToU* tariff

As described above, at a later point in the study we asked participants to estimate their usage pattern. From these responses we were able to calculate the tariff that would have been cheapest given their estimation of their own current usage. Figure 3 compares these optimal (cheapest) tariff choices with actual choices. The *Standard ToU* tariff was estimated to be the cheapest tariff for more than three-quarters of participants (78.6%), according to their estimated usage. However, fewer than half this number chose it. Indeed, there appears to be an aversion to choosing the *Standard ToU* tariff that is strongly statistically significant (χ^2= 142.825, p< 0.001). Relative to choices that would minimise bills, participants preferred both the *NS2 ToU* tariff (cheapest for 2.1%) (χ^2= 393.474, p< 0.001) and the *Flat Rate* tariff (cheapest for 19.3%) (χ^2= 7.480, p= 0.006). Based on estimated usage, *NS3 ToU* tariff was a dominated option, i.e. was not cheapest for any participant. Model 3 in Table 2 shows that whether the *Standard ToU* tariff was the cheapest tariff for a participant was not a statistically significant predictor of their choice of this tariff (*p*= 0.160), although the coefficient was positive. This suggests that other preferences (e.g. risk aversion, familiarity, or simplicity) drove decisions.

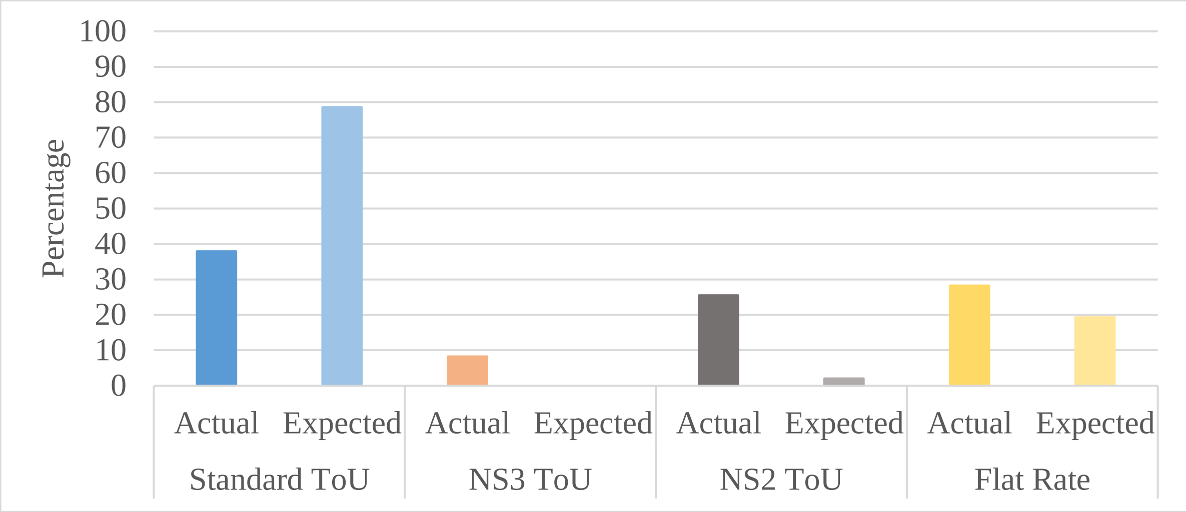

Figure 3. Distribution of actual and expected tariff choice

For an average annual bill, assuming an annual usage of 4,000 kWh, those who did not select the cheapest tariff would have paid approximately 11.0% (€74.65) extra per year for their electricity, rising to 13.1% (€87.40) for those who specifically failed to select the *Standard ToU* when it was cheapest. Thus, reluctance to select new types of tariff may lead to losses in consumer welfare. The simple interventions we tested that aimed to make the *Standard ToU* tariff more salient were insufficient to overcome this.

4.3. ToU Tariff MCQ task

Overall, participants were correct on an average 7.0/12 (*SD*= 2.09) MCQ questions. Performance was similar across Memory (3.4/6, *SD*= 1.36) and Comprehension (3.6/6, *SD*= 1.31) questions. Contrary to expectations, average performance was better when tariffs were presented in the *Standard* format (7.7/12, *SD*= 1.84) than the *Hourly Breakdown* (6.3/12, *SD*= 2.11) (*t*= 4.280, *p*< 0.001). Participants presented with the *Standard* format performed better on the Memory questions (4.0/6, *SD*= 1.14) than the Comprehension questions (3.7/6, *SD*= 1.27) (*t*= 1.723, *p*= 0.089), while the reverse was true for the *Hourly Breakdown* format, in which participants performed significantly worse on the Memory (2.9/6, *SD*= 1.32) than

Comprehension (3.4/6, *SD*= 1.33) questions (*t*= -3.060, *p*= 0.003). Table 3 reports OLS regression models with MCQ score as the dependent variable[8].

Model 1 finds that participants in the *Hourly Breakdown* format answered an average of 1.41 fewer questions correctly than those in the *Standard* format (*p*< 0.001). This effect persists when controlling for background characteristics as in Model 2. When separating questions by type in Models 3 and 4, participants in the *Hourly Breakdown* format performed significantly worse than those in the *Standard* format on the Memory questions (*p*< 0.001), but not the Comprehension questions (*p*= 0.249). The persistent negative coefficient indicates that there was not even a hint that the *Hourly Breakdown* format was of any assistance.

Educational attainment affected performance. Participants with a degree performed significantly better than those without (*p*= 0.001), increasing the average number of correct answers by approximately 1.29 – roughly equivalent to the difference between formats. This applied to both Memory (*p*= 0.029) and Comprehension (*p*= 0.001) questions. Females performed significantly better than males on Memory questions (*p*= 0.027). There were no significant differences based on age or response time.

MCQ Score	**Model 1** All	**Model 2** All	**Model 3** Memory	**Model 4** Comprehension
Hourly Breakdown	-1.4070***	-1.3093***	-1.0561***	-0.2532
	(0.329)	*(0.329)*	*(0.203)*	*(0.219)*
Age: 18 - 40	-------	0.0429	0.3464	-0.3035
	-------	*(0.353)*	*(0.217)*	*(0.234)*
Female	-------	0.4259	0.4580**	-0.0321
	-------	*(0.331)*	*(0.204)*	*(0.220)*
Degree	-------	1.2911***	0.4949**	0.7962***
	-------	*(0.364)*	*(0.224)*	*(0.242)*
< Median Response Time	-------	-0.2292	-0.0718	-0.1574
	-------	*(0.334)*	*(0.206)*	*(0.222)*
Constant	7.7083***	7.0538***	3.3914***	3.6624***
	(0.233)	*(0.372)*	*(0.229)*	*(0.247)*
Observations	145	143	143	143
R-squared	0.114	0.201	0.271	0.084

Standard errors in parentheses

Table 3. OLS regression models of tariff presentation on MCQ score

[8] Running OLS regression models assumes normality of residuals in the model. A Shapiro-Wilk test for normality in Models 1-4 indicates that we cannot reject the null hypothesis that the residuals are normally distributed for each (*p*= 0.102, *p*= 0.345, *p*= 0.105, *p*= 0.341, respectively), and so we judge OLS regression models to be appropriate. An alternative model would be an ordered logistic model, and the results are unchanged when an ordered logistic model was used.

Appendix D reports performance by question type. Performance was significantly worse in *Hourly Breakdown* for questions relating to the specific timings of rates (t= 7.277, p< 0.001; t= 2.171, p= 0.032), but did not differ for questions about rate costs (t= 1.080, p= 0.282). It is possible that the time-line rather than colour coding reduced retention of information. The only advantage of the *Hourly Breakdown* format was the speed with which participants were able to respond to questions about durations of rates, which was faster than for the *Standard* format (p= 0.005), presumably because they could simply count hours on the line rather than perform the elementary arithmetic.

Overall, we found no evidence that the *Hourly Breakdown* format systematically improves tariff understanding. Indeed, we found strong evidence that it negatively affects retention of key tariff attributes of the tariffs. In addition, as shown in analyses for other stages (Tables 2, 4 and 5), the format did not affect responses in other stages of the study.

4.4. ToU Price Comparison Site task

In the ToU Price Comparison Site task, those who only saw average tariff costs in the Average Usage condition correctly chose 4.3/6 (SD= 1.39) tariffs. Those who were able to personalise tariff costs in the Personal Usage condition correctly chose 5.1/6 (SD= 1.21), a statistically significant difference (t= 3.718, p< 0.001). Table 4 presents ordered logistic regression models. The number of correct decisions is the dependent variable with scores of 0, 1, and 2 (i.e. those performing at or below chance) pooled to satisfy the proportional odds assumption[9].

Model 1 shows that participants in the Personal Usage condition had significantly higher total correct scores than those in the Average Usage condition (p< 0.001). Model 2 finds a marginally significant effect of educational attainment; participants with a degree had higher total correct scores than those without (p= 0.075). There were no significant differences by age or gender. Model 3 incorporates participants' accuracy at estimating their exact weekly usages. Participants whose estimates deviated no more that 20%-points for all combined time periods from the calculated usage had significantly higher total correct scores than those with greater

[9] Here we determined that an OLS regression model would be inappropriate. The distribution of correct responses was heavily left-skewed and non-normal (Shapiro-Wilk, p< 0.001). The appropriateness of an ordered logistic regression is predicated on it passing the proportional odds assumption. Due to very low incidence of 0/6 and 1/6 scores it was not possible to compute the Brant test required to test the proportional odds assumption. Pooling scores of 0/6, 1/6 and 2/6 (i.e. those performing at or below chance) overcame this issue, and a Brant test indicates Models 1, 2 and 3 passed the proportional odds assumption (p= 0.423, p= 0.733, p= 0.745 respectively). The results of the models do not substantively not differ when these scores are not pooled.

than 20%-points ($p < 0.001$). Once estimate accuracy is specified, in Model 3, the effect of having a degree is reduced and no longer statistically significant. The main effect of the Personal Usage tool is unchanged.

Total Correct	**Model 1** All	**Model 2** All	**Model 3** All
Personal Usage	1.2550*** *(0.316)*	1.1056*** *(0.343)*	1.1367*** *(0.351)*
Hourly Breakdown	------- -------	-0.2495 *(0.313)*	-0.0820 *(0.320)*
Age: 18 – 40	------- -------	-0.1091 *(0.347)*	-0.1406 *(0.359)*
Female	------- -------	-0.3277 *(0.317)*	-0.2228 *(0.322)*
Degree	------- -------	0.6195* *(0.348)*	0.3201 *(0.363)*
< Median Response Time	------- -------	0.3233 *(0.332)*	0.5141 *(0.347)*
Estimate Inaccuracy (21% +)	------- -------	------- -------	-1.3660*** *(0.351)*
Observations	145	143	143

Standard errors in parentheses, coefficients reported as log odds

Table 4. Ordered logistic regression models of likelihood to choose the *Standard ToU* tariff

In the Personal Usage condition it was necessarily true that the Personal Usage tool was of use only if it was engaged with, otherwise the interface was just as in the Average Usage condition. Participants in Personal Usage condition set the tool to match their estimated usage 67.8% of the time and to something other than their estimated usage 21.0% of the time. It remained unused 11.2% of the time. When the tool was set equal to estimated usage participants chose the cheapest tariff 91.9% of the time, falling to 73.9% when set to something other than the estimated usage and 65.3% when the calculator was not used. Table 5 reports logistic regression models with whether a cheapest tariff was chosen as the dependent variable for participants in the Personal Usage condition only. To account for the non-independence of decisions at the participant level, we specified a random-effect that assumed normal variation in the likelihood of a correct response. The reference category is "Used – Not Estimate", which corresponds to using the tool but setting the values to something other than the usage estimate.

Model 1 shows that when participants used the tool and set it equal to the value of their estimated usage, they were significantly more likely to choose the cheapest tariff for their own usage than when it was used but set to something else ($p < 0.001$). There was no statistically significant difference between using the tool but setting it to something other than estimated usage and not engaging with the tool at all, although the incidence rate of not engaging with the tool was low (11.2%). Model 2 finds no significant differences in the likelihood of choosing the cheapest tariff based on tariff presentation, age, gender, educational attainment or response time, while the effects of personal usage tool engagement remain largely unchanged. Evidently, the personal usage tool helped consumers to choose the cheapest tariff for their usage, but only if used, and used correctly.

Cheapest Tariff Choice	**Model 1** All	**Model 2** All
Used - Estimate	1.7902***	1.5823***
	(0.451)	*(0.488)*
Not Used	-0.1507	-0.2994
	(0.545)	*(0.562)*
Hourly Breakdown	-------	-0.2421
	-------	*(0.428)*
Age: 18 - 40	-------	0.2486
	-------	*(0.480)*
Female	-------	-0.1993
	-------	*(0.454)*
Degree	-------	0.2759
	-------	*(0.525)*
< Median Response Time	-------	0.2611
	-------	*(0.382)*
Constant	1.1428***	1.1680**
	(0.348)	*(0.547)*
Observations	438	426
Participants	73	71

Standard errors in parentheses, coefficients reported as log odds

Table 5. Logistic regression models of likelihood to choose the cheapest tariff among those in the Personal Usage condition

5. Discussion

This exploratory study obtained responses from a representative sample of consumers to a series of questions, decisions and judgements related to smart meter installation and ToU tariff choice. It assessed attitudes to the installation of smart meters, initial choice of tariff and the ability to match an estimated pattern of personal usage to a ToU tariff. At each stage, experimental manipulations were used to test whether consumer choices were affected by how information was presented.

The positive attitude to smart meter installation recorded in this study was greater than in other recent findings in Ireland (Commission for Regulation of Utilities, 2018b). These previous findings were responses to single survey questions asked without any communication regarding the potential benefits of smart meters. It is therefore possible that providing citizens with information about benefits increases acceptance, although there are clearly other differences between the studies. The positive response rate we observed is, naturally, likely to be an overestimate of response rates if letters were to be sent to homes. In addition to the possibility of exaggerated responses due to hypothetical bias within the study, in real contexts some letters may never be opened or read. In this study, letters were placed in front of participants who dedicated time solely to reading the letter. Moreover, this study asked only about intentions to act. Intentions may not lead to action. Nevertheless, the findings indicate a high degree of acceptability of smart meters.

The study recorded a significant aversion to more complex ToU tariffs, relative to more conventional tariff options. For most consumers in this experiment, based on the estimated usage they supplied, the *Standard ToU* tariff would have been cheaper than conventional alternatives based on their own estimates of their current usage, yet many did not choose it. This aversion might lead to consumer detriment. Participants who did not select the *Standard ToU* tariff when it was cheapest would have added an average of 13.1% to their electricity bill. Simple interventions involving accreditation and ordering of tariff choice were insufficient to mitigate this aversion. Relative to the *Standard ToU* tariff, the more popular *Flat Rate* and *NS2 ToU* were simpler (comprised fewer changing time periods) and hence required less cognitive effort for comparisons of cost calculations. Furthermore, for individuals who were unsure of their usage, the simpler tariffs entailed less uncertainty, as there were fewer changes in rates throughout the day. The simpler tariffs also contained less costly penalties for using electricity at more expensive times. Arguably, therefore, despite making an apparently disadvantageous decision by avoiding the smart tariff, a rational consumer might be understandably wary of a more complex offering with uncertain benefits, offered by a provider who has presumably designed it on the basis of data and analysis. In addition, the simpler tariffs were probably more familiar to consumers (as they are already present in current domestic markets) and evidence from behavioural science suggests that individuals respond more positively to familiar alternatives – a mere-exposure effect (e.g. Bornstein, 1989).

The comparability of the four choice options relative to one another may also have been a factor. Behavioural evidence surrounding the attraction, compromise and similarity effects shows that relative differences between options can alter choices in systematic and predictable ways (Huber *et al.,* 1982, Simonson, 1989). The availability of multiple ToU tariffs may have induced participants to select some form of dynamic pricing tariff, such that the *NS2 ToU* tariff became attractive as a compromise option – dynamic but the least dynamic ToU tariff. Future research could isolate and test these hypotheses by independently manipulating the range and types of tariff choice options presented.

This study intentionally removed the potential for anticipated energy behaviour change to influence responses throughout the experimental stages. However, this is undeniably an important consideration for consumers choosing between different ToU tariffs. This issue is particularly pertinent given the existence of an intention-behaviour gap (e.g. Sheeran and Webb, 2016), where anticipated actions do not necessarily result in behaviour change. Future research could incorporate the role of anticipated behaviour change into the tariff choice decisions of consumers, and in electricity markets where these are real choice decisions, the accuracy of consumer's predictions of their own future behaviour change could be measured. A propensity for consumers to incorrectly predict future behaviour change could also lead to reduced quality of tariff choices.

Allowing consumers to make use of a personalised calculation tool when choosing between different ToU tariffs had a substantial positive effect on the quality of decision-making, compared to showing costs only for an average consumer. This is potentially important for the introduction of ToU tariffs. Smart meters generate exact readings of time-specific usage, allowing consumers to compare tariffs based on their specific usage patterns, provided they have a means for doing so. Presently, price comparison sites often default to comparisons based on average annual usage. Our findings show that this has a negative impact on choices.

Finally, the finding that the way ToU tariffs are presented can influence consumers' ability to retain key information is also important. The linearization of time in the *Hourly Breakdown* condition hindered recall, perhaps because the colour coding and depiction of an individual block for each hour of the day meant that the exact timing of transitions from one period to the next became less salient. The ease with which a consumer can recall tariff information may be indicative of the immediacy of understanding and is likely to be important, for instance, when comparing tariffs across providers. Nevertheless, participants could answer questions about tariff rate duration more quickly when presented with this *Hourly Breakdown* format. The appropriateness of tariff presentation may therefore depend on which aspects of ToU tariffs are judged to be most important.

6. Conclusions

The main aim of this study was to provide insight into decisions faced by electricity consumers in anticipation of the roll-out of smart meters and ToU tariffs. In particular, we identified a gap in the literature regarding how effectively individuals could decide between ToU tariffs, given that the benefits are dependent on usage patterns. There is some positive support for the introduction of smart meters, but an aversion to ToU tariffs relative to less complex ones (including existing flat rate tariffs). This aversion may lead to consumer detriment and is impervious to relatively simple interventions designed to improve take-up. Allowing consumers to use tools that facilitate personalised price comparison can improve decisions and may encourage successful ToU tariff adoption among electricity consumers. However, an important overall message from the present study is that consumers' ability to match usage to appropriate ToU tariffs cannot be taken for granted.

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<u>Appendix A.</u> Templates of smart meter letters in Smart Meter Letter task

Appendix A.1. Smart Meter Letter - Environment Benefits

Dear Sir/ Madam,

We are offering to replace your current electricity meter with a new -X- Electric smart meter. Smart meters offer real time feedback of electricity usage, by reporting current electricity usage every 30 minutes.

Smart meters can help each of us to do our bit for the environment by providing real time usage information and showing you how much electricity you are using at any given time. This can help you to cut out wasteful electricity use.

We will come and install a new smart meter for free. It will take approximately 2 hours for an engineer to fit the meter and your electricity supply will not be interrupted during the installation.

Your current contract will not change, but if you install a smart meter, you will have the option to consider future time-of-use tariffs, as well as the flat rate tariffs currently available to you. If you keep your current meter type, you will not be able to consider time-of-use tariffs in the future.

While current flat rate tariffs only charge one price for electricity for the whole day, time-of-use tariffs charge different prices for electricity at different times of the day. They help address the issues of demand on electricity supply, by charging more when demand is higher and less when demand is lower. This helps to make electricity supply more reliable and can reduce the risk of power outages.

[The government is committed to rolling out smart meters in every household by 2024. This means that if you do not arrange a smart meter installation now, we will get in touch to try and arrange installation at another time.][10]

Why not start taking advantage of a smart meter today?

Yours Sincerely,

Smart Metering Team, -X- Electric

[10] This paragraph was only included in the Roll-Out condition

Appendix A.2. Smart Meter Letter - Money Benefits

Dear Sir/ Madam,

We are offering to replace your current electricity meter with a new -X- Electric smart meter. Smart meters offer real time feedback of electricity usage, by reporting current electricity usage every 30 minutes.

Smart meters can help to make electricity billing simpler by providing real time electricity usage. This removes the need for estimated bills and so means you only ever pay for the electricity you use.

We will come and install a new smart meter for free. It will take approximately 2 hours for an engineer to fit the meter and your electricity supply will not be interrupted during the installation.

Your current contract will not change, but if you install a smart meter, you will have the option to consider future time-of-use tariffs, as well as the flat rate tariffs currently available to you. If you keep your current meter type, you will not be able to consider time-of-use tariffs in the future.

While current flat rate tariffs only charge one price for electricity for the whole day, time-of-use tariffs charge different prices for electricity at different times of the day. This may allow some customers to save money on their electricity bills by shifting their electricity usage to times of the day when electricity is cheaper. This can give customers more control over their electricity costs.

[The government is committed to rolling out smart meters in every household by 2024. This means that if you do not arrange a smart meter installation now, we will get in touch to try and arrange installation at another time.][11]

Why not start taking advantage of a smart meter today?

Yours Sincerely,

Smart Metering Team, -X- Electric

[11] This paragraph was only included in the Roll-Out condition

<u>Appendix B.</u> Additional information about tariff usage patterns

Appendix B.1. Time periods for rates for different tariffs in Tariff Choice task with example rates

Standard ToU:

Normal Rate	08:00 – 17:00	13.8 c/kWh
Peak Rate	17:00 – 21:00	29.1 c/kWh
Normal Rate	21:00 – 23:00	13.8 c/kWh
Off-Peak Rate	23:00 – 08:00	9.7 c/kWh

NS3 ToU:

Normal Rate	08:00 – 17:00	16.3 c/kWh
Peak Rate	17:00 – 23:00	27.2 c/kWh
Off-Peak Rate	23:00 – 08:00	12.2 c/kWh

NS2 ToU:

Normal Rate	08:00 – 23:00	21.4 c/kWh
Off-Peak Rate	23:00 – 08:00	12.2 c/kWh

Flat Rate:

Normal Rate	08:00 – 08:00	19.6 c/kWh

Appendix B.2. Average usage profile for *Standard ToU* tariffs

For the proposed *Standard ToU* tariff, the average usage profile assumed in this study was as follows:

Normal Rate	08:00 – 17:00	**40%**
Peak Rate	17:00 – 21:00	**25%**
Normal Rate	21:00 – 23:00	**10%**
Off-Peak Rate	23:00 – 08:00	**25%**

<u>Appendix C.</u> Multiple choice questions in ToU Tariff MCQ task by question type

Memory Questions

Cost Memory

What was the Peak rate in Tariff [A][12]?

What was the Normal rate in Tariff [B]?

Rate Memory

For how many hours did the Peak rate in Tariff [B] last?

At what time did the Off-Peak rate start in Tariff [A]?

Time Specific Memory

What rate would be used at 09:30 in Tariff [A]?

What rate would be used at 20:00 in Tariff [B]?

Comprehension Questions

Tariff Calculation

For how many hours in total does the Normal rate in Tariff [A] last?

In Tariff [B], which rate lasts for a longer time, the first Normal rate, or the Off-Peak rate?

Cost Calculation

What is the difference in cost between the Peak rates of the two tariffs?

Which tariff has the greatest difference in cost between Peak and Off-Peak rates?

Usage Calculation

If a customer used 50% of all electricity at Peak rate and 50% at Normal rate, which of the two tariffs would be cheaper?

If a customer used 25% of all electricity in each of the four time rates, which of the two tariffs would be cheaper?

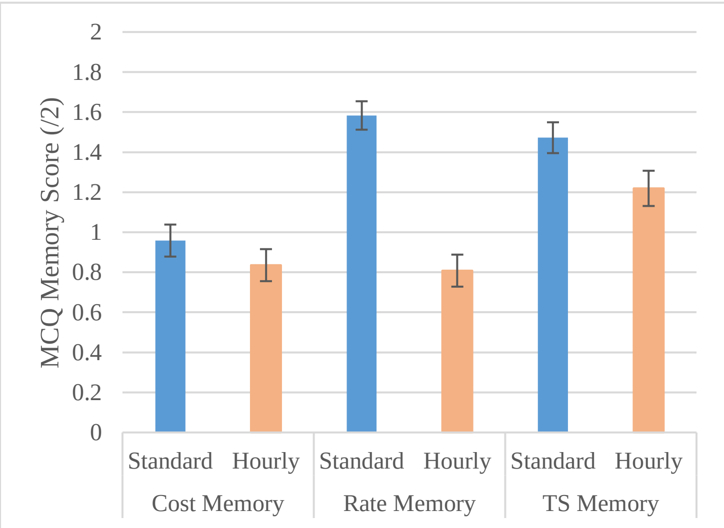
[12] To attempt to control for possible order effects in understanding of these questions, the tariff order and specific tariff used in each question was randomised.

<u>Appendix D.</u> Question type in ToU Tariff MCQ task

Appendix D.1. Performance by question type in ToU Tariff MCQ task

As can be seen from Figure D.1 below, performance within the subsets of Memory questions was consistently worse on average in *Hourly Breakdown* than in *Standard*. However, performance in the Cost Memory questions was not significantly worse in *Hourly Breakdown* ($p = 0.282$). Performance in both Rate Memory ($p < 0.001$) and Time Specific Memory ($p = 0.032$) were significantly worse and especially so in Rate Memory. This suggests that the difficulty that participants in *Hourly Breakdown* faced was related to the specific times of the rates, as opposed to the actual rate costs themselves. Tentatively, this suggests performance was hindered more by the linearization of time as opposed to the 'traffic-light' colour coding, however, as we have not explicitly tested for this, this is conjecture.

As can be seen in Figure D.2 below, performance within each of the subsets of Comprehension questions was consistently worse on average for *Hourly Breakdown* than *Standard*. However, these differences in all three, Tariff Calculation ($p = 0.890$), Cost Calculation ($p = 0.226$) and Usage Calculation ($p = 0.418$) were not statistically significant.



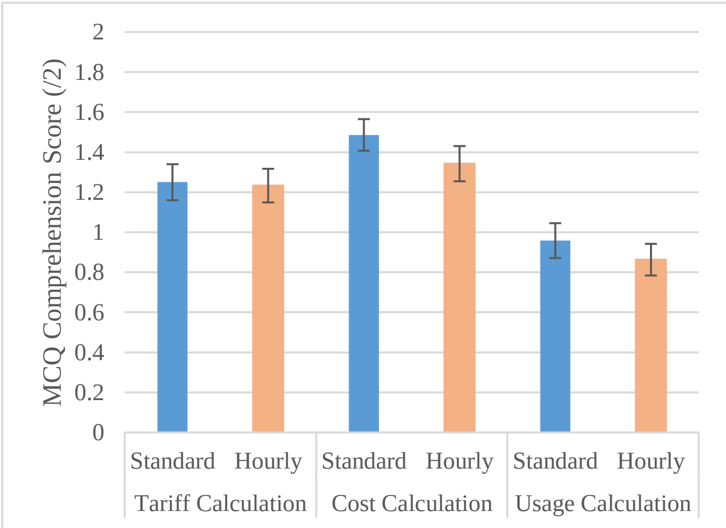


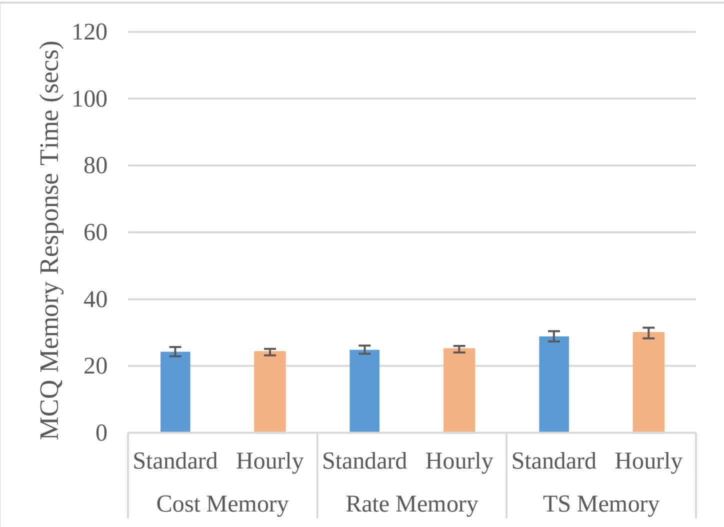
Figure D.1. Tariff Memory question performance by presentation type (*left*)

Figure D.2. Tariff Comprehension question performance by presentation type (*right*)

Appendix D.2. Response time by question type in ToU Tariff MCQ task

Separating question types and measuring response times may give some indication as to the ease with which participants responded to different questions. Figure D.3 below reports that there were no significant differences in average response times within the Memory questions, neither for the questions that performance differed by format: Rate Memory (p= 0.930) or Time Specific Memory (p= 0.658), nor for the questions that performance did not significantly differ by format: Cost Memory (p= 0.937).

Figure D.4 below reports that, on average, response times for Comprehension questions were significantly longer than those for Memory questions. Across question types there was evidence of substantial difference in response times for Tariff Calculation questions, with participants who saw the *Hourly Breakdown* format responding significantly quicker than those who saw the *Standard* format (p= 0.005). This was in spite of there being no significant differences in the likelihood to answer these questions correctly. There were no significant differences in the response times of Cost Calculation (p= 0.156) or Usage Calculation (p= 0.491) questions.



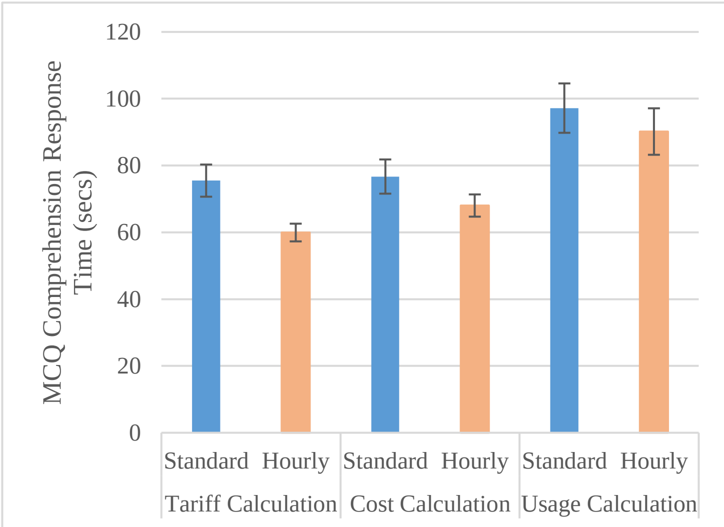


Figure D.3. Tariff Memory question response times by presentation type (*left*)

Figure D.4. Tariff Comprehension question response times by presentation type (*right*)

<u>Appendix E.</u> Usage information in ToU Price Comparison Site task

Appendix E.1. Calculation of *weekly* usage in ToU Price Comparison Site task

Below is an example of *weekly* usage calculation in the ToU Price Comparison Site task.

Suppose a participant estimated the following *weekday* usage:

Normal Rate	08:00 – 17:00	**45%**
Peak Rate	17:00 – 21:00	**20%**
Normal Rate	21:00 – 23:00	**10%**
Off-Peak Rate	23:00 – 08:00	**25%**

Suppose this participant estimated the following *weekend* usage:

Normal Rate	08:00 – 17:00	**55%**
Peak Rate	17:00 – 21:00	**20%**
Normal Rate	21:00 – 23:00	**15%**
Off-Peak Rate	23:00 – 08:00	**10%**

The *weekly* usage was calculated in the following way:

Normal Rate	08:00 – 17:00	(45% * (5/7)) + (55% * (2/7)) = **47.9%**
Peak Rate	17:00 – 21:00	(20% * (5/7)) + (20% * (2/7)) = **20.0%**
Normal Rate	21:00 – 23:00	(10% * (5/7)) + (15% * (2/7)) = **11.4%**
Off-Peak Rate	23:00 – 08:00	(25% * (5/7)) + (10% * (2/7)) = **20.7%**

This calculation assumes that actual usage is identical across the seven days of a week; weekday usage accounts for 5 days a week, and weekend usage accounts for 2 days a week. To help participants understand this, it was stressed in the instructions for this task, as seen below:

"*Calculating your weekly electricity usage assumes you use the same amount of electricity every day, but remember that there are more weekdays than weekend days*."

Appendix E.2. Comparison of *estimated* vs. *exact* usage calculations in ToU Price Comparison Site task

Rate	**Time Period**	**Average**	**Estimated**	**Exact**
Normal Rate	08:00 – 17:00	**40.0%**	**32.2%**	**30.5%**
Peak Rate	17:00 – 21:00	**25.0%**	**32.1%**	**33.2%**
Normal Rate	21:00 – 23:00	**10.0%**	**19.3%**	**20.5%**
Off-Peak Rate	23:00 – 08:00	**25.0%**	**16.4%**	**15.8%**