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Are consumers willing to switch to smart time of use electricity tariffs? The importance of loss-aversion and electric vehicle ownership

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ABSTRACT

Smart time of use tariffs are a key part of most government's strategies to ensure our future electricity supply is clean, affordable and secure – but will consumers be willing to switch to them? This paper presents the results of a survey experiment conducted on a nationally representative sample of 2020 British energy bill payers. The data suggests that over a third of bill payers are in favour of switching to a 3-tiered smart time of use tariff, indicating a sizeable *potential* market for these tariffs. There is substantial variation in willingness to switch, driven by differences in loss-aversion and ownership of demand flexible appliances rather than standard socio-economic/demographic factors. This is the first time loss-aversion has been measured amongst energy bill payers and the results suggest loss-aversion is likely to stifle consumer uptake; 93% of bill payers are loss-averse (care more about avoiding financial losses than making savings) and loss-averse people are substantially less willing to switch to the time of use tariff ($p < 0.001$). A randomised control trial finds that loss-framed messages are unlikely to overcome loss-aversion to boost uptake. Marketing campaigns tailored towards electric vehicle owners, who were significantly more willing to switch, could increase uptake during and after the smart meter roll-out.

1. Introduction and literature review

A major challenge for renewable energy consumption, energy security and energy affordability is how to encourage consumers to switch from flat-rate electricity tariffs to time of use tariffs which charge consumers for their electricity according to the time of day they are using it [1–4]. This is because, in the transition away from fossil fuels, governments need to ensure that people can access the energy they need, at prices they can afford, when the sun is not shining and the wind is not blowing, particularly at times of peak demand. One solution is to increase fossil-fuel supply capacity for use at peak times [5], however this will be costly and could lead to an increase in net carbon emissions. Alternative ways to provide this flexibility include energy storage, interconnectors [6] and demand-side response (DSR), an additional but much less cited solution.

DSR, sometimes referred to as DR (demand response), can be defined as "a change in electricity consumption patterns in response to a signal" [7,p. 9].[1] Three main types of signal are price (e.g. static time of use tariffs and dynamic time of use tariffs), volume (e.g. load capping) and direct control contracts (e.g. direct load control in which a third party provider remotely switches appliances on/off) [8,9]. Static time of use tariffs charge consumers two or more fixed prices for their electricity depending on the time of day, day of week or season, with higher rates applied at peak periods, providing consumers with certainty about what price they will pay and when [10]. Consumers can save money on these tariffs by shifting their consumption away from times of peak demand, for example, by running their washing machines or tumble-dryers at off-peak periods, when the electricity rate is cheaper. Dynamic time of use tariffs offer consumers prices which could vary on an hourly

[1] DSR is defined in a number of slightly different ways however all of them assume that it involves a change in the timing of electricity use in response to some sort of signal [9,91,94]. This distinguishes DSR from another form of demand-side management called demand reduction, which aims to achieve an overall reduction in energy consumption [2,67].

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or sub-hourly basis [11] and are most effective when combined with additional equipment that reduces peak demand by automatically turning off non-essential electrical devices [12,13]. However, until these additional automation technologies are fully tested and costed [4], it is expected that static time of use tariffs will be the predominant mechanism by which consumers are incentivised to undertake DSR [14]. This paper therefore solely discusses static time of use tariffs because they are the simplest form of tariff that can deliver peak-load reductions in electricity demand [12] without the need for any other technology than a smart meter. Although static time of use tariffs can be implemented without smart meters – in the UK, 13%–21% of energy bill payers are on ‘legacy’ time of use tariffs introduced in the 1970s to stimulate night-time demand for nuclear power – the provision of near real-time electricity consumption data from smart meters will enable suppliers to offer new types of ‘smart’ time of use tariffs (hereafter referred to as sTOU tariffs) which can charge consumers two or more rates for electricity without having to install additional meters. Before smart meters, these ‘legacy’ time of use tariffs required the installation of special meters that could record, for example, day-time and night-time electricity independently [15]. As such, the business cases for the majority of smart meter programmes around the world assume that consumers will participate in DSR through sTOU tariffs [16–19]. In the UK, for example, the Government’s business case for smart meters relies on an additional 20% of consumers switching to a sTOU tariff by 2030, in addition to those who are already on ‘legacy’ time of use tariffs [4].

However, to work, sTOU tariffs require two types of consumer participation: (1) consumers to switch to a sTOU tariff (switching) and; (2) respond to the price signals by changing their consumption patterns (load shifting). Ample evidence suggests that, once on a sTOU tariff, consumers will shift their consumption away from peak times (see Ref. [12] for a literature review of 30 trials). However, it is one thing to create a set of tariffs and technologies that aim to change the timing of consumers’ electricity use – it is another thing to design and market tariffs that the average consumer will actually switch to. The majority of consumers rarely switch their energy tariff or supplier, despite the large savings on offer [20]. In the UK, for example, in the two decades since the privatisation of the retail energy market, less than half of the British population have left their incumbent supplier [20] and, every year, more than half of British consumers forego hundreds of pounds worth of savings by not switching energy tariff [21]. Why is this and how can we prevent it from threatening consumer participation in DSR?

According to classical economics, consumers expecting to maximise their utility from sTOU tariffs will switch to a sTOU tariff and any increase in tariff choice enabled by smart meters will increase the number of sTOU tariff users by increasing the number of people for whom these tariffs offer maximum utility. However, the seeming failure of consumers to make decisions which maximise their net utility is well documented in all domains from health to personal finances and, for a variety of reasons, is particularly prevalent in the environmental sector [22]. For example, the discrepancy between actual and optimum levels of householder investment in energy efficiency is a well-documented phenomenon which has come to be known as the ‘energy efficiency gap’ [23–25] since Hirst and Brown coined the term in 1990 [23]. Economists have long recognised that market failures (including externalities, imperfect competition and imperfect information) can lead to suboptimal decision making [24], which they argue should be corrected as directly as possible, for example, by providing information to imperfectly informed consumers [25] or state interventions such as Pigouvian taxes, mandates and bans [24]. For example, to achieve its targets, the Irish energy regulator is making sTOU tariffs mandatory following the smart meter roll out [26].

However, it has not been until more recently that, following the early seminal work of psychologists Kahneman and Tversky in 1979 [27–29] and Herbert Simon [30], some environmental economists have proposed that people do not just fail to make optimal decisions because of market failures but because they are not rational decision-makers who evaluate costs and benefits like economist do [24,31–34]. The integration of psychology into a classical economic framework has become known as behavioural economics [35], a field which has documented numerous ways in which real-world consumer choices deviate systematically from those predicted by classical economics.

One of the most serious violations of classical economics which could stifle uptake to sTOU tariffs is loss-aversion [36]. Loss-aversion was first inferred from the observation that participants in laboratory experiments will turn down coin-toss gambles of the type in which they have a 50% chance of winning £110 or a 50% chance of losing £100–even though the expected outcome is that they would be financially better off from taking the gamble [27]. Loss-aversion is one component of Prospect Theory [27,29,37] which predicts that, rather than maximising their utility against a fixed budget constraint, people evaluate costs and benefits in relation to deviations from a reference point, which is commonly taken to be the status quo [36]. Downward deviations from the status-quo are perceived as losses and, according to studies on loss-aversion, people care twice as much about avoiding losses than gains [27,29,37], regardless of whether these losses are financial or otherwise [37–39]. In the energy tariff domain, for example, qualitative research by British energy regulator Ofgem found that energy bill payers tend to “focus too much on potential losses (e.g. higher prices, problems during the switching process) than potential gains” when considering whether to switch energy tariff and suggested this may explain why people do not switch more often [17,p. 3]. Loss-aversion could play an even bigger role in reducing switching rates to sTOU tariffs because, although consumers could save money by switching from a flat-rate to a sTOU tariff and shift their electricity use away from the peak times (gains), they could also see a large increase in their bills (losses) if they are unable to shift their electricity away from the expensive peak times. If consumers care twice as much about avoiding financial losses as they do about making financial gains, they will prefer to stay on their current tariff, rather than face the prospect of paying more if they switch to a sTOU tariff. Loss-aversion thus leads to another violation of classical economics called status-quo bias [42], defined as a preference for the current state of affairs [42]. Since the majority of British consumers are on flat-rate tariffs (80–90% [15]), status-quo bias would favour flat-rate over sTOU tariffs. Further, as noted, loss-aversion does not just apply to money and switching from a flat-rate to a sTOU tariff also means losing flexibility over when household appliances can be run, which could reduce comfort and convenience (losses), which studies of loss-aversion suggest will be weighed twice as high as the potential gains (savings from off-peak usage) [27,43].

However, although there are ample studies on loss-aversion [44–49], there is still a lack of evidence on the extent to which loss-aversion affects the average person and therefore disagreement over the extent to which loss-aversion poses a threat to people’s abilities to make optimal decisions [36]. This is because loss-aversion has predominantly been measured in laboratory experiments amongst psychology students [27] or inferred from the real-world behaviour of the select group of individuals who participate in the stock market [48–51], individuals who are likely to have very different attitudes towards risk than the average person. Although there have been some attempts to study loss-aversion in the real world amongst more typical people (e.g. taxi drivers [52]), these studies have not measured loss-aversion directly, making it hard to rule out alternative explanations for the behaviour observed

[53]. For example, it has been pointed out that the willingness-to-pay/willingness-to-accept gap could be better explained by a lack of market experience [54] than loss-aversion. This uncertainty over how to apply loss-aversion in real life [36] is also evident in its application in the energy literature. For example, although a number of studies suggest that loss-aversion is likely to reduce consumer uptake of a range environmentally beneficial goods such as energy efficient appliances and green energy tariffs [33,55], none of them have tested this hypothesis quantitatively and linked it to the behaviour in question. In particular, although participants in Ofgem's research workshops have tended to focus more on the costs than the benefits of switching energy tariff [41,p. 3], it is not known whether the average energy bill payer is loss-averse, and, if so, whether this loss-aversion is likely to have a statistically significant reduction on their willingness to switch to a sTOU tariff. This is because loss aversion has never been measured amongst a nationally representative sample of energy bill payers and linked to their decision to switch energy tariff. This is problematic for two reasons.

Firstly, if loss-aversion only affects a minority of energy bill payers it would be unlikely to pose a substantial threat to uptake to sTOU tariffs; on the other hand, if the majority of bill payers are loss-averse, this could, as hypothesised by Ofgem [40], explain why so few people switch tariff as well as presenting a significant barrier to the uptake of sTOU tariffs. In other words, the mere existence of people who are loss-averse, whilst violating a fundamental assumption of classical economics, does not on its own imply that consumer behaviour will be sufficiently adversely affected as to require intervention from government or from energy companies to ensure sufficient uptake of sTOU tariffs.

Secondly, unless loss-aversion is measured directly, and linked to people's tariff switching decisions, it is hard to validate the underlying model that is meant to explain people's tariff choices [56]. This is important because, if energy bill payers do not behave as classical economic models predict, then standard policies used by energy regulators such as information provision and price comparisons will be less effective than those which account for the way in which people actually make decisions about their energy tariff. As pointed out in [33], "until researchers offer up a viable theoretical alternative to [classical] economics, others will continue to rely on rational choice as the benchmark to guide benefit-cost analyses" (5). For example, the UK smart meter impact assessment implicitly assumes that consumers are rational decision-makers who will sign up to a time off use tariff if they expect to save money by doing so [4]. However, if consumers weigh losses higher than gains, fewer people will switch to a sTOU tariff than predicted by most cost-benefit analyses and different consumer engagement strategies will be required to encourage people to switch.

Energy tariff marketing is currently overwhelmingly characterised by messages which encourage consumers to switch to save money. However, if energy bill payers are loss-averse, emphasising the financial losses from not switching could be more persuasive than emphasising the savings if they do. For example, the loss-framed message "Three people die every day because there are not enough organ donors" encouraged more people to sign up to the organ donor register than a gain-framed message, "You could save or transform up to 9 lives by joining the organ donor register" [39]. Moreover, unlike flat-rate tariffs, sTOU tariffs have additional social benefits for the environment and energy security. According to classical economics, telling people about these social benefits should make no difference to uptake. However, the persistence of cooperation in Dictator Games and Public Goods Experiments and the large real-world donations made by individuals to public goods such as the Red Cross [57], has led some economists to infer that human beings are motivated not only by purely selfish concerns but also "by a desire to 'do the right thing' or 'make the moral choice"' [58,p. 3]. These studies argue that, when making decisions, people make trade-offs between what they judge to be in their own self-interest and the potential costs and benefits that their decisions may have on others in society [58]. If consumers have so-called pro-social preferences, telling people about these additional environmental and energy security benefits should be more motivating than just focusing on the financial benefits. If people have pro-social preferences and weigh losses higher than gains, telling people about the social costs to the environment and energy security of not participating in DSR should be even more motivating than telling them about the additional social and environmental benefits.

However, until we test this using a randomised control trial, it is completely unknown whether such a strategy would be more effective, less effective or no better than the current marketing methods used by energy companies to encourage customers to switch tariffs. Whilst an abundance of research has tested methods of motivating people to engage in pro-environmental behaviours such as energy demand reduction, consumer participation in DSR has received substantially less attention in the academic literature,[2] especially amongst disciplines that study human behaviour such as psychology and economics [59]. Three randomised control trials tested the effect of framed marketing messages on the willingness of consumers to switch to time-based electricity tariffs, and all of these have been performed on student or other types of convenience samples, including 107 Dutch university students [60], participants of online labour markets in the US [61] and a convenience sample recruited via social media and email [62].[3] However, it is unlikely that a framed marketing message will have the same effect on the average energy bill payer's willingness to switch to a sTOU tariff as on the willingness of a Dutch undergraduate student or the average participant of MTurk (an online labour market in which US citizens can undertake tasks in return for financial payment). Students are more likely to pay a fixed rate for their energy as part of their rent or to live in shared accommodation in which bills are split between a number of adults, lowering potential individual financial savings (or losses) from switching tariff. On the other hand, an MTurk sample could overestimate the persuasiveness of an environmental/energy security frame because, compared to a high quality online market research panel, MTurk participants tend to be younger and more likely to affiliate with the Democratic party [63], characteristics associated with greater concern for climate change [64]. Consistent with this, the MTurk survey noted above [61], found that emphasizing a peak-load shaving programme's monetary benefits reduced MTurker participants' willingness to enrol relative to when only the environmental benefits were mentioned.

Moreover, a framed marketing message is unlikely to have the same effect when placed within the context of real-life energy tariff marketing literature, as when presented to people in a series of isolated sentences, such as excerpts from the Stern Report, as in Morton et al. [65], or a report from the Intergovernmental Panel on Climate Change, as in Spence and Pidgeon [66]. Further, telling people about the environmental benefits of sTOU tariffs may not

[2] For example, a crude search of Science Direct using the keyword 'energy' alongside keywords indicating energy demand reduction ('conservation', 'saving', 'reduction'), yields over a million search hits whereas when the keyword 'energy' is used alongside words indicating demand side response ('demand response', 'load shifting', 'peak load reduction', 'demand side response'), just over 6000 hits are obtained when no exclusion criteria are applied such as date or language of publication. Although the total number of hits varies depending on different synonyms used, the ratio of hits for energy demand reduction compared to demand side response is similar.

[3] The exception is the US SGIG Consumer Behaviour Studies, which trialled the effect of opt-out recruitment on enrolment rates to time of use tariffs amongst central air conditioning customers of several US utility companies. However opt-out enrolment is ethically problematic [95,96].

be equally motivating when the marketing literature includes the price of energy on the sTOU tariff [61], especially if peak-time rate is much higher than the off-peak rate, as is likely to be the case for most commercial sTOU tariffs.

With the smart meter roll-out already underway in most countries, evidence is rapidly required as to what level of consumer demand there is for these tariffs and, if demand is lower than required, what consumer engagement strategies will effectively boost demand. Although previous evidence finds that those on a sTOU tariff do shift their consumption away from peaks [12], if switching rates are too low, then sTOU tariffs will have no noticeable impact on peak electricity loads.

To be most useful, this evidence needs to test whether some consumer groups are more likely to want to switch than others, particularly those with higher than average flexible peak time consumption (e.g. those with wet goods with timers [washing machines, dishwashers, tumble dryers] and electric vehicles), because these groups will deliver the greatest peak-load reductions from shifting the timing of their electricity consumption. The electrification of transport is expected to place one of the greatest strains on the future electricity network [67] making electric vehicle owners particularly important candidates for domestic DSR. Field studies suggest that charging clusters of electric vehicles are likely to double the domestic electricity load [68], with most vehicle owners electing to charge for convenience during weekday mornings and upon arriving back home from work during the existing evening peak time [68,69], except when they are enrolled on sTOU tariffs [68]. In one study, plug-in electric vehicle owners enrolled on a static sTOU tariff reduced their daytime and evening peak charging by 50%, compared to a control group [69]. Considering that electricity is historically three times the price of other fuels [70], ensuring electric vehicle owners are on favourable tariff structures will also ensure that energy bills remain affordable as more people adopt electric vehicles and charge them from home. This study therefore seeks to build on the work of Spence et al. [71] and Fell et al. [8] by collecting data on flexible electric appliance ownership in Great Britain, to test whether these groups do have an above average willingness to participate in time-based pricing, as assumed by most smart meter impact assessments [4]. The study will also collect demographic data on people who are likely to have more flexible working patterns, such as those who are retired or employed part-time, and may therefore be better able to modify the timing of their appliance usage.

Moreover, policymakers must also ensure that vulnerable consumers are not excluded from the wider benefits of smart meters, such as sTOU tariffs [4,72]. Only two other nationally representative surveys have measured consumer demand for DSR programmes [8,71], and they found conflicting results about the willingness of low-income consumers to participate in DSR programmes.

2. Aims

This paper seeks to answer five main questions: (1) To what extent are British energy bill payers loss-averse?; (2) Does loss-aversion reduce willingness to switch to a sTOU electricity tariffs?; (3); If loss-aversion reduces willingness to switch, would it be possible to exploit consumer loss-aversion to increase consumer willingness to switch to sTOU tariffs by using loss-framed rather than gain-framed marketing messages?; (4) What is the overall willingness to switch to sTOU tariffs amongst bill payers? and; (5) Does willingness to switch vary across demographic groups, particularly vulnerable groups and those with high consuming flexible electrical appliances such as washing machines and electric vehicles?

3. Method—an online field experiment

To achieve the aims of the research, whilst generating results that could be generalised to the average energy bill payer in Britain, a survey experiment was conducted. Gerber and Green [73] recommend applying four criteria to evaluate the generalisability of experimental results: (1) authenticity of treatments; (2) authenticity of participants; (3) authenticity of setting and; (4) authenticity of outcome measures. The experimental design is described before addressing each of these criteria in turn.

3.1. Experimental design

A broadly nationally representative sample of British energy bill payers (N = 2020) were recruited by a market research company to participate in an online survey in which they were randomly assigned to one of four digital leaflets containing factually equivalent descriptions of a three-tiered sTOU tariff which emphasised either: (1) the private financial benefits of switching ("financial gain-frame"); (2) the private financial costs of not switching (financial loss-frame); (3) the private financial and environmental/energy security benefits of switching ("financial and environmental/energy security gain-frame"); or (4) the private financial and environmental/energy security costs of not switching ("financial and environmental/energy security loss-frame"). Randomisation was carried out on a rolling basis by the market research company's survey software, using Microsoft Excel's random number generator. Participants had a 1 in 4 probability of being assigned to any of the four experimental groups. A 1:1 allocation ratio was employed to achieve an equal number of participants across groups on average. The market research company pays participants a small sum of money for each survey they complete which they can redeem for cash or vouchers. Participants are also entered in quarterly prize draws to win larger cash prizes (either 1 × £100 or 25 × £10 Amazon vouchers).

3.2. Authenticity of treatments

The study adopted the sTOU tariff used in the CLNR trials that was designed by Northern Powergrid and British Gas to be commercially viable in 2020 [74]. The leaflets were designed to resemble the marketing content available on the websites of major energy suppliers and are reproduced in full in Appendix A of the Supplementary material. In line with real-world marketing literature, which often uses green to promote the 'green' credentials of products, the environmental/energy security framed leaflets also presented the tariffs 'green' credentials in green font.

Manipulation checks conducted following participant exposure to the leaflets reveal that participants perceived the frame manipulations exactly as intended, with only a few minor exceptions. Although the leaflets which included the environmental/energy security implications of DSR contained more information than the financial-only leaflets, the manipulation checks revealed no statistically significant differences in the self-reported ease of understanding of the information across participants assigned to the environmental/energy security framed leaflets and those assigned to the private financial framed leaflets. Participants in the environmental/energy security groups were just as able to recall factual information about the tariff in a series of true/false questions than participants in the control group. The results of these checks are presented in Appendix B of the Supplementary material.

The financial gain-framed leaflet serves as the control group because this is the current status-quo method amongst energy suppliers of advertising their tariffs.

3.3. Authenticity of outcome

Until sTOU tariffs become commercially available, it is not possible to use switching rates to a sTOU tariff as a national measure of demand for a sTOU tariff. This study used willingness to switch as a measure of demand. Willingness to switch to the sTOU tariff was captured immediately after exposure the leaflets: participants were then asked to rate, on a 7-point end-point Likert scale, how willing they would be to switch to the sTOU tariff if it were available on the market today.

3.4. Authenticity of participants and correcting for sample selection

As in the two previous studies on consumer acceptance of DSR amongst broadly nationally representative populations [8,71], participants are panel members of a market research company's online omnibus, a pre-recruited group of individuals who have agreed to take part in online market research and social surveys. Participants for this study were recruited by the market research company from its existing pool of panel members via email to be representative of the online adult population of Great Britain in terms of five demographic variables – age, gender, region, social grade and employment status using quota sampling. The flow of participants from the initial recruitment email, intervention via the questionnaire and filtering on basis of completed and incomplete questionnaire status is shown in Fig. 1. Participant inclusion criteria are: (1) aged 18 or over; (2) live in England, Wales or Scotland and; (3) solely or jointly financially responsible for paying either the household gas or electricity bill (energy bill payers). Participants meeting the first and second eligibility criteria were recruited by the market research company via email. The first item in the questionnaire screened participants for the third eligibility criterion; participants self-identified as being solely, jointly or not financially responsible for paying their household gas or electricity bills. Participants who identified as not being financially responsible were excluded after the first question. A total of 14 people dropped out after randomisation but before responding to the Likert scale. However, since this attrition rate was extremely low (0.07%) and reasonably balanced across groups, no bias will have been introduced.

There are two key sources of sample selection owing to using a nationally representative sample of online market research participants which are common to all national surveys [75]. The members of the online market research panel differ from the average British energy bill payer in two main ways: (1) they belong to the 86% of the British population with internet access [76]; (2) they have opted-in to participate in online market research in return for a per-survey fee. Sampling weights will therefore be used in all analyses to help correct for both sources of sample selection along the observed covariates from which the weights are constructed, namely age, gender, region, social grade and employment status. Participants were recruited topic-blind to avoid self-selection of people who are interested in energy and tariffs.

3.5. Authenticity of setting

The online survey environment shares some similarities with the setting to which the results will be generalised because, in a drive to cut costs, communication from energy suppliers is increasingly delivered online via email or websites, rather than by mail, phone and is never face-to-face, as is the case in laboratory studies on this topic (e.g. [60]). Although respondents are aware that they are participating in research, they are not under the direct observation of a researcher, as they would be in classroom laboratory settings such as Kahneman and Tversky's original experiments on loss-aversion [27,29,37] or laboratory [60] or focus groups studies of consumer acceptance of DSR [77]. This will help to minimise evaluation driven effects such as social-desirability bias and Hawthorne effects.

3.6. Questionnaire design and eliciting consumer loss-aversion

A 20-item closed-question multiple-choice questionnaire was designed to: (1) screen participants on inclusion criteria; (2) expose participants to the treatment leaflets and collect their willingness to switch to the sTOU tariff presented and; (3) gather additional demographic and household-level data about participants, including a measure of loss-aversion and whether the respondent is already on a legacy time of use tariff. The full questionnaire is reproduced in Appendix C of the Supplementary material.

Loss-aversion was elicited from participants using a standard set of financial decision-problems from the economics literature which require participants to accept or reject gambles with positive expected outcomes involving hypothetical financial losses and gains. In each gamble, the winning price was fixed at £6 and only the losing price was varied (between −£2 to −£7). These questions are reproduced in full in Table 1.

Small financial stakes are used because people are risk-neutral in small stake gambles, which means the questions capture loss-aversion rather than risk-aversion [39]. Classical economics explains aversion to large-scale risk using the concept of risk-aversion: we might reject making high-value bets because a pound that helps us avoid poverty is more valuable than a pound that helps us become very rich. However, classical economic theory also implies that people are risk neutral when the stakes are small [43]. In other words, amongst various gambles giving the same expected net positive return (here £6), people should always prefer to accept the gamble, because the expected loss is so small; winning £6 will not make us rich but losing £6 would not make us poor. People should therefore accept gambles #1–#5 because they all have a positive expected value. Rejecting any of these gambles indicates loss-aversion [43,78] and the more of these gambles people reject, the more loss-averse they can be inferred as being.

The questions used in this survey were adapted from those used in Gachter et al. [78] to measure loss-aversion amongst a sample of German car buyers. Unlike Kahneman and Tversky's [27] original questions, these questions require a very limited understanding of probability ("heads you win, tails you lose") as opposed to mathematical notation such as (4000, 0.50); (3000, 0.50), which were delivered to university students and staff. These questions provide a very accessible and parsimonious method of eliciting loss-aversion amongst the average energy bill payer to reduce measurement error from fatigue effects.

These questions were placed immediately after the questions which screened people for the third inclusion criteria (identifying whether participants were energy bill payers) to avoid biasing our estimation of loss-aversion due to possible priming effects from other questions in the survey, particularly exposure to the loss-framed leaflets. A number of neutral 'buffer' questions were included after the loss-aversion questions but before the subsequent exposure to the treatment leaflets and the measurement of the outcome (willingness to switch), to minimise priming effects from the loss-aversion questions on response to the tariffs.

3.7. Statistical model

The equations presented in this section were specified prior to the authors receiving the data from the market research company and were documented in a Pre-Analysis Plan (PAP) submitted to the Experiments in Governance and Politics (EGAP) website on 27 June 2014 (registration number 20140627). By planning and disclosing

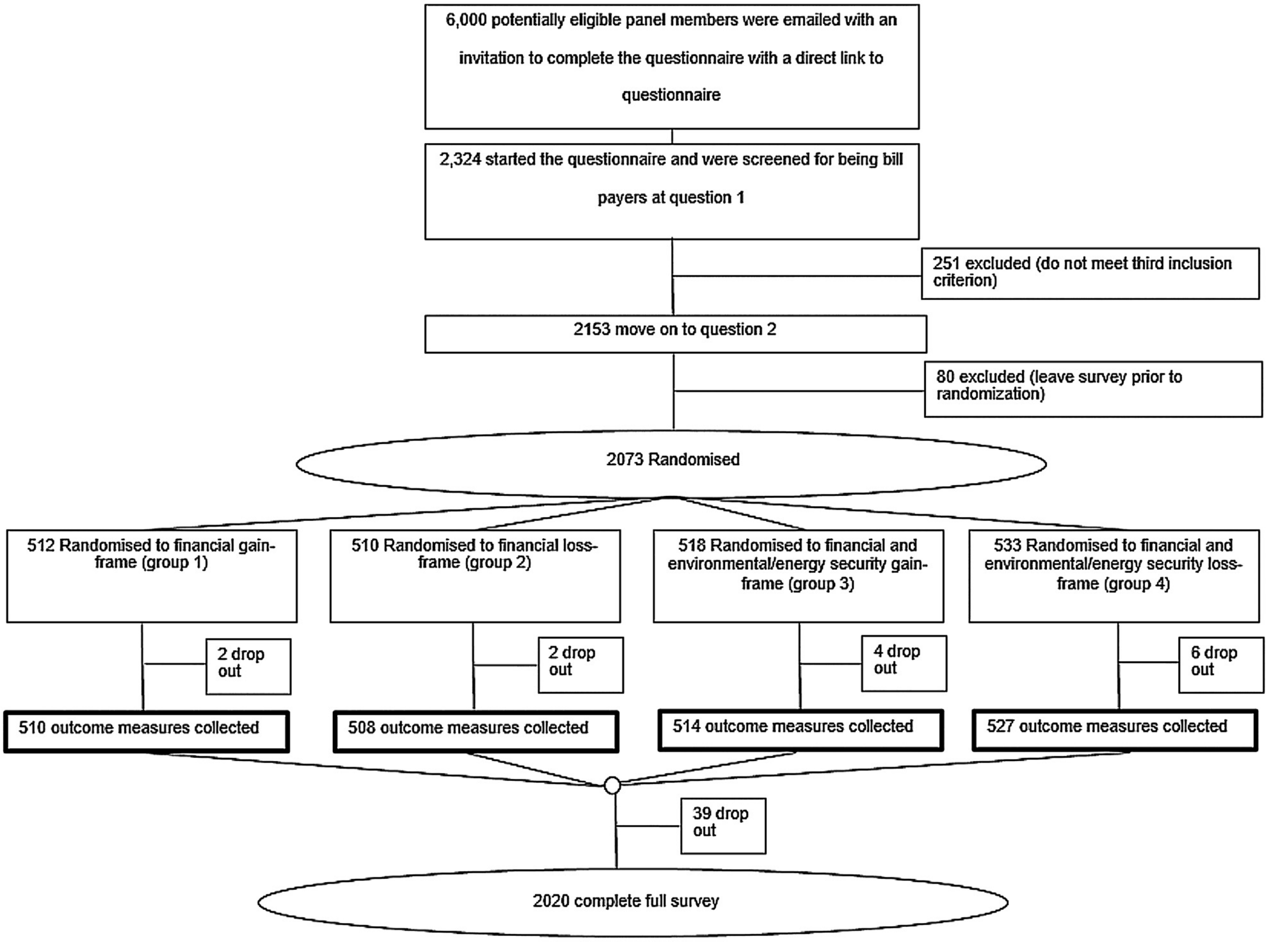

Fig. 1. Flow of study participants.

Table 1
Measuring loss-aversion using simple experiments.

Gamble	Yes I would take this gamble	No I would not take this gamble
#1 If the coin turns up heads then you lose £2; if the coin turns up tails then you win £6	◦	◦
#2 If the coin turns up heads then you lose £3; if the coin turns up tails then you win £6	◦	◦
#3 If the coin turns up heads then you lose £4; if the coin turns up tails then you win £6	◦	◦
#4 If the coin turns up heads then you lose £5; if the coin turns up tails then you win £6	◦	◦
#5 If the coin turns up heads then you lose £6; if the coin turns up tails then you win £6	◦	◦
#6 If the coin turns up heads then you lose £7; if the coin turns up tails then you win £6	◦	◦

Note: these financial decision-making questions are reproduced from Gachter et al. [78] with the exception that the amounts were changed to Pounds Sterling rather than Euros for use on British participants.

the hypotheses to be tested and specifications to be used in advance of seeing the data, the PAP should "avoid (or at least minimize) issues of data mining and specification searching" [79,p. 3].

The following equation, including baseline covariates, will be used to test the impact of message-framing on the stated willingness of British electricity bill-payers to switch to the sTOU tariff employed in this trial:

$$\begin{aligned} switch_i = {} & c + \beta_1 T1_i + \beta_2 T2_i + \beta_3 T3_i + \chi_1\ no\ qualifications \\ & _i + \chi_2\ gcses_i + \chi_3\ under\ \ grad_i + \chi_4\ higher\ \ qualifications \\ & _i + \chi_5\ education\ \ no\ response_i + \chi_6\ female_i + \chi_7\ private\ renter \\ & _i + \chi_8\ social\ renter_i + \chi_9\ other\ renter_i + \chi_{10}\ loss\ \ averse_i + \varepsilon_i \end{aligned} \quad (1)$$

In Eq. (1),[4] $switch_i$ represents the outcome variable which is a measure of the respondent's stated willingness to switch to the sTOU tariff on a 7-point end-point Likert scale. The treatment dummies, $T1$, $T2$ and $T3$, indicate whether individual i was assigned to see the financial loss-framed leaflet, the financial and environmental/energy security gain-framed leaflet or the financial and environmental/energy security loss-framed leaflet rather than the

[4] The original specification included a control variable for whether the individual was responsible for making decisions about the household's energy tariff; consistent with the pre-analysis plan, this variable was excluded because it had less than 95% variation. The original specification also intended to control for loss-aversion on a continuous scale – however, having observed the data, it was clear that loss-aversion is not linearly correlation with willingness to switch.

control group leaflet, which is the financial gain-framed leaflet respectively.

The coefficients of interest, β_1, β_2 and β_3, represent the average treatment effect of being exposed to the financial loss-framed leaflet, financial and environmental/energy security gain-framed leaflet or the financial and environmental/energy security loss-framed leaflet respectively on an individual's stated willingness to sign up to the sTOU tariff as compared to the control group leaflet (gain-framed private interests). The error term, ε_i, captures the unexplained variation in respondents' willingness to switch to a sTOU tariff.

Covariates were included in Eq. (1) to increase the statistical power of the study and were selected on the basis of theoretical and empirical evidence [80] that they were correlated with the outcome variable but, because they were measured prior to participant exposure to the leaflets, are uncorrelated with treatment status. Selected covariates include: an ordinal measure of the respondent's highest educational qualification (no education, GCSEs or equivalent, A-level or equivalent, undergraduate degree or equivalent, postgraduate degree of equivalent, education not declared – the reference category is having achieved A-levels as highest qualification); tenure (homeowner, private renter, social renter, other renter – homeowner is the reference variable); gender (male, female) and; a dummy variable indicating whether the individual is loss-averse. Although other variables were measured prior to participant exposure to the leaflets (employment status and age), the review of the literature suggested that the combination of variables chosen would have the most explanatory power for the outcome, without needing to include employment status and age as additional covariates [15,77,81].

3.8. Hypotheses and multiple comparisons

The model seeks to test four hypotheses therefore all results report statistical significance levels adjusted according to the Benjamini and Hochberg method [82].

Hypothesis 1. Loss-aversion will be correlated with a reduced willingness to switch to the sTOU tariff. A negative coefficient is expected on the dummy variable indicating loss-aversion.

Hypothesis 2. The financial loss-framed leaflet will be more persuasive than the control leaflet (financial gain-frame). A positive coefficient is expected on the dummy variable indicating that the participant was in the financial loss-framed group when the financial gain-framed group is the reference category.

Hypothesis 3. The financial and environmental/energy security gain-framed leaflet will be more persuasive than the control leaflet (financial gain-frame). A positive coefficient is expected on the dummy variable indicating that the participant was in the financial and environmental/energy security gain-framed group when the financial gain-framed group is the reference category.

Hypothesis 4. Loss-aversion and pro-social preferences imply that a message which emphasises the financial and social costs to the environment and energy security of not switching to a sTOU tariff should encourage more people to sign up to a sTOU tariff than any other message. A positive coefficient is expected on the dummy variable indicating that the participant was in the financial and environmental/energy security loss-framed group when the financial gain-framed group is the reference category and for this coefficient to be the coefficient with the highest magnitude.

3.9. Statistical power

Following the recommended power standards [83], the study was designed to have 80% power to detect treatment effects of 10% or more in either direction with 95% confidence. Smaller percentage increases in switching rates than 10% would only be commercially meaningful if baseline switching rates are already relatively high, which is unlikely to be the case, given that so few people switch tariff each year.

4. Results

4.1. Descriptive statistics

In line with national population statistics, the average profile of participants in the survey are homeowners in their late forties, in full-time employment living in England in a two-person household with gas central heating. Participant characteristics are discussed in terms of the weighted estimates rather than the in-sample estimates because the two are substantively identical. Table 2 reports statistics on a selection of these sample characteristics.

Randomisation checks reveal that these characteristics are equally distributed across groups. Of 63 hypothesis tests, three variables are unbalanced across groups at the 95% confidence level which is fewer than would be expected by chance, indicating the success of randomisation. For brevity, these results are not reported here but are presented in Appendix D of the Supplementary material.

4.2. Are British consumers loss-averse?

In line with Hypothesis 1, the overwhelming majority of British energy bill payers displayed loss-aversion in their response to the 50/50 gamble questions.[5] Exactly 5% of participants accepted all the gambles indicating that they were willing to lose £7, the maximum that could be lost in the decision-making scenarios and 2% accepted all the net positive gambles (#1–#5), but rejected gamble #6, consistent with classical economics. These two small groups of consumers, (just 7% of energy bill payers) are not loss-averse. The remaining 93% rejected at least one of the net positive gambles, indicating loss-aversion. Amongst this loss-averse group, people displayed varying levels of loss-aversion. At the most extreme end of the loss-aversion spectrum, 28% of participants rejected all gambles implying that they were only willing to lose an amount smaller than the value of £2. This means that nearly one third of British energy bill payers are extremely loss-averse.

4.3. What is overall stated willingness to switch to a smart time of use tariff?

Fig. 2 presents a horizontal bar graph of the main outcome variable, stated willingness to switch to the sTOU tariff as expressed on a 7-point Likert scale (here coded from 0 to 6) where 0 = Not at all likely to switch and 6 = Very likely to switch. The bars represent the percentage of participants who selected each point on the scale.

[5] There is no gold standard way of coding loss aversion [97] so we took a data driven approach. To account for non-linearity in preferences, loss-aversion was coded according to whether a participant rejected any of the net positive gambles. However, the results are substantively identical, regardless of how loss-aversion is coded. In Gachter et al. [78], loss-aversion was coded according to which gambles participants rejected e.g. participants who rejected no gambles, gamble (1), gambles (1–2), (1–3), (1–4) etc. However, this assumes that people have linear (or transitive) preferences – that they would not reject gambles 1, 2, 3 which involve losses of £4 or less and accept gamble 4, a higher value gamble involving potential losses of £5. The transitivity assumption is another major assumption of classical economics but, consistent with empirical literature that suggests that preferences are sometimes non-linear [98], analysis of this data revealed that a small proportion (8%) of participants in this sample rejected some of the lower value gambles whilst accepting some higher value ones.

Table 2
Characteristics of all trial participants.

Characteristics	Mean	Standard error
Respondent demographics and socio-economic status		
Female (dummy)	51%	13%
Age	47.9	0.45
Employment status:		
Employed full-time (dummy)	44%	1%
Employed part-time (dummy)	16%	1%
Unemployed (dummy)	5%	0.3%
Retired (dummy)	26%	1%
Student (dummy)	6%	1%
Not reported (dummy)	4%	1%
Highest educational qualification:		
No qualifications (dummy)	9%	1%
GCSEs/O-levels/school leavers certificate (dummy)	29%	1%
AS/A levels or equivalent (dummy)	23%	1%
Undergraduate degree (dummy)	25%	1%
Higher degree (dummy)	12%	1%
Education not reported (dummy)	2%	0.4%
Household characteristics		
Tenure:		
Homeowner (dummy)	63%	1%
Private renter (dummy)	17%	1%
Social renter (dummy)	18%	1%
Other (dummy)	2%	0.4%
Household energy		
Main method of heating home:		
Gas central heating (dummy)	77%	1%
Electric night storage (dummy)	8%	1%
Other (dummy)	15%	1%
Currently on a legacy time of use tariff:		
Yes (dummy)	20%	1%
No (dummy)	70%	1%
Don't know (dummy)	9%	1%

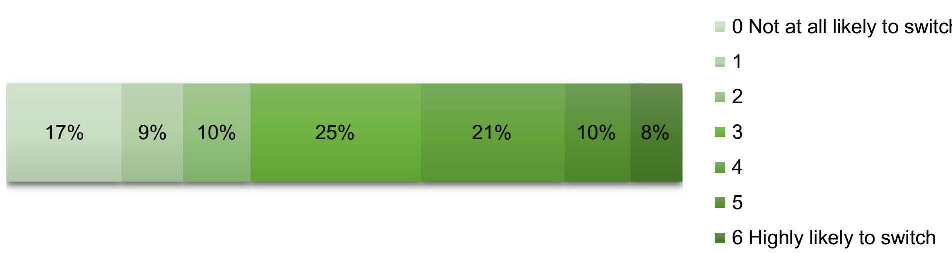

Fig. 2. Variation in stated willingness to switch to the sTOU tariff as expressed on 7 point Likert scale.

The bar graph reveals that there is considerable variation amongst British energy bill payers in terms of their stated willingness to switch to the sTOU tariff. The standard deviation is more than half the size of the mean willingness to switch (M = 2.8, SD = 1.8). The median response on the Likert scale is 3 and the distribution is skewed slightly to the right (Skewness = –0.14), with three percent more of the sample selecting responses above the mid-point value on the Likert scale than below it.

In total, 39% of participants selected responses above the mid-point on the Likert scale and 36% of participants placed themselves below the mid-point. Therefore, when analysing the distribution with reference to the mid-point on the Likert scale, these results suggest that over a third (39%) of British consumers are, to varying degrees, in favour of switching to a next-generation sTOU tariff and a similar proportion (36%) are not in favour of switching. A quarter of participants (25%) placed themselves on the mid-point of the scale which could be interpreted as meaning that they are unsure about what they think of the tariff or that they do not have a strong opinion either way.

When just looking at the extreme ends of the distribution, eight percent of British bill payers rated themselves as being 'Very likely to switch' (the highest point on the Likert scale) and twice as many (17%) rated themselves as '0 Not at all likely to switch' (Fig. 2).

4.4. Do loss-framed marketing messages increase average stated willingness to switch to a smart time of use tariff?

Contrary to Hypothesis 2, there is no statistically significant difference in mean stated willingness to switch to the sTOU tariff across those exposed to the financial loss-framed leaflet rather than the financial gain-framed leaflet (Table 3, column 1). Contrary to Hypothesis 3, there is no statistically significant difference in mean willingness to switch between participants exposed to the financial gain-framed leaflet and those exposed to the gain-framed financial and environmental/energy security framed leaflet. There is no statistically significant difference in willingness to switch across those exposed to the loss-framed environmental/energy security leaflet compared to the financial gain-framed leaflet, in contrast to Hypothesis 4 (Table 3, column 1). Although the coefficients on the 11 covariates cannot be interpreted causally, they are reported for completeness. The statistical significance and magnitude of the coefficients are almost identical in an Ordered Logit robustness check (Table 3, column 2) and in three further specifications which redefine the control group leaflet – nor is there any evidence that the effect of loss-framing is mediated by consumer loss-aversion in a model which interacts a dummy variable for the six loss-aversion

Table 3
Average treatment effects of message framing on stated willingness to switch to sTOU tariff.

Independent variables	Dependent variable = Stated willingness to switch to the sTOU tariff (standard error) [p-value]	
	Ordinary Least Squares (1)	Ordered Logit Robustness Check (2)
Treatment Dummies:		
Financial loss-framed leaflet	−0.14 (0.147) [0.324]	−0.145 (0.150) [0.333]
Financial and environmental/energy security gain-framed leaflet	0.032 (0.142) [0.819]	0.018 (0.142) [0.894]
Financial and environmental/energy security loss-framed leaflet	0.024 (0.139) [0.862]	0.036 (0.140) [0.800]
Covariates:		
Highest educational qualification:		
No qualifications (dummy)	−0.130 (0.235) [0.579]	−0.134 (0.243) [0.582]
GCSEs/O-levels/school leavers certificate (dummy)	0.272 (0.140) [0.053]	0.258 (0.139) [0.063]
AS/A levels or equivalent (dummy)	Reference category	Reference category
Undergraduate degree (dummy)	0.166 (0.142) [0.243]	0.155 (0.141) [0.274]
Higher degree (dummy)	0.401 (0.160) [0.012]*	0.410 (0.162) [0.011]*
Education not reported (dummy)	−0.154 (0.376) [0.682]	−0.162 (0.358) [0.651]
Female (dummy)	−0.092 (0.098) [0.348]	−0.110 (0.099) [0.270]
Tenure:		
Homeowner (dummy)	Reference category	Reference category
Private renter (dummy)	0.029 (0.134) [0.827]	0.017 (0.132) [0.895]
Social renter (dummy)	0.014 (0.148) [0.924]	−0.003 (0.150) [0.987]
Other (dummy)	−0.049 (0.400) [0.902]	−0.0003 (0.371) [0.999]
Loss-aversion (dummy)	−0.976 (0.175) [0.000]***	−0.979 (0.191) [0.000]***
N	2020	2020
F statistic	0.0000	0.0000
R squared	0.03	–

Notes: Sampling weights applied. Classical standard errors are reported in brackets with p-values reported in square brackets. P-values relate to coefficient's t-score, testing the null hypothesis that the coefficient value is equal to zero. For ease of interpretation, I do not report the coefficients on the covariates which consist of the following individual-level controls as specified in Eq. (1).
*** Significant at the 0.1% level (Benjamini and Hochberg [82] modified p-value is $p > 0.00026$).
* Significant at the 5% (Benjamini and Hochberg [82] modified p-value is $p > 0.015$).
** Significant at the 1% level (Benjamini and Hochberg [82] modified p-value is $p > 0.0026$).

categories with a dummy variable indicating assignment to either of the loss-framed leaflets.[6]

4.5. *What predicts stated willingness to switch to a smart time of use tariff?*

Table 4 reports the results of an OLS linear regression of a series of individual and household-level control variables on stated willingness to switch to the sTOU tariff.[7] The variables were chosen because prior qualitative research suggests they are theoretically likely to be correlated with stated willingness to switch to a sTOU tariff [15]. The model uses Region Fixed Effects to control for unobserved regional heterogeneity in stated willingness to switch to a sTOU tariff across each geographic region identified in the survey (North East, North West, Yorkshire and Humber, East Midlands, West Midlands, East of England, London, South East, South West, Wales and Scotland) to minimise the risk of omitted variable bias.

The only variable that is statistically significantly negatively correlated with stated willingness to switch to a sTOU tariff at the 99.9% level is loss-aversion, the empirically documented observation that consumers will reject prospects with positive expected utility if they involve losses. The magnitude of this effect is evident even in the raw data.

Fig. 3 is a bar chart showing the average stated willingness to switch to the sTOU tariff on the 7-point Likert scale according to whether the bill payer is loss-averse. As the graph shows, loss-averse people are substantially less willing to switch to the sTOU tariff and the regression results confirm that this difference is statistically significant at the highest level (Table 4). The results estimate that loss-averse bill payers, which encompasses 93% of bill payers, rate themselves more than half a point lower on the Likert scale measuring stated willingness to switch as compared to a respondent who is not loss-averse.

[6] Results available upon request.
[7] The pre-analysis plan intended to control for switching habits using Ofgem's four-stage consumer typology however the final model uses two dummy variables (switched in 2013, switched in 2014) because it is more parsimonious and including the Ofgem variables did not provide the model with greater explanatory power.

Table 4
Modelling stated willingness to switch to the sTOU tariff.

	Stated willingness to switch to the sTOU tariff (standard error) [p-value]
Socio-demographic controls	
Highest education qualification (in categories):	
No qualifications (dummy)	−0.12 (0.239) [0.610]
GCSEs/O-levels/school leavers certificate (dummy)	0.22 (0.133) [0.052]†
AS/A levels or equivalent (dummy)	Reference group
Undergraduate degree (dummy)	0.12 (0.137) [0.430]
Higher degree (dummy)	0.30 (0.157) [0.052]†
Education not reported (dummy)	−0.49 (0.363) [0.176]
Female (dummy)	−0.04 (0.099) [0.709]
Age:	
18-24	−0.15 (0.296) [0.610]
25-44	0.10 (0.130) [0.449]
45-64	Reference group
65-74	0.40 (0.193) [0.042]*
75+	0.65 (0.314) [0.038]*
Tenure:	
Homeowner (dummy)	Reference group
Private renter (dummy)	0.14 (0.139) [0.327]
Social renter (dummy)	−0.07 (0.158) [0.671]
Other (dummy)	0.25 (0.424) [0.547]
Employment status:	
Employed full-time (dummy)	Reference group
Employed part-time (dummy)	0.13 (0.118) [0.271]
Unemployed (dummy)	0.01 (0.150) [0.960]
Retired (dummy)	0.03 (0.193) [0.873]
Student (dummy)	0.21 (0.375) [0.569]
Not reported (dummy)	0.44 (0.541) [0.420]
Household lifestyle:	
Household regularly empty on weekdays but regularly occupied on weekday evenings and mornings (dummy)	0.35 (0.144) [0.015]*
Household regularly occupied on weekdays and weekends (dummy)	0.02 (0.116) [0.879]
Main method of heating home:	
Gas central heating (dummy)	−0.10 (0.187) [0.615]
Electric night storage (dummy)	Reference group
Other (dummy)	−0.14 (0.211) [0.519]
Has washing machine with timer (dummy)	0.09 (0.108) [0.378]
Has tumble dryer with timer (dummy)	0.27 (0.157) [0.083]†
Has dishwasher with timer (dummy)	0.14 (0.140) [0.322]
Owns electric or hybrid vehicle (dummy)	0.49 (0.237) [0.039]*
Number of household occupants	0.10 (0.045) [0.025]*
Has children aged <15 living at home (dummy)	−0.05 (0.149) [0.740]
Switched supplier in 2013 (dummy)	0.06 (0.116) [0.631]
Switched supplier in 2014 (dummy)	−0.17 (0.144) [0.248]
Is a prepayment meter customer (dummy)	0.40 (0.156) [0.011]*
Is currently on a legacy time of use tariff (dummy)	0.52 (0.122) [0.000]***
Loss-aversion (dummy)	−0.61 (0.174) [0.000]***
N	2020
F statistic	0.0000
R squared	0.10

Notes: Sampling weights applied. Classical standard errors are reported in brackets with p-values reported in square brackets. P-values relate to coefficient's *t*-score, testing the null hypothesis that the coefficient value is equal to zero. The specification includes regional Fixed Effects which consist of a series of dummy variables for each geographic region identified in the survey [North East, North West, Yorkshire and Humber, East Midlands, West Midlands, East of England, London, South East, South West, Wales and Scotland]. However, for brevity, the coefficients on these variables are not reported.
*** Significant at the 0.1 percent level.
** Significant at the 1 percent level.
* Significant at the 5 percent level.
† Significant at the 10 percent level.

The second largest coefficient, is on the time of use tariff dummy. Participants who are already time of use tariff customers (those on legacy time of use tariffs such as Economy 7, introduced in the 1970s and which require the installation of a special, but not smart, meter) placed themselves half a point higher on the 7-point Likert scale measuring stated willingness to switch to the sTOU tariff in this trial. This result is statistically significant at the 99.9% level and is robust to the inclusion of controls for regional heterogeneity in stated willingness to switch to a sTOU tariff.

The third largest coefficient, is the coefficient on the dummy variable indicating the consumer owns an electric or hybrid vehicle, after controlling for all other variables, indicating we can be over 95% confident that British energy bill payers who own an electric or hybrid vehicle are more willing to switch to a sTOU tariff than owners of traditional internal combustion engine vehicles (e.g. that run on petrol or diesel) regardless of which region in the country they live. Although not statistically significant at the 95% level, the results indicates that we can still be over 90% confident that owners of tumble dryers with timers are more willing to switch to a 3-tiered sTOU tariff than bill payers who do not.[8]

In descending order of the magnitude of the coefficient, the following variables are statistically significantly positively correlated with stated willingness to switch at the 95% level: being over 75 years old as compared to being aged between 45 and 64; being aged 65–74 as compared to being aged 45–64; living in a household that is regularly unoccupied on weekdays but regularly occupied on weekday evenings and mornings, when the price of electricity on the sTOU tariff is at its most expensive; being a

[8] Although it is conventional to treat p-values which fall below the threshold of $p = 0.05$ as statistically significant and those which exceed $p = 0.05$ as not statistically significant, the p-value is a continuous variable which, if interpreted as such, can provide a more informative or nuanced account of the likelihood that any given result is true. This is because, "In the same way that a small P value does not guarantee that there is a real effect, a P value just above 0.05 does not mean no effect." [99,p. 1], particularly if the independent variable of interest has a low prevalence in the population or has a small effect on the dependent variable of interest given the sample size. Indeed, there are not many people in the UK with tumble dryers with timers. We therefore interpret results in terms of the conventional significance level of $p < 0.05$ but also a slightly less stringent threshold of $p < 0.10$.

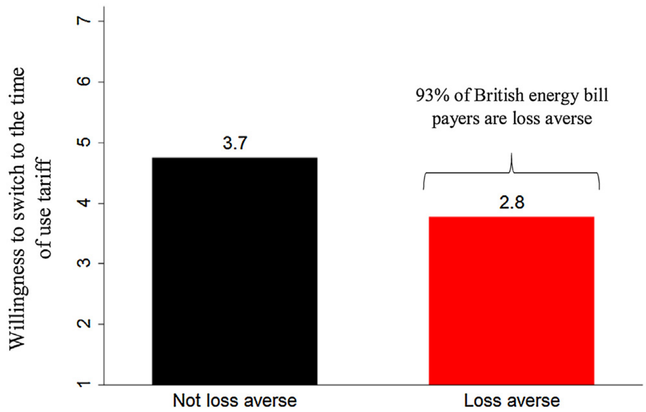

Fig. 3. Stated willingness to switch is negatively correlated with loss-aversion.
Note: The bars represent the mean stated willingness to switch to the sTOU tariff across non-loss averse and loss-averse energy bill payers.

pre-payment electricity customer and; marginal increases in the number of household occupants.

Only two further demographic characteristics are statistically significantly correlated with stated willingness to switch at the 90% level: having been educated up to higher education level as compared to having been educated up to A-level and having been educated up to GCSE level or equivalent as compared to having been educated up to A-level.

No other covariates are statistically significantly correlated with intention to switch, at the 95% confidence level or even a slightly less stringent confidence level of 90%, including: employment status (including whether people were retired); tenure (whether people are private or social renters rather than homeowners); whether people have children under the age of 15 living at home and; whether people had switched their energy tariff in either of the previous two years.

5. Discussion

This study sought to answer five main questions: (1) To what extent are British energy bill payers loss-averse?; (2) Is loss-aversion associated with a reduced willingness to switch to sTOU electricity tariffs?; (3); If loss-aversion reduces willingness to switch, would it be possible to exploit consumer loss-aversion to increase consumer willingness to switch to sTOU tariffs by using loss-framed rather than gain-framed marketing messages?; (4) What is the overall willingness to switch to sTOU tariffs amongst bill payers? and; (5) Does willingness to switch vary across demographic groups, particularly vulnerable groups and consumers with high consuming flexible electrical appliances such as washing machines and electric cars? Six main conclusions can be drawn from the results.

5.1. A third of British consumers are in favour of switching to a smart time of use tariff

The study provides further evidence that there is a sizeable potential market for sTOU tariffs amongst British consumers. In total, over one third (39%) of British energy bill payers surveyed said they were somewhat or strongly in favour of switching to a static sTOU tariff, consistent with the only other British survey on time of use tariffs [8], suggesting that it is a robust measure of current British consumer willingness to switch to these tariffs.

This does not mean that one third of consumers would switch, if energy suppliers offered these tariffs to consumers today. Many factors will affect the likelihood that a consumer with strong intentions to switch to a sTOU tariff will actually switch. However, there is clearly a sizeable potential market of British people who energy suppliers could convert into sTOU tariff customers, after the smart meter roll out. However, there are still many barriers to uptake that will need to be addressed before these tariffs are adopted *en* masse. One of the factors identified by this study is loss-aversion, the empirically well documented phenomenon that people care more about avoiding losses than they do about making gains.

5.2. Loss-aversion is likely to reduce willingness to switch to smart time of use tariffs in Britain and may account for low rates of tariff switching generally

Consistent with experimental findings from behavioural economics, this study finds strong evidence that loss-aversion is likely to present an important barrier to domestic consumer uptake of sTOU tariffs. The overwhelmingly majority of British energy bill payers are loss-averse (93%), and results from a Fixed Effects regression model estimate that we can be over 99.9% confident that loss-averse people are less willing to switch to a sTOU tariff. The effect is equivalent to 0.3 standard deviation units, a large effect considering how evidently difficult it is to motivate consumers to even *consider* switching their energy tariff [81] and given that the size of the coefficient indicates that loss-aversion is having the largest singular impact on stated willingness to switch out of all 37 individual and household-level control variables in the analysis.

Although this study was unable to determine what losses people were most concerned about (financial losses from being unable to shift away from peak times, inconvenience at having to shift certain household chores into different periods of the day, or some other potential losses, e.g. to comfort if people feel they have to curb their electricity use beyond a point which they deem to be comfortable), the evidence on loss-aversion to date suggests that any of these potential downsides to sTOU tariffs could play a role in reducing the appeal of sTOU tariffs. Moreover, since loss-aversion has been found to affect such an overwhelming proportion of energy bill payers, loss-aversion is likely to present a substantive barrier to consumer uptake to sTOU tariffs. In particular, the results suggest that fewer people will switch to a sTOU tariff than predicted by most cost-benefit analyses which tend to model consumer adoption based on a classical economic model of human behaviour, which assumes that people weigh gains and losses equally.

Loss-aversion is therefore one plausible explanation as to why more people were strongly against than strongly in favour of switching to the tariff in this survey, and, why so few people switch tariffs generally, despite the large savings on offer. Prior evidence from focus groups [84] suggested that loss-aversion was a key reason for the inertia in the retail electricity market [20] however, this is the first time that loss-aversion has been measured quantitatively, using Kahneman and Tversky's original decision-question questions [27] adapted for use amongst a representative sample of energy bill payers to test whether loss-aversion is statistically significantly related to their willingness to switch energy tariff.

The remaining question now is, what, if anything, can marketers and tariff designers do to help ensure that loss-aversion does not stifle consumer switching rates to sTOU tariffs, once they become widely commercially available, following the smart meter roll out?

5.3. Loss-framed marketing messages are unlikely to boost willingness to switch to smart time of use tariffs, regardless of whether they include the environmental and energy security losses

Whilst loss-framed messages influence university students' attitudes towards climate change [66], the study provides strong evidence that loss-framed messages will have no commercially meaningful impact on the average energy bill payer's decision over whether to switch to a sTOU tariff. This is likely to be true regardless of whether people are also told about the negative environmental consequences of not participating in DSR (being less able to exploit renewable generation) as well as the increased risk of black-outs from lower energy system security.

Stronger interventions, such as bill protection or direct load control (in which a supplier offers consumers guaranteed savings in return for remote control over some of their electrical appliances), are likely to be more effective at overcoming people's loss-aversion. Alternatively, energy suppliers could design sTOU tariffs so that the off-peak reduction in price (the potential benefit/gain), is greater than the peak increment in price (the potential loss, relative to a flat-rate tariff), as proposed in a recent review article on cost-reflecting electricity pricing [85]. Estimates of loss-aversion typically suggest that people weigh losses twice as high as they do equivalent gains [29,86] suggesting that, for this to work, the off-peak rate should be at least 50% lower than the peak rate to make a time of use tariff at least as appealing as a flat-rate tariff for a loss-averse consumer. If a tariff with such price differentials is not commercially viable, an alternative approach would be to reduce the perceived actual costs (e.g. loss of time, comfort) by simplifying the switching process and offering automation technology free of charge [85]. In addition, since consumer awareness and knowledge of these new types of tariffs is relatively low [72], marketing will be crucial to ensuring that customers are informed about new tariff launches.

5.4. *Electric vehicle ownership and existing legacy time of use tariff customers—a role for tailored marketing campaigns*

A promising approach to boost uptake to sTOU tariffs is to tailor tariff marketing to easily identifiable sub-groups who have expressed an interest in sTOU tariffs. This study finds that existing legacy time of use tariff customers, electric vehicle owners and owners of tumble dryers with timers are all more willing to switch to a sTOU tariff than any other consumer group in Britain. Existing legacy time of use tariff customers, the majority of whom are likely to be Economy 7 customers (a two-tiered time of use tariff introduced in the 1970s), would be particularly easy for energy companies to target because companies have a record of which tariffs their customers are on.

The finding that electric vehicle drivers are more willing to switch to a sTOU tariff is important because it is expected that plug-in electric vehicle drivers will perform the majority of their charging at home [87], with most charging for convenience during the existing peak times [68,69]. Encouraging electric vehicle owners to switch to a sTOU tariff and charge their vehicles overnight could substantially reduce the strain on the electricity network [69,88], which is expected to face considerable challenges due to the electrification of transport [67].

5.5. *Vulnerable groups expressed just as much willingness to switch to a smart time of use tariff as anyone else*

This study provides no evidence that the vulnerable consumers present in our sample population will be less willing to switch to a sTOU tariff than anyone else. Stated willingness to switch did not vary by gender, income, educational attainment or across bill payers who live in social housing as opposed to private renters or homeowners. Pre-payment meter customers, the majority of whom are thought to belong to some of the most disadvantaged groups in Britain, were slightly more willing to switch to the tariff than credit customers. The study therefore finds no evidence that disadvantaged or vulnerable customers are less likely to benefit from smart meters as a result of being unwilling and therefore less likely to switch to a sTOU tariff. This finding almost perfectly replicates those published in a similar study in this journal [8], also a nationally representative online survey, as well as the only other comprehensive empirical survey of consumers and sTOU tariffs [15].

Although one study [71], also conducted online, did find evidence that pre-payment customers and those with energy affordability concerns would be less willing to accept a variety of different DSR actions such as having one's shower or TV turned off after a set period, it did not mention that such actions would likely be rewarded financially (e.g. through a lower unit price for electricity). Taken together with the results of this study and those in [34], this suggests that policymakers and DSR providers should ensure that people are given sufficient information to estimate the possible financial benefits of participating in DSR to ensure that the potential benefits of participation are equally distributed.

The results also suggest that more consideration should be given to the possible risks of people choosing to switch to time-based tariffs that are unsuitable for them, rather than that they might be excluded from the benefits of DSR through being unwilling to sign up to them. The key research priority should now be to establish whether actual switching rates to these tariffs are the same across all socio-demographic groups. Ideally, this research would also test whether low-income groups are equally able to adjust their consumption patterns, once on such tariffs, to avoid the expensive peak time rates. Low-income groups may be less able to purchase the types of technologies which make it easier or financially advantageous for households to shift their electricity consumption away from peak times. For example, at present, plug-in electric vehicles are about twice the price of new petrol cars. Moreover, if low-income consumers already have very low baseline consumption, this could constrain their ability to save money on sTOU tariffs compared to those with above average consumption, particularly those with high flexible peak time consumption.

5.6. *Home occupancy patterns and children do not influence stated willingness to switch*

Consumer organisations [15,89] have sometimes argued that sTOU tariffs will not be popular amongst people with children whom they claim need to be able to use the washing machine frequently, regardless of the time of day, as well as people who are not in the house during the cheaper off-peak times (e.g. people working standard business hours). However, stated willingness to switch to the tariff did not vary by employment status or across people living in households with and without children under the age of 15. Participants who reported living in a household in which one adult was regularly at home during off-peak hours did not indicate a greater stated willingness to switch to the tariff. In fact, the tariff was more popular amongst participants who reported living in a household which was regularly empty during off-peak times and occupied during peak-times, even after controlling for other demographic differences and whether or not they owned wet goods with timers.

The discrepancy between opinions expressed about DSR tariffs by individual focus group participants and the collective opinion of national survey participants is not unusual or surprising [8]. However, these results suggest that we should not make assumptions about the likely willingness of consumers to switch to time-based tariffs based on their home occupancy patterns and employment statuses. In particular, this study suggests that concerns raised about sTOU tariffs by focus group participants with children or participants with 9 a.m.–5 p.m. jobs [15] do not generalise to the average British family with children or the average working person with standard business working hours.

This study is unable to rule out the possibility that people with children or who are frequently at home during the expensive, peak times may find it harder to save money on sTOU tariffs. However, these consumers are not precluded from benefitting from time of use pricing if they own or purchase the right enabling technologies.[9] Indeed, sTOU tariffs aim to change people's consumption patterns; if sTOU tariffs were only adopted by consumers who were already consuming energy at off-peak times, there would be no added benefit to the electricity network in introducing time of use pricing. Nevertheless, since women perform the overwhelming share of domestic chores and childrearing responsibilities [90], including most peak-time energy using activities [91], we may be concerned that the burden of adjusting consumption patterns to suit these tariffs could fall disproportionately on female householder members. Home automation equipment or third party direct load control could help to reduce the burden on those undertaking the majority of electricity intensive household tasks, such as washing and drying clothes.

6. Limitations

There are four main limitations to this study. First, whilst the results can be reliably generalised to the 86% of British energy bill payers with internet access regardless of age, gender, region, employment status and social grade, the results may not generalise to energy bill payers who do not participate in online market research (self-selection bias) or to the ~14% of energy bill payers without internet access (coverage bias). Selection bias is a common problem with any research in which people's consent to participate must be explicitly obtained in advance. However, selection bias is not a major threat to the generalisability of the findings because it seems unlikely that differences between energy bill payers who participate in market research and those who do not would be so weakly correlated with the key demographic variables from which the survey weights were constructed yet so strongly correlated with willingness to switch to a sTOU tariff, so as to render the selection bias sufficiently large as to substantively alter the results. Coverage bias is potentially a greater limitation. According to data collected by the UK Office for National Statistics (ONS), the majority (53%) of people who report not having access to the internet say that this is because they do not need it [92] suggesting that, for the most part, lack of internet access is not a proxy for vulnerability. However, an important minority state that their lack of access is due to a lack of skills (32%) and the high cost of equipment (12%) and access (11%) [92]. Survey weights can only correct for this type of selection error to the extent that computer literacy and affordability concerns are correlated with age, gender, region and social grade (the variables from which the weights were constructed). Second, this study measured intention to switch rather than actual switching rates to a sTOU tariff and evidence suggests that purchase intentions are not perfect predictors of actual purchasing choices [93]. However, until sTOU tariffs become widely commercially available, studies that are based on hypothetical choices (such as this one) can provide a useful indication of the likely level of uptake to sTOU tariffs amongst energy bill payers. Third, although it was found that loss-aversion was negatively correlated with stated willingness to switch, the study was not set up to measure what losses people were most concerned about. Future research could attempt to identify the reference point used to evaluate gains and losses to aid in the design of interventions to overcome loss-aversion. Finally, although we modelled the drivers of willingness to switch to a sTOU with nearly 40 individual-level control variables, there may be other important determinants of willingness to switch for which we were unable to control, which means the coefficients are correlational and must not be interpreted causally.

[9] The results are robust to regression specifications which exclude the dummy variable controlling for ownership of wet goods with timers (results for this specification not reported here).

7. Conclusion

A major challenge for realising the business case for smart meters and for maintaining future energy security is to encourage consumers to switch from flat-rate electricity tariffs to one of a new generation of smart meter enabled time of use electricity tariffs (sTOU) [3]. This is one of the first studies to measure national demand for a next generation sTOU tariff and the very first study to test whether insights from behavioural economics, which have been most successfully applied in the health and personal finance domains, could also be used to boost uptake to sTOU tariffs amongst a nationally representative sample of energy bill payers. It is also the first study to measure loss-aversion amongst a nationally representative sample of energy bill payers and directly link it to their willingness to switch to an energy tariff, in this case a sTOU tariff.

To achieve this, the authors designed and ran a representative survey experiment on a nationally representative sample of over 2000 British energy bill payers. Consistent with a previous national survey [8], the data suggests that over a third of energy bill payers are in favour of switching to a sTOU tariff, indicating a sizeable potential market for these tariffs. However, there is substantial variation in willingness to switch, with more people being strongly against than strongly in favour of switching. The results suggest that these differences are driven by differences in loss-aversion and ownership of demand-flexible appliances rather than standard socio-economic/demographic factors. The results found that over 90% of energy bill payers are loss-averse (care more about avoiding financial losses than making financial savings) and also that people who evaluate costs and benefits in this way were statistically significantly less willing to switch to the sTOU tariff. This makes sense because, although people could save money by switching to a sTOU tariff and using less electricity at peak times, they could also stand to increase their bills if they are unable to shift their consumption away from peaks. They would also lose flexibility over the timing of their electricity use. Further research is now required to test whether a third of bill payers would switch, if given the choice in reality, and how to overcome loss-aversion to ensure domestic consumers do participate in DSR.

Conflicts of interest

The author declares no conflicts of interest.

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Appendix A. Supplementary material

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