



**HAL**  
open science

## **Nudges and peak pricing: A common pool resource energy conservation experiment**

Penelope Buckley, Daniel Llerena

► **To cite this version:**

Penelope Buckley, Daniel Llerena. Nudges and peak pricing: A common pool resource energy conservation experiment. *Journal of Behavioral and Experimental Economics*, 2022, 101, pp.101928. <10.1016/j.socec.2022.101928>. <hal-03765755>

**HAL Id: hal-03765755**

**<https://hal.science/hal-03765755v1>**

Submitted on 2 Sep 2022

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

# Nudges and peak pricing: A common pool resource energy conservation experiment\*

Penelope Buckley<sup>†1</sup> and Daniel Llerena<sup>1</sup>

<sup>1</sup>Univ. Grenoble Alpes, CNRS, INRAE, Grenoble INP, GAEL, 38000

Grenoble, France

19th August 2022

---

\*This work has been partially supported by the CDP Eco-Sesa receiving funding from the ANR project ANR-15-IDEX-02.

<sup>†</sup>Corresponding author: [research@penelopebuckley.com](mailto:research@penelopebuckley.com)

## **Abstract**

Using a contextualised common pool resource framework, individual energy consumption choices are studied. Individuals are nudged towards the socially optimal level of consumption by the use of a happy (sad) face if they are underconsuming (overconsuming). A price is set to incentivise a second group to choose the level of consumption observed in the nudge treatment in order to quantify the nudge via an equivalent price. Across all 10 periods, consumption is significantly lower in treatment groups compared to control groups without nudges and prices. The price treatment leads to an average level of consumption above the Nash equilibrium. There are implications for policy makers as the nudge treatment performs as well, on average, as an equivalent price without the implied loss of welfare, and is understood and integrated into subjects' decision making quicker than an equivalent price. However, there is a tendency for both the nudge and the price to reinforce existing consumption behaviour as those who overconsume continue to overconsume.

**Keywords:** energy conservation, financial incentive, laboratory experiment, nudge.

**JEL Classifications:** C91, H31, Q40

# 1 Introduction

2 With the increasing integration of renewable energy sources (RES) in the pro-  
3 duction mix, encouraging households to lower their energy consumption during peri-  
4 ods of peak demand can create supply and demand issues in the electricity market  
5 ([Bistline, 2017](#)). Possible solutions to capture the value of RES include demand side  
6 management (DSM) and energy storage systems<sup>1</sup>. The former calls for significant  
7 behavioural change on the part of residential households, while the latter requires  
8 significant technological advancements and cost reductions to be feasible. The power  
9 generation infrastructure is highly capital intensive, such that DSM may be one of  
10 the cheaper tools available for balancing supply and demand. Demand response  
11 programmes, defined as the changes in electricity usage by end-use consumers from  
12 their normal consumption patterns in response to signals, are the main tool used  
13 or experimented in the management of the electricity grid ([Balijepalli \*et al.\*, 2011](#)).  
14 Demand response programmes implement incentives to encourage households to  
15 conserve energy.

16 Economic incentives use financial motivation to restrict or to encourage cer-  
17 tain behaviour, whereas nudges influence individuals' behaviour without removing  
18 any of the choices available to them nor affecting their economic incentives ([Thaler  
19 and Sunstein, 2008](#)). Both policy tools have been used to encourage households  
20 to partake in energy conserving behaviour ([Andor and Fels, 2018](#), [Buckley, 2020](#)).  
21 Dynamic pricing restricts consumption at certain times through increased prices, or  
22 encourages consumption at other times through decreased prices or rebates ([Faruqui  
23 and Sergici, 2013](#)). However, opponents argue that residential consumers should not  
24 be asked to bear the risks associated with the volatility of wholesale market prices  
25 ([Alexander, 2010](#)). Nudges have been used to encourage energy conservation by

---

<sup>1</sup>Decentralised energy storage systems may facilitate the integration of RES by providing com-  
munities with stored energy when RES are not available ([Dincer and Acar, 2018](#)). However,  
consumers have voiced concerns over the fair and equitable sharing of energy from community  
energy storage systems ([Ambrosio-Albalá \*et al.\*, 2019](#)). Such community storage systems echo the  
characteristics of common pool resource extraction.

26 creating a sense of competition among similar households regarding who can lower  
27 their consumption the most (Schultz *et al.*, 2007, Allcott, 2011), and by encour-  
28 aging households to commit to energy conservation by setting themselves energy  
29 savings goals (Harding and Hsiaw, 2014). However, questions have been raised as  
30 to the cost-effectiveness and social welfare implications of such nudges (Allcott and  
31 Kessler, 2019, Andor *et al.*, 2020), the effectiveness of a one-nudge-for-all approach  
32 (Costa and Kahn, 2013, Brandsma and Blasch, 2019) and the value (both financial  
33 and ethical) of such interventions compared to traditional incentives (Hausman and  
34 Welch, 2010, Lehner *et al.*, 2016, Kasperbauer, 2017, Hagmann *et al.*, 2019).

35 Encouraging households to lower their consumption during times of peak de-  
36 mand creates a situation in which there is a social dilemma; there is a collective goal  
37 of reducing energy consumption, which contrasts with the individual goal of each  
38 household consuming as they wish without constraint. Given these characteristics,  
39 a common pool resource (CPR) approach may shed light on community-based solu-  
40 tions for flexibility in order to integrate decentralised production from RES (Melville  
41 *et al.*, 2017).

42 This paper contributes to the literature on the impact of economic and beha-  
43 vioural interventions on environmental behaviours by applying a CPR framework  
44 to the social dilemma associated with consumption at times of peak demand. We  
45 explore the effectiveness of both a behavioural and an economic incentive within  
46 a stylised electricity consumption game based upon CPR theory (Ostrom, 1990).  
47 Here, the CPRs are the intermittent renewable energy sources which are sustained  
48 so long as electricity consumption does not exceed power capacities. Such an ap-  
49 proach allows us to explore, in an experimental setting, the impacts of demand  
50 response tools on consumers' behaviour when they are placed in the social dilemma  
51 resulting from the need to balance supply and demand during a peak period, while  
52 maintaining their desired level of consumption.

53 Economic incentives affect behaviour by appealing to extrinsic motivation to

54 encourage a desired behaviour that an individual would not necessarily do in its ab-  
55 sence. By its nature, asking individuals to conserve energy appeals to intrinsic mo-  
56 tivations to do so which may be crowded out by the implementation of an economic  
57 incentive. Behavioural interventions, on the other hand, appeal to these intrinsic  
58 motivations and can make energy conservation more accessible (by defaulting more  
59 environmental options (Brown *et al.*, 2013)) and more entertaining (by encouraging  
60 households to compete to lower their energy consumption (Allcott, 2011), and by  
61 setting and meeting energy conservation goals (Harding and Hsiaw, 2014)).

62 We conduct a laboratory experiment in which subjects are asked to choose a  
63 level of energy consumption in response to a behavioural (moral suasion) incentive  
64 relative to an absence of incentives. After observing the behaviour under this nudge,  
65 we calculate a price increase which theoretically should result in an equivalent level  
66 of consumption. This is the originality of our approach: we observe behaviour in  
67 response to a nudge then calculate a price increase in order to quantify the monetary  
68 value of the nudge. While there is a voluminous literature on financial incentives,  
69 and nudges are increasingly studied, there is a less research comparing these types  
70 of incentives (Fanghella *et al.*, 2021).

71 The energy frame is used as nudging has been increasingly used in this domain  
72 (Andor and Fels, 2018, Buckley, 2020). The principal objective of the experiment is  
73 to use a contextualised CPR game to explore the effect of nudges and peak prices on  
74 subjects' consumption choices compared to an absence of policies. The secondary  
75 objective is to implement a price designed to replicate the behaviour observed under  
76 a nudge policy and assess its effect on behaviour.

77 We find that both policies, nudge and price, lower consumption choices compared  
78 to an absence of policy. The nudge policy has an immediate effect on subjects'  
79 consumption choices whereas the price policy is more slowly integrated into subjects'  
80 decision making processes. Our results suggest that the nudge policy, rather than  
81 curbing overconsumption, tends to reinforce existing behaviours and that the price

82 policy can lead to inefficient private choices over the Nash equilibrium (NE). We  
83 thus advise caution when implementing similar nudge and price policies.

84 The rest of the paper is set out as follows: Section 2 discusses the relevant  
85 literature, Section 3 outlines the experimental design and procedure. Section 4  
86 gives the behavioural predictions. In Section 5, we present the results, followed by  
87 a discussion in Section 6. Finally, Section 7 concludes.

## 88 2 Related literature

### 89 2.1 Monetary incentives

90 In CPR laboratory experiments, monetary incentives are often modelled as per  
91 unit taxes. These are found to be a first best policy when it comes to managing  
92 behaviours which result in negative externalities (Ballard and Medema, 1993). In  
93 experimental games with negative externalities, studies have shown that subjects  
94 perform at near optimal levels when incentivised to do so by a tax equal to the  
95 marginal social cost of the externality (Plott, 1983, Heres *et al.*, 2013). Yet, taxes are  
96 seldom accepted by the public. This can be explained by a preference for the status  
97 quo (Cherry *et al.*, 2014), by tax aversion; individuals feel that negative incentives,  
98 such as taxes, impede their free-will and are controlling; by framing; acceptance for  
99 taxes increases when the mechanism behind them is explained (Kallbekken *et al.*,  
100 2011, Heres *et al.*, 2013).

101 Given that monetary interventions such as taxes (and dynamic pricing in the  
102 context of electricity consumption (Alexander, 2010)) can be politically difficult to  
103 implement, as well as costly, policy makers have also used non-price interventions  
104 or nudges to influence households to reduce their electricity consumption.

## 105 **2.2 Non-monetary incentives**

106 The nudge intervention used in the present experiment relates to both inform-  
107 ation on suggested play as the feedback is based upon the optimal level of con-  
108 sumption, and on social approval as we add an element of whether an individual's  
109 consumption behaviour is approved of or not.

### 110 **2.2.1 Suggested play**

111 Experiments using suggested play recommend a course of action to subjects  
112 concerning their contribution to a public good or their extractions from a common  
113 pool resource. In threshold public good games, [Marks \*et al.\* \(1999\)](#) and [Croson and](#)  
114 [Marks \(2001\)](#) find that suggesting a fair contribution to subjects before they decide  
115 on their contribution only results in the provision of the public good when preferences  
116 are heterogeneous. [Dal Bó and Dal Bó \(2014\)](#) find that suggested play works only  
117 under the addition of an element of moral suasion; the idea in a public good game  
118 that increasing your contribution to the maximum amount benefits everyone. [Barron](#)  
119 [and Nurminen \(2020\)](#) reproduce this result in a public good game in which the  
120 experimenter states a minimum contribution level which they view as "good" - moral  
121 suasion - which leads to contributions 40% above those of the baseline subjects.

122 In a CPR game, [Delaney and Jacobson \(2015\)](#) nudge groups to increase their  
123 payoffs using both informative and normative messaging, and compare this to a  
124 subsidy. The informative messaging states what the group should do to increase  
125 their earnings in the following period. Under normative messaging, a group is told  
126 whether they earned as much as possible or whether they earned less than they  
127 could have in the previous period, along with a smiling or sad face, and emphatic  
128 language directing subjects to change their behaviour. The subsidy is the most  
129 effective, followed by normative then informative messaging. The authors note that  
130 it is unusual that the normative messaging treatment results in only a slightly greater  
131 reduction in extraction level when compared to information alone given that previous

132 research has found significant effects on energy and water consumption reduction  
133 through the use of normative messages (Schultz *et al.*, 2007, Allcott, 2011, Ayres  
134 *et al.*, 2012, Ferraro and Price, 2013). This may be due to a certain level of overlap  
135 between the two treatments, as the informative treatment also contains normative  
136 language. In both treatments, subjects are told what they *should* do to increase  
137 their earnings. The two treatments, information and normative messaging should  
138 perhaps instead be viewed as a weak normative message and as a strong normative  
139 message, respectively.

140 Boun My and Ouvrard (2019) explore the impact of recommended play, or a  
141 nudge, and taxes on contributions to an environmental public good for reducing  
142 pollution in a hypothetical community. They hypothesise that reaction to a nudge is  
143 greater when subjects are more sensitive to environmental issues. Subjects are split  
144 into groups according to whether they are more or less environmentally sensitive than  
145 average and are then faced with either a nudge; a statement of the socially optimal  
146 contribution to the public good, or a tax; a linear tax based upon the optimal  
147 contribution. The tax treatment shows the greatest increase in contributions for  
148 both high and low sensitivity groups. The nudge divides subjects according to their  
149 environmental sensitivity, with the least sensitive reducing their contribution by  
150 twice as much as the most sensitive.

151 Other recent experiments have also compared the effect of taxes on nudges in  
152 positional goods experiments. Antinyan *et al.* (2020) find that while both their  
153 nudge (based on suggested play) and tax are effective at the beginning of the game,  
154 the effectiveness of the tax persists to the end of the game whereas the effectiveness  
155 of the nudge diminishes.

### 156 2.2.2 Social approval

157 In addition to suggested play, the nature of the nudge used in our experiment  
158 provides social approval or disapproval of an individual's behaviour in the game.

159 The rationale is that social approval increases optimal behaviour in CPR games as  
160 subjects perceive utility (disutility) from social approval (disapproval) (Rege and  
161 Telle, 2004). There is mixed evidence as to whether social information and ap-  
162 proval encourages optimal behaviour in collective action games. It has been shown  
163 both theoretically (Holländer, 1990, Fehr and Schmidt, 1999) and experimentally  
164 (Cialdini, 2003, Rege and Telle, 2004, Spraggon *et al.*, 2015) that such social norms  
165 can increase contributions in collective action games. In other experiments, social  
166 approval has been shown to have a negative effect on behaviour - increasing extrac-  
167 tions in CPR games (Brent *et al.*, 2019) and reducing contributions to the public  
168 good (Noussair and Tucker, 2007).

169 In a one-shot public good game, Rege and Telle (2004) find that when there is  
170 indirect social approval of a subject's contribution (subjects reveal their contribution  
171 to the group), contributions are much higher than the contribution in the base game  
172 and the theoretical prediction of 0 contributions. However, Noussair and Tucker  
173 (2007) run a similar experiment, finding that social approval of subjects' decisions  
174 does not have a significant effect on contributions in both a one-shot game and a  
175 repeated game. Indeed, in the repeated game, the possibility for social approval or  
176 disapproval leads to lower contributions than in the absence of approval.

177 Gächter and Fehr (1999) find that such social approval, created by publicly  
178 disclosing all contributions to all subjects at the end of a 10 period game, only  
179 has a significant effect when subjects are allowed to create a group identity. When  
180 subjects are complete strangers, the revelation of their contributions has a weak  
181 positive effect on contributions. In a CPR game, making public the decisions of  
182 subjects has been shown to have a negative effect on optimal behaviour. When  
183 faced with heterogeneous levels of extraction in a CPR game, Brent *et al.* (2019)  
184 find that the use of social approval by observing individuals' actions increases the  
185 level of resource extraction.

186 The social approval used in our experiment does not come from the other sub-

187 jects, but from the experimenter who informs subjects via a happy or sad face  
188 whether they are consuming more or less than the optimal amount.

## 189 **2.3 Energy consumption contextualisation**

190 Finally, as we use CPR theory as the basis of a hypothetical electricity con-  
191 sumption game, our experiment is also related to literature on the contextualisation  
192 of experiments. Environmental framing is often applied to laboratory (and increas-  
193 ingly, online experiments) in order to capture environmental aspects of the decisions  
194 being studied (McCalley *et al.*, 2011, Skatova *et al.*, 2016, Bühren and Daskalakis,  
195 2020, Fanghella *et al.*, 2021).

196 Economic experiments are typically abstract and context free so as to retain  
197 control and maintain internal validity (Smith, 1976). However, contextualisation  
198 may lead to a greater understanding of the game and better, as well as more realistic,  
199 decision making (Rommel *et al.*, 2019, Hsiao *et al.*, 2020). Experimental participants  
200 may bring their own context to abstract experiments in order to make meaning of the  
201 terminology (Hennig-Schmidt *et al.*, 2010) and over which the experimenter does not  
202 have control (Harrison and List, 2004). Alekseev *et al.* (2017) argue that by adding  
203 context to an experiment, and increasing participants' understanding, the observed  
204 behaviour can be more representative of the behaviour that is under study.

205 Highlighting the influence of the context that participants may bring to an exper-  
206 iment, subjects who associate a neutrally framed public good game with teamwork  
207 rather than tax payments, contribute more and believe that others will also contrib-  
208 ute more (Eriksson and Strimling, 2014). Elliott *et al.* (1998) find that when primed  
209 with a cooperative strategy, rather than an entrepreneurial strategy, participants  
210 contribute more to the public good. Similar results are found in environmentally  
211 framed games concerning pollution and climate change (Pevnitskaya and Ryvkin,  
212 2013, Brick *et al.*, 2016).

213 Contextualisation is also used in experimental games, in particular those con-

214 cerning environmental research questions, in order to render more salient the social  
215 aspects of decision making as well as the psychological costs of negative externalities  
216 (Eckel and Grossman, 1996, Alekseev *et al.*, 2017).

217 In the present experiment, we contextualise a CPR game as hypothetical electricity  
218 consumption choices. Our intention is firstly to ensure that our participants find  
219 themselves in the same contextual setting and clearly understand the consequences  
220 of their individual decisions and interdependencies. The second reason is to explicitly  
221 introduce the social component, as perceived by participants. In settings such  
222 as pollution regulation or resource depletion, the use of abstract terms may eliminate  
223 important social considerations that are inherent to them in naturally-occurring  
224 situations. Experiments, which model these scenarios but do not use their language,  
225 may yield results that have low external validity.

226 It is our belief that an entirely abstract and context free experiment would not  
227 cover all dimensions of energy consumption decisions, however, we recognise that  
228 we cannot include all of such dimensions within the constraints of a laboratory  
229 experiment. We assume that context affects behaviour in our electricity consumption  
230 setting, though we do not seek to determine to what extent this is true. We apply  
231 the same context to both our treatments and our control group.

### 232 3 Methodology

233 We implement a laboratory experiment in which participants are asked whether  
234 or not to use different energy consuming appliances, and whether to lower their heating  
235 or keep it at the same temperature. While the choices are hypothetical, they  
236 do mimic elements of real-life energy conservation efforts which are characterised  
237 by a trade-off between private and social benefits on the one hand, and personal  
238 disutility on the other. The experimental game is built upon CPR theory (Ostrom,  
239 1990) in which individuals derive private benefits from their extraction of the re-

240 source and social benefits from collective efforts to maintain the availability of the  
241 resource. There is a personal disutility due to lowering one's own private earnings  
242 from extracting the resource for the benefit of the group.

243 CPR theory has been applied to residential electricity consumption (Bäckman,  
244 2011, Goldthau, 2014, Gollwitzer *et al.*, 2018). The electricity network (power sta-  
245 tions, distribution centres, transmission lines) represents a man-made resource sys-  
246 tem and the resource units are the kilowatt hours which can be consumed. In the  
247 short run it can be considered that this system provides a stock of electricity units  
248 to households. The stock of electricity is renewable in the sense that once electri-  
249 city has been consumed it must be immediately reproduced in order to maintain  
250 supply and demand balance. Currently, generated electricity cannot be stored so  
251 the amount generated needs to correspond to the amount being consumed. There is  
252 limited storage capability in generators which are able to maintain electricity supply  
253 for under a minute. Beyond a minute, the supply is unstable and there is a risk of  
254 blackouts due to drops in frequency and voltage (Pratt and Fuller, 2016). Given  
255 this, on days of extreme weather, or when renewable energy resources supply elec-  
256 tricity, there is risk of demand outstripping supply which implies a need to reduce  
257 the demand for electricity<sup>2</sup>.

### 258 3.1 Common pool resource theory

259 A CPR game can be modelled as follows: a group of  $n$  players share a common  
260 resource. They each have an endowment of  $e$  tokens which can be used to invest  
261 in the extraction of the common resource in each period. The amount invested  
262 in resource extraction by individual  $i$  is  $x_i$  with  $\Sigma x_i$  the amount invested by the  
263 group. The return on extraction depends on the amount invested in extraction by

---

<sup>2</sup>This is a current problem and in the months leading to the experimental sessions of this paper, the local electricity utility led an information campaign asking households to lower their consumption during a particularly cold snap to avoid voltage reductions and the closure of various industrial sites. See (in French) <https://france3-regions.francetvinfo.fr/auvergne-rhone-alpes/vague-froid-grenoble-geg-appelle-ses-clients-reduire-leur-consommation-electrique-1174591.html> [Last consulted 19/08/2022.]

264 the individual  $x_i$  and the amount invested in extraction by the group  $\Sigma x_i$ . The  
 265 profit to individual  $i$  is the return from the amount not spent on extraction  $e_i - cx_i$   
 266 plus the return from CPR appropriation. To account for the externality, the payoff  
 267 from CPR extraction increases by  $a$  for each token invested by the individual and  
 268 decreases by  $b$  for each token any member of the group invests in extraction of the  
 269 CPR. The cost of investing in the extraction of the resource is  $c$ . Each player's profit  
 270 depends on his own investment in extraction as well as the group investment:

$$\pi_i = e - cx_i + x_i(a - b\Sigma x_i) \quad (1)$$

271 This formulation of the CPR game follows [Delaney and Jacobson \(2015\)](#) and  
 272 [Ostrom \*et al.\* \(1994\)](#) and the non-linearity of the profit function results in an interior  
 273 solution  $0 < x_i < e$ . A rational, self-interested player invests an amount  $x_i$  that  
 274 maximises their profit:

$$\max_{x_i} \pi(x_i, \Sigma x_i) = e - cx_i + x_i(a - b\Sigma x_i) \quad (2)$$

275 The first order condition is:

$$-c + a - bx_i - b\Sigma x_i = 0 \quad (3)$$

276 Supposing that all agents are equal, a symmetric NE can be found such that  
 277  $x_i = x_j = x$  for all players  $i, j$ .

$$x_i = \frac{(a - c)}{b(n + 1)} \quad (4)$$

278 This level of extraction maximises individual profits regardless of the effects of  
 279 individual extraction on the group.

280 The socially optimal investment in resource extraction is the amount  $x$  which

281 maximises the collective profit. Assuming symmetry, the player maximises:

$$\max_x n\pi(x) = n[e - cx + x(a - bn.x)] \quad (5)$$

282 The first order condition is:

$$-cn + an - 2bn^2x = 0 \quad (6)$$

283 which gives an optimal investment where:

$$x_i = \frac{(a - c)}{2bn} \quad (7)$$

284 This level of extraction takes into consideration the effect of each individual's  
285 extraction on the CPR.

286 The NE results in a higher level of extraction than the socially optimal amount.  
287 One option to align the private earnings with the social optimum (SO), is to increase  
288 the cost of extraction  $c$  such that the NE and socially optimum levels of extraction  
289 are equal. The cost of extraction  $c$  is increased by an amount  $d$  and its value is  
290 found by equating the NE and the socially optimal solutions:

$$\begin{aligned} \frac{a - c - d}{b(n + 1)} &= \frac{a - c}{2bn} \\ d &= \frac{(a - c)(n - 1)}{2n} \end{aligned} \quad (8)$$

291 The novelty of the present experiment is that instead of finding the amount  $d$   
292 which aligns the new NE with the original SO, we first run our nudge treatment and  
293 observe the players' behaviour, then we calculate the amount  $d'$  by which the cost  
294 of extraction  $c$  must increase in order to align the NE with the level of extraction  
295 observed in the nudge treatment,  $\bar{x}^{nudge}$ .

$$\frac{a - c - d'}{b(n + 1)} = \bar{x}^{nudge} \tag{9}$$

$$d' = a - c - (n + 1)b\bar{x}^{nudge}$$

296 We then implement this increase in the cost of extraction which we frame as a  
 297 price increase  $p = c + d'$ . This implementation and parameters of our price treatment  
 298 are further explained in Section 3.3.2.

299 In the framework presented above, the parameter  $a$  represents the personal be-  
 300 nefit of consuming electricity without constraint in terms of increased comfort. The  
 301 parameter  $b$  represents the negative externality of consumption of electricity in terms  
 302 of voltage reductions and brief power cuts which affect everyone. The parameter  $c$   
 303 represents the personal disutility associated with paying for electricity and not hav-  
 304 ing the money for other expenses. Table 1 summarises how the features of energy  
 305 consumption and those of our experiment relate.

Feature	Field	Experiment	Parameter
Private benefit	Money saved from saving energy	Personal gain from consumption choice	$a$
Negative externality	High consumption during peak periods puts strain on the grid	The more of the resource individuals take, the higher the cost on the collective	$b$
Private cost	Price of consumption, effort expended to conserve energy	Price, effort to reduce consumption through choice of appliances	$c$

Table 1: Features of energy conservation in our field replicated in the experiment

## 3.2 Experimental task

The game concerns electricity consumption during 10 peak periods when demand can be greater than supply requiring that all individuals lower their consumption in order to reduce strain on the grid, or on the local community energy storage system. In the experiment, subjects form groups of four ( $n = 4$ ) for 10 peak periods ( $t = 10$ ). Subjects remain in the same groups for the duration of the experiment following a partners design. Each group makes up an electricity consumption system of four households which represents a community. In this context, the demand response challenge is represented as a repeated CPR game.

At the start of each period, each subject receives an endowment  $e = 100$  ECU<sup>3</sup> which they can use to consume electricity (measured in energy units (EU)). In the control and nudge treatments each EU costs 1 ECU ( $c = 1$ ). The cost of each EU changes in the price treatment ( $p = 3$ ) as discussed below. Any ECU that the subject does not use to consume electricity is kept by the subject and included in their profit function. For every EU consumed, the subject receives  $a = 13$  and every EU consumed costs  $b = 0.1$  for all subjects in the group regardless of who consumed it. Subjects' profit function is as follows:

$$\pi_i = 100 - cx_i + x_i(13 - 0.1\Sigma x_i) \quad (10)$$

Individually, subjects maximise their profit at the NE,  $x^{NE} = 24$  for an individual profit of 158 ECU. This level of consumption is greater, and the payoff is lower than if subjects maximised the collective gains. Collectively subjects should each consume  $x^{SO} = 15$  for an individual profit of 190 ECU. This represents the collective interest of lowering consumption for demand response.

In each period, subjects must decide how much of their endowment to spend on consuming electricity by choosing whether or not to use five different electrical

---

<sup>3</sup>ECU = Experimental Currency Units. The exchange rate is communicated to all subjects during the instruction phase and is 150 ECU = 1€.

330 items. Table 2 details the different levels of consumption that subjects can choose  
 331 from. Subjects are told that their electricity consumption brings them comfort (via  
 332 a monetary gain) of 13 ECU for every unit consumed and that the total consumption  
 333 of their group leads to a reduction in personal comfort due to voltage reductions  
 334 and brief power cuts when demand is greater than supply (a monetary cost). The  
 335 greater the total consumption of the group, the greater the reduction in comfort.

Item	Consumption levels	Consumption amount (EU)
Electric heating	Unchanged	15
	1°C reduction in heating	10
	2°C reduction in heating	5
Electric water heater	On	5
	Off	0
Washing machine/ dishwasher	On	10
	Off	0
Cooking equipment	On	10
	Off	0
Television/ Computer	On	5
	Of	0

Table 2: Electricity consumption choices

336 When deciding whether or not to use the different electrical appliances proposed,  
 337 subjects are choosing to consume energy units in increments of 5. We discretise the  
 338 choice of electricity consumption to reflect the idea that in real life individuals con-  
 339 sume electricity by turning appliances on or off. We allow three levels of consumption  
 340 for the heating choice. Given the discretisation of the consumption choice, the NE  
 341 is  $x_i = 25$  EU and the SO is  $x_i = 15$  EU. To assist subjects in deciding how many  
 342 EU to consume, a simulator is available as well as a printed profit table<sup>4</sup>. At the  
 343 end of each period, subjects see how much they have consumed and their profit for  
 344 the period.

<sup>4</sup>The simulator is described to subjects during the explanation of the game phase. See Appendix A for an English translation of the instructions concerning the simulator and Appendix B for the profit table. Slides of the presentation of the game are available in French, and an English translation of all instructions by request to the corresponding author.

### 345 3.3 Treatments

#### 346 3.3.1 Nudge treatment

347 In the nudge treatment, in addition to the above, subjects are told that in order  
348 to avoid power cuts, consumers can be asked to lower their consumption during  
349 peak periods. This implies a lower level of comfort (as the individual may lower  
350 their heating or use their washing machine at a different time, for example) but  
351 allows all individuals, including oneself, to avoid a much lower comfort level, i.e. a  
352 power cut, or a reduction in the quality of electricity distribution.

353 At the end of each period, subjects receive additional feedback on their consump-  
354 tion by means of an injunctive norm which provides social approval or disapproval  
355 of their consumption choice (Cialdini *et al.*, 1991). If their choice of consumption  
356 is less than or equal to the level of consumption which minimises the reduction in  
357 comfort for the group, i.e.: the socially optimal level, they see a picture of a smiley  
358 face. If their consumption is greater than this level, then they see a sad face.

359 We recognise that there may be demand effects as a result of this treatment  
360 (Zizzo, 2010). However, we also believe that this is fundamental to nudge policy;  
361 individuals can easily deduce the action that they are being encouraged to take from  
362 the presence of a nudge. To minimise such demand effects, subjects were told that  
363 they would receive feedback in the form of faces relating their consumption decision  
364 to the socially optimal level. This is presented factually and is not presented as a  
365 target that they should reach. Subjects were free to follow the nudge or not, and  
366 all responses are anonymous. Compared with previous experiments using nudge-  
367 based treatments, we use no normative language suggesting a certain action or  
368 behaviour. In other experiments, nudges are presented textually as behaviour that  
369 subjects *should* do in order to maximise their gains (see Delaney and Jacobson  
370 (2015), Boun My and Ouvrard (2019), Antinyan *et al.* (2020)).

371 **3.3.2 Price treatment**

372 In the price treatment, subjects are told that voltage reductions and brief power  
 373 cuts can be avoided by incentivising consumers to consume less during peak periods  
 374 by increasing the price of electricity. The price  $p$  for this treatment is calculated  
 375 with respect to the average levels of consumption observed in the nudge treatment.  
 376 Subjects are told that each energy unit consumed during the peak period costs  
 377 3 ECU which is three times more expensive than in a normal period<sup>5</sup>. The goal  
 378 is to compare whether the price results in the same level of consumption as the  
 379 nudge when the implemented price is designed to achieve the level of consumption  
 380 observed in the nudge treatment. The average level of consumption observed in the  
 381 nudge treatment is 19.07 across all periods. Given that subjects can only choose  
 382 consumption in increments of 5, the price is calculated such that the NE consumption  
 383 level in the price treatment is  $x_i^{NE,P} = 20$ .

$$\begin{aligned}\frac{a - p}{b(n + 1)} &= 20 \\ \frac{13 - p}{0.1(4 + 1)} &= 20 \\ p &= 3\end{aligned}\tag{11}$$

384 The price of electricity for subjects in the price treatment is thus equal to 3 ECU.  
 385 In this treatment the subjects maximise:

$$\max_{x_i} \pi(x_i, \Sigma x_i) = 100 - 3x_i + x_i(13 - 0.1\Sigma x_i)\tag{12}$$

386 The feedback given at the end of each period is the subject's level of consumption  
 387 and their earnings for that period.

---

<sup>5</sup>This is comparable to tariffs proposed by EDF at the time of the experiment; the highest peak price is approximately 3.5 times the standard tariff (EDF, 2016).

### 388 3.4 Experimental procedure

389 240 subjects took part in the experiment, during 12 sessions in March and April  
390 2017 at Grenoble Applied Economics Laboratory. The experiment was programmed  
391 using zTree software (Fischbacher, 2007). Each session lasted one and a half hours.  
392 At the beginning of each session, subjects themselves randomly chose a subject  
393 number and a computer post. Once the subjects were seated, the experimenter read  
394 aloud all instructions. These were also displayed on two screens at the front of the  
395 room which all subjects could see.

396 Table 3 shows the number of subjects, groups, and sessions per treatment. For  
397 participating in the experiment, subjects received a 10€ show-up fee. In addition,  
398 subjects earned 7€20 to 18€00, with average earnings across sessions of 12€30.  
399 The subjects are undergraduate or graduate students in various disciplines, 59%  
400 were female subjects, and the average age across subjects was 22 years.

Treatment	Number of subjects	Number of groups	Number of sessions
Nudge	100	25	5
Price	80	20	4
Control	60	15	3
Total	240	60	12

Table 3: Number of subjects per treatment

401 After general instructions concerning confidentiality, anonymity of data and the  
402 code of conduct were given, the experimenter described the context of the game.  
403 Subjects were told that the experiment would include several phases. The first phase  
404 of the experiment was the CPR game. The second phase involved a risk aversion  
405 test<sup>6</sup> (Holt *et al.*, 2002). In the third and final phase, subjects completed three  
406 questionnaires: the General Ecological Behaviour Scale (Kaiser, 1998), an altruism  
407 questionnaire (Costa and McCrae, 1992) and finally a demographic questionnaire<sup>7</sup>.

<sup>6</sup>Analyses on risk attitudes were not conclusive and so are not discussed further in the rest of the paper.

<sup>7</sup>Following Boun My and Ouvrard (2019), we use a shorter version of the GEB scale including

408 The instructions for each phase were read aloud then the subjects completed  
409 the phase before listening to the instructions on the following phase. Before the  
410 beginning of the CPR game phase, subjects completed a questionnaire to determine  
411 their understanding of the game. Subjects were informed of any wrong answers and  
412 had to correct them before advancing to the first period of the game.

## 413 4 Behavioural hypotheses

414 Under the assumption that subjects are rational and self-interested, we would  
415 expect them to choose the NE consumption amount in all treatments, i.e.: 25 in the  
416 control and nudge treatment, and 20 in the price treatment. Such players would not  
417 be influenced by the nudge described above as this has no effect on their economic  
418 incentives. As individuals are not necessarily rational and self-interested, and are  
419 influenced by nudges which motivate a particular behaviour by exploiting systematic  
420 biases in decision making (Thaler and Sunstein, 2008), we expect that our nudge  
421 will influence consumption choices.

422 **Hypothesis 1** *Consumption choices in the nudge treatment will be lower than in*  
423 *the control treatment.*

424 Previous experiments have found that aligning the NE with the SO via the use  
425 of a tax (framed as a price increase in our experiment) is a first best policy for  
426 dealing with social dilemmas in public good and CPR games (Plott, 1983, Ballard  
427 and Medema, 1993, Cochard *et al.*, 2005).

428 **Hypothesis 2** *Consumption choices in the price treatment will be lower than in the*  
429 *control treatment.*

430 In our experiment, we align the NE of the price treatment with the observed  
431 consumption choices in the nudge treatment.

---

28 items. See Kaiser (1998) and Costa and McCrae (1992) for details of the GEB and altruism questionnaires, respectively.

432 **Hypothesis 3** *In the price treatment, consumption choices will be similar to those*  
433 *in the nudge treatment.*

434 The nudge used in the present experiment creates a social norm of consumption  
435 at the optimal level. Those subjects who are averse to defying social norms will  
436 adjust their behaviour accordingly (Schultz *et al.*, 2007). Simply suggesting a course  
437 of action does not necessarily result in the desired outcome as individuals are not  
438 constrained to do so thus we also include an injunctive norm in our nudge. The  
439 injunctive norm reinforces whether a certain behaviour is approved of or not (Cialdini  
440 *et al.*, 1991). As such, it provides a positive frame for those who underconsume or  
441 who consume optimally and approves of their normative correctness (Farrow *et al.*,  
442 2017). This leads to the following hypotheses in the nudge treatment:

443 **Hypothesis 4** *Subjects who receive ‘happy face’ feedback will not change their con-*  
444 *sumption in the following period (those who consume the optimal amount or*  
445 *less).*

446 **Hypothesis 5** *Subjects who receive ‘sad face’ feedback will lower their consumption*  
447 *in the following period (those who consume more than the optimal amount).*

## 448 5 Results

### 449 5.1 Average consumption at the group level

450 Figure 1 displays the average group consumption by treatment for each period.  
451 Table 4 reports the values of average consumption and the results of non-parametric  
452 tests on between and within treatments compared to the corresponding NE, the SO,  
453 and in the case of the price treatment, the target consumption of 20 EU. All analysis  
454 in this section is performed using Stata 15 (StataCorp, 2017).

455 We also report the results of post-hoc power analysis in Table 5 using GPower  
456 (Faul *et al.*, 2009). The power analysis shows that our main comparisons between

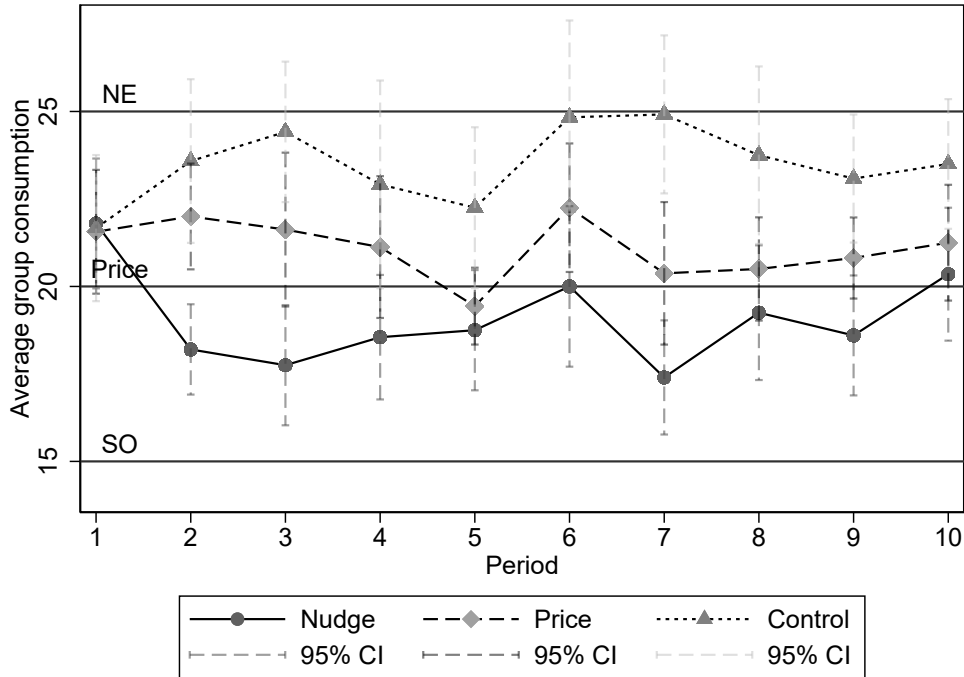


Figure 1: Dynamics of average consumption by treatment

457 treatments and the control group and between each treatment are highly powered  
 458 given our sample size and the observed effect size. Our within group comparisons to  
 459 the NE or the SO are also highly powered in the case of the nudge treatment and for  
 460 the control group with comparison to the SO. We calculate a power slightly below  
 461 the widely accepted threshold of 0.8 (Lenth, 2001) for the comparison within the  
 462 control group and the NE and between the price group and the Nash equilibrium.  
 463 Given that the control group faces no incentive to consume anything other than the  
 464 NE and that the price treatment is designed to encourage a consumption equal to the  
 465 NE, we do not find these slightly less powered tests to be of concern for our  
 466 statistical inference below.

	Period										Overall
	1	2	3	4	5	6	7	8	9	10	
Average consumption											
Nudge	21.80 (4.49)	18.20 (3.13)	17.75 (4.16)	18.55 (4.31)	18.75 (4.16)	20.00 (5.56)	17.40 (3.95)	19.25 (4.66)	18.60 (4.15)	20.35 (4.60)	19.07 (4.46)
Price	21.56 (3.78)	22.00 (3.23)	21.63 (4.70)	21.13 (4.33)	19.44 (2.35)	22.25 (3.92)	20.38 (4.35)	20.50 (3.15)	20.81 (2.48)	21.25 (3.54)	21.09 (3.66)
Control	21.67 (3.77)	23.58 (4.22)	24.42 (3.62)	22.92 (5.36)	22.25 (4.15)	24.83 (5.00)	24.92 (4.08)	23.75 (4.58)	23.08 (3.30)	23.50 (3.35)	23.49 (4.19)
Wilcoxon rank-sum test (Between treatment $p$ -values)											
Nudge = Control	0.9216	0.0005	0.0001	0.0147	0.0104	0.0160	0.0000	0.0111	0.0008	0.0256	0.0001
Price = Control	0.9194	0.2027	0.0293	0.2842	0.0313	0.1181	0.0042	0.0275	0.0127	0.0278	0.0035
Nudge = Price	0.9083	0.0004	0.0086	0.0732	0.2947	0.2560	0.0300	0.4215	0.0275	0.6960	0.0046
Wilcoxon signed-rank test (Within treatment $p$ -values)											
Nudge = 15	0.0000	0.0002	0.0048	0.0008	0.0004	0.0006	0.0095	0.0009	0.0006	0.0001	0.0000
Nudge = 25	0.0025	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0002	0.0000
Control = 15	0.0007	0.0006	0.0006	0.0007	0.0007	0.0006	0.0006	0.0006	0.0007	0.0006	0.0007
Control = 25	0.0083	0.3314	0.5642	0.1897	0.0243	0.8416	0.9772	0.1946	0.0329	0.1665	0.0355
Price = 20	0.0370	0.0139	0.2290	0.3203	0.4250	0.0238	0.9700	0.5452	0.1491	0.1505	0.0057

Standard deviations in brackets

Between treatment  $p$ -values are  $p$ -values of Wilcoxon rank-sum tests.

Within treatment  $p$ -values are  $p$ -values of Wilcoxon signed rank tests.

Table 4: Mean group consumption by treatment and associated statistical tests

Test	Mean	SD	n	Power
Nudge = Control	19.07	4.46	100	1.000
	23.49	4.19	60	
Nudge = Price	19.07	4.46	100	0.894
	21.09	3.66	80	
Price = Control	21.09	3.66	80	0.934
	23.49	4.19	60	
Nudge = 15	19.07	4.46	100	1.000
Nudge = 25	19.07	4.46	100	1.000
Control = 15	23.49	4.19	60	1.000
Control = 25	23.49	4.19	60	0.765
Price = 20	21.09	3.66	80	0.729

Table 5: Power analysis for overall results reported in Table 4

467 *Control group*

468 In the absence of any policies, the control groups consume 23.49 on average  
469 across all periods. This level of consumption is significantly different from both the  
470 NE and the SO. Subjects' consumption is significantly different from the SO in all  
471 periods, and statistically indistinguishable from the NE in 7 out of 10 periods.

472

473 **Result 1:** In the absence of policy, subjects do not achieve the socially optimal  
474 level of consumption.

475

476 *Nudge compared to control*

477 The nudge intervention results in a level of consumption of 19.07 on average  
478 across all 10 periods. This is statistically different from both the SO and the NE  
479 overall and in all periods. Consumption in the nudge treatment is statistically  
480 different from that of the control group in all but the initial period.

481 While, on average, the nudge does encourage a lower level of consumption com-  
482 pared to the control group, it does not achieve its target of 15. An examination of  
483 individual choices shows that 15 is the level of consumption most chosen by sub-  
484 jects which suggests that there are individual effects at play. This is explored in

485 Section 5.2.

486

487 **Result 2:** Average consumption in the nudge treatment is significantly lower  
488 than in the control groups.

489

490 *Price compared to control*

491 In the price treatment, the price is such that consumers are incentivised to con-  
492 sume 20 at the NE whereas in the control group the NE is equal to 25. The average  
493 group level of consumption is 21.09. Overall, this is statistically different to that of  
494 control groups. Average consumption between the two groups begins at a similar  
495 level then is consistently and statistically different from period 7 onwards.

496 Similarly to the nudge treatment, the price does not result in an average level  
497 of consumption equal to 20 as designed. There are again individual effects at play  
498 as 20 is the level of consumption chosen by 31 to 43% of subjects. This is further  
499 explored in section Section 5.2.

500

501 **Result 3:** Average consumption in the price treatment is significantly lower than  
502 in the control groups and consistently so starting in the seventh period.

503

504 *Price compared to nudge*

505 The price treatment is designed to incentivise subjects to consume approximately  
506 the amount observed in the nudge treatment. Overall, average consumption between  
507 the two treatments is statistically different. Excluding the first period, consumption  
508 in the price treatment is greater than that of the nudge treatment. The observed  
509 consumption in the price treatment is significantly different to the nudge treatment  
510 overall and in periods 2, 3, 7 and 9.

511 Given the design of the experiment, the price is calculated to encourage a level of  
512 consumption equal to 20 (the rounded value of the average observed consumption in

513 the nudge treatment), thus we also compare the behaviour in the price treatment to  
514 this level. Overall, and in the first two periods, consumption in the price treatment  
515 is statistically different from the target consumption of 20.

516

517 **Result 4a:** Consumption in the price treatment is higher than in the nudge  
518 treatment.

519 **Result 4b:** Consumption in the price treatment consistently reaches its object-  
520 ive of 20 from period 7 onwards.

521

#### 522 *Average consumption during the game*

523 In the first period, all treatments start at a similar level of average consump-  
524 tion. This difference is insignificant ( $p=0.9899$ , Kruskal-Wallis test). For the control  
525 group, this shows that some subjects consumed closer to the SO but this was not  
526 maintained for the rest of the game. Given that in the nudge treatment, subjects  
527 do not receive feedback until after having made their consumption decision, it is  
528 to be expected that average group consumption in the first period will be similar  
529 between the nudge and control groups. In Figure 1 it can be seen that after the  
530 initial feedback, the average consumption immediately decreases and from period 2  
531 it is lower than that of control groups. Post-feedback, average consumption in the  
532 nudge treatment is consistently lower in all periods compared to the control groups.

533 In the price treatment, subjects are aware of the price prior to any decision mak-  
534 ing. We would therefore expect these subjects to consume significantly less than the  
535 control group from the first period. However, this difference is not significant. The  
536 average group consumption is only consistently and significantly different between  
537 price and control groups from the seventh period. This suggests that subjects do  
538 not immediately integrate the price into their decision making. They require a few  
539 periods of play before they take into consideration the effect of the price on their  
540 consumption level. Although the experiment follows a between-subjects design and

541 therefore the subjects in the price treatment saw only a price of 3 ECU, in the  
542 instructions to the experiment, we explained that the price is three times more ex-  
543 pensive compared to normal periods. We therefore interpret our results as a framing  
544 effect.

545 During the course of the game, we observe inflection points at periods 5 and  
546 6. There is no significant difference in average consumption within a treatment  
547 between periods 4 and 5, nor between periods 5 and 6 within the nudge treatment.  
548 We consider these points to be statistical noise. In the control group and price  
549 treatment, average consumption sharply increases in period 6 following a downward  
550 trend before decreasing again towards the end of the game. Subjects may have  
551 felt that the mid-point of the game was an opportunity to change strategy and  
552 so to increase consumption above the previous trend. Indeed, when looking at  
553 the per period average consumption at the group level, there are certain groups  
554 whose average consumption is markedly increased in period 6 compared to the others  
555 periods<sup>8</sup>. It may be that there is a an opportunity effect at play wherby these  
556 subjects are increasingly risk averse towards the end of the game ([Friedman and](#)  
557 [Cassar, 2004](#)). If these groups are removed, the period 6 average falls but reduces  
558 the already small sample size so we have ultimately decided to include the groups  
559 in the analysis.

560 The linear trend in the control group is upward sloping with average consump-  
561 tion tending towards the NE in the final period. Such behaviour is typically ob-  
562 served in experiments with a finite and known timeframe ([Croson, 1996](#), [Keser and](#)  
563 [Van Winden, 2000](#)). However, the two treatments show a much flatter linear trend.  
564 With the average consumption in the final period being only marginally lower than  
565 in the first period. This lack of decay towards the NE is indicative of the establish-  
566 ment of norm, in our case around 20 EU ([Andreoni, 1988](#)).

567 The results described in this section are robust to panel data estimation as

---

<sup>8</sup>See Appendix C for the graphs of these groups.

568 shown in Table 6 which presents regression estimates of treatment effects. The  
569 specifications have been estimated using panel data random effects estimation. Panel  
570 data methods are used as there are  $n$  subjects making a consumption decision in  $t$   
571 periods. Random effects estimation is preferable to OLS or fixed effects estimation  
572 as it is more efficient, and given that the experiment uses a between-subject design,  
573 random effects estimation allows for the estimation of the time-invariant treatment  
574 variables (Moffatt, 2015).

	(1)	(2)
Nudge	-4.427*** (0.830)	-4.427*** (0.830)
Price	-2.398*** (0.702)	-2.398*** (0.703)
Period		-0.018 (0.052)
Constant	23.492*** (0.607)	23.588*** (0.670)
Observations	600	600

Standard errors in parentheses  
Robust standard errors clustered by group.  
\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 6: Average group consumption (random effects estimation)

575 The value of the constant represents the average consumption of the control  
576 group controlling for different variables. Both specifications show a clear significant  
577 effect of both the nudge and price treatments compared to the control groups. In  
578 specification 2, a period variable is included to control for variation during the  
579 game, however, the coefficient is not significant indicating no decay in consumption  
580 decisions towards the NE during the course of the game. This can be seen in  
581 Figure 1 as there is little variation between the average consumption in the first  
582 period and the tenth period.

## 583 5.2 Average consumption at the individual level

584 Table 7 shows the regression estimates of random effects specifications of treat-  
585 ment and covariates on individual consumption choice. Specification 1 shows a signi-  
586 ficant treatment effect for both the nudge and the price treatment at the individual  
587 level. In even numbered specifications, profit in  $t-1$  is included and has a significant  
588 but small positive effect on average individual consumption. As the amount earned  
589 in  $t-1$  increases, subjects increase their consumption in  $t$ . This could be indicative  
590 of a rebound effect where subjects who earn more, increase their consumption.

591 Specifications 3, 4 and 7 show that individuals who underconsumed<sup>9</sup> in  $t-1$ , re-  
592 duce their consumption in  $t$  compared to individuals consuming the socially optimal  
593 amount. Those who overconsume in  $t-1$  continue to do so. Once individual con-  
594 sumption type is controlled for, the significant effect of the price treatment falls out  
595 as the price treats all individuals equally and does not differentiate according to how  
596 an individual consumes (under, optimally, or over).

597 Finally, in specifications 5-7, variables concerning subjects' sensitivity towards  
598 the environment and their level of altruism<sup>10</sup> are included. Individuals who are  
599 more sensitive to environmental issues consume less. Given the context of the CPR  
600 game as an electricity consumption decision, such individuals may have additional  
601 motivation to choose a lower level of consumption so as to decrease their hypothetical  
602 impact on the environment. There is no significant effect of altruism on individual  
603 consumption choice.

---

<sup>9</sup>The share of individuals who underconsume in each treatment is shown in Appendix D.

<sup>10</sup>The construction of these variables is explained in Section 5.3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Nudge	-4.427*** (0.829)	-5.655*** (0.952)	-3.899*** (0.720)	-4.802*** (0.840)	-4.275*** (0.835)	-5.515*** (0.955)	-3.794*** (0.720)
Price	-2.398*** (0.701)	-1.799** (0.901)	-0.843 (0.636)	-0.062 (0.872)	-2.318*** (0.759)	-1.742* (0.943)	-0.802 (0.677)
Profit in t-1		0.033*** (0.005)		0.037*** (0.007)		0.032*** (0.005)	
Individual under consumed (t-1)			-2.091*** (0.584)	-1.619*** (0.572)			-2.013*** (0.575)
Individual over consumed (t-1)			3.589*** (0.496)	3.342*** (0.483)			3.572*** (0.497)
High Environmental sensitivity					-1.545** (0.655)	-1.447** (0.669)	-1.314** (0.552)
High Altruism					-0.856 (0.652)	-0.603 (0.651)	-0.492 (0.527)
Constant	23.492*** (0.606)	18.682*** (1.189)	21.294*** (0.672)	15.785*** (1.494)	24.732*** (0.800)	19.807*** (1.366)	22.229*** (0.851)
Observations	2400	2160	2160	2160	2400	2160	2160

Standard errors in parentheses

Robust standard errors clustered by group.

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 7: Individual consumption (random effects estimation)

### 604 5.2.1 Influence of past behaviour

605 As subjects' consumption decisions in the previous period significantly influence  
606 their consumption choice in the present period, we examine the effect of previous  
607 behaviour in more detail in Table 8. This is of particular importance in the nudge  
608 treatment as whether subjects under or over consumed in period  $t-1$  is made clear  
609 to them via the feedback received. In the price treatment and control groups it is  
610 not. Specification 1-3 includes only subjects' consumption choice in the previous  
611 period for the nudge, price and control groups, respectively. Specifications 4-6 also  
612 include past profit, and environmental sensitivity and altruism scores.

613 In the nudge treatment, subjects who underconsume receive happy face feedback  
614 and subjects who overconsume receive sad face feedback. Compared to optimally  
615 consuming groups, this feedback has the effect of reinforcing an individual's beha-  
616 viour in the previous period. With regard to the feedback received by subjects in  
617 the nudge treatment, both hypotheses 4 and 5 are rejected, as rather than nudging  
618 subjects towards the socially optimal level of consumption, the nudge employed in  
619 this experiment reinforces subjects' existing behaviour. Subjects who under (over)  
620 consume in the previous period tend to decrease (increase) their consumption in the  
621 present period. This suggests that while the nudge shows a decrease in average con-  
622 sumption at the group level, at the individual level the nudge may serve to reinforce  
623 behaviours that are already present.

624

625 **Result 5:** The feedback in the nudge treatment reinforces subjects' existing  
626 consumption behaviour.

627

628 To explore how past behaviour influences consumption choices in the present  
629 period across all treatments, we run the same analysis in the price treatment and  
630 the control groups as shown in Table 8. We see that there is a significant effect of  
631 previous consumption choice (under or overconsuming) on individual consumption

632 choice in the present period in both specifications concerning the price treatment.  
633 For the control groups, there is a significant effect of previous behaviour for those  
634 subjects who overconsumed. Regardless of treatment feedback, we see that subjects  
635 tend to under (over) consume in period  $t$  if they did so in period  $t - 1$ .

	(1)	(2)	(3)	(4)	(5)	(6)
	Nudge	Price	Control	Nudge	Price	Control
Under consumption :- (t-1) <sup>a</sup>	-2.317*** (0.791)	-1.937** (0.895)	-3.127* (1.879)	-1.545* (0.851)	-1.839** (0.831)	-2.328 (1.988)
Over consumption :- (t-1) <sup>a</sup>	4.067*** (0.765)	3.174*** (0.820)	3.383*** (0.978)	3.274*** (0.861)	3.502*** (0.802)	3.001*** (0.924)
Profit in t-1				0.029* (0.015)	0.035*** (0.011)	0.041*** (0.010)
High Environmental sensitivity				-2.399*** (0.670)	-0.398 (0.763)	-0.927 (1.615)
High Altruism				-1.714** (0.843)	0.724 (0.623)	-0.100 (1.415)
Constant	17.203*** (0.408)	20.545*** (0.355)	21.581*** (1.074)	14.804*** (2.911)	15.715*** (1.624)	15.958*** (2.335)
Observations	900	720	540	900	720	540

Standard errors in parentheses.

Robust standard errors clustered by group.

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

<sup>a</sup> In the nudge treatment, subjects received feedback on whether they under or overconsumed in the form of

a :-) or a :-(. In the price treatment and control groups, subjects did not receive such feedback

Table 8: Individual consumption by treatment (random effects estimation)

636 In order to further analyse the effect of previous behaviour on present period  
637 choices, we look at the proportion of subjects who consistently underconsume (Table 9)  
638 as well as those who play, in period  $t$ , their best response to the consumption of  
639 others in their group in period  $t - 1$  (Table 10). Subjects have a profit table at their  
640 disposition (see Appendix B) which they can use to infer the best response in period  
641  $t$  to the collective choice of the others in their group in period  $t - 1$ .

642 A greater proportion of subjects underconsumed in more periods in each of our  
643 treatments compared to the control groups. This is particularly true of the price  
644 treatment, in which more subjects also played their best response to others' con-  
645 sumption in more periods. In the nudge treatment, we see a tendency to not play  
646 the best response as the game progresses with a smaller proportion choosing that  
647 option in later periods. In the price and control treatments, the opposite is true; a  
648 greater proportion of subjects play their best response in period  $t$  in response to the  
649 consumption of others in their group in period  $t - 1$ .

650 This analysis shows that there is an individual effect at play: subjects have a  
651 type (under or over-consumer) and they tend to stick to that type. Thus, average  
652 consumption tends towards its objective for each of the treatments but not entirely,  
653 due to subjects who persistently overconsume. Furthermore, in the price treatment  
654 and control group, we see that more individuals play their best response in period  $t$   
655 to the observed consumption of their group in period  $t - 1$ , whereas the opposite is  
656 true in the nudge treatment.

### 657 5.3 Questionnaire results

658 In this section, the results of the questionnaires completed after the CPR game  
659 regarding environmental sensitivity and altruism are detailed. While it is true that  
660 the different treatments may have primed subjects' responses to the questionnaires,  
661 the questionnaires were implemented after the main game of the experiment in order  
662 to avoid priming subjects' behaviour for environmental or altruistic reasons before

Treatment	Total number of periods in which subject underconsumed										
	0	1	2	3	4	5	6	7	8	9	10
Nudge	37%	20%	17%	6%	7%	3%	4%	2%	1%	1%	2%
Price	20%	16%	14%	11%	15%	9%	4%	5%	4%	1%	1%
Control	53%	18%	12%	7%	3%	0%	2%	3%	0%	0%	2%
Total	35%	18%	15%	8%	9%	4%	3%	3%	2%	1%	2%

For the nudge and control groups, underconsumption is consuming less than the social optimum of 15. In the price treatment, underconsumption is consuming less than the target level of consumption of 20.

Table 9: Percentage of subjects by number of periods in which they under consume

Treatment	Subjects playing best response in each period (%)									
	2	3	4	5	6	7	8	9	10	Overall
Nudge	21%	5%	12%	14%	14%	20%	9%	15%	19%	13%
Price	30%	31%	34%	39%	40%	45%	30%	44%	40%	33%
Control	20%	28%	25%	27%	33%	23%	33%	38%	38%	27%
Total	24%	20%	23%	25%	28%	29%	22%	30%	31%	23%

Table 10: Percentage of subjects playing best response in each period by treatment

663 playing.

### 664 5.3.1 General Ecological Behaviour Scale

665 The GEB questionnaire measures environmental sensitivity (Kaiser, 1998). Of  
666 the 28 items in the questionnaire, the mean score per item is 3.34 (std. dev. = 0.22)  
667 and Cronbach's  $\alpha = 0.73$ <sup>11</sup>. The GEB scale is therefore acceptable.

668 Table 11a shows the average consumption decisions of individuals in each treat-  
669 ment according to their sensitivity to environmental issues. High environmental  
670 sensitivity is classed as greater than the average of the sample ( $M = 107.58$ )<sup>12</sup>.

<sup>11</sup>Cronbach's  $\alpha$  is statistic of the reliability of questionnaires which measures the internal consistency of multiple-items. The value ranges between 0 and 1, with a higher number indicating a greater level of reliability. A Cronbach's  $\alpha > 0.7$  is considered to be the cutoff at which survey scales are reliable (Lavrakas, 2008). For comparison, Boun My and Ouvrard (2019) found a Cronbach's  $\alpha = 0.74$ .

<sup>12</sup>In the nudge, price and control groups, 58%, 55% and 52% of subjects have high environmentally sensitivity, respectively. This may indicate a certain level of priming of subjects' responses by treatment, however, the analysis in this section is robust to alternative calculations of high and low environmental sensitivity: about the per treatment mean and median.

671 Overall and for each treatment, more environmentally sensitive subjects choose to  
 672 consume less. The difference in consumption level by environmental sensitivity is  
 673 greatest in the nudge treatment. This difference is statistically significant as shown  
 674 in Table 11b ( $p < 0.01$ , Wilcoxon signed-rank test).

Treatment				High			
Treatment	Low	High	Total		Nudge	Price	Control
Nudge	20.68	17.90	19.07				
Price	21.38	20.86	21.09				
Control	24.14	22.88	23.49				
Total	21.85	20.04		Low	Nudge	0.0000	
					Price		0.2036
					Control		0.1770

(a) Average individual consumption by treatment and by level of altruism

(b) Between treatment  $p$ -values

Table 11: Average individual consumption by treatment and by environmental sensitivity

675 **Result 7:** Individuals are affected differently by the nudge according to their  
 676 level of environmental sensitivity. In the price and control groups, there is no dif-  
 677 ference according to environmental sensitivity.

678

### 679 5.3.2 Altruism Questionnaire

680 The altruism questionnaire is used to measure subjects' altruistic tendencies.  
 681 The mean score per item is 3.28 (std. dev. = 0.33). Cronbach's  $\alpha$  is 0.68. The  
 682 altruism questionnaire is moderately acceptable.

683 Table 12a shows the average individual consumption by treatment according to  
 684 level of altruism and Table 12b the associated Wilcoxon signed-rank tests. High  
 685 altruism is greater than the average of the sample ( $M = 32.38$ )<sup>13</sup>. In the nudge  
 686 treatment, highly altruistic individuals choose to consume less than less altruistic in-  
 687 dividuals. The levels are similar across altruism types in the control groups, and the

<sup>13</sup>In the nudge, price and control groups, 58%, 55% and 52% showed a high altruism level, respectively. This analysis is also robust to alternative calculations of high and low altruism: about the per treatment mean and median.

688 opposite is observed in the price treatment. With regard to statistical significance,  
 689 the differences are only significant in the nudge treatment. As with environmental  
 690 sensitivity, it appears that a nudge based policy can separate subjects based upon  
 691 their level of altruism.

692

Treatment	Low	High	Total	High			
Nudge	20.57	17.97	19.07		Nudge	Price	Control
Price	20.88	21.27	21.09				
Control	23.66	23.34	23.49				
Total	21.51	20.32		Low	Nudge	0.0000	
					Price	0.6936	
					Control		0.6117

(a) Average consumption by altruism level

(b) Between treatment  $p$ -values

Table 12: Average individual consumption

693 **Result 8:** Individuals are affected differently by the nudge treatment according  
 694 to their level of altruism. In the price and control groups, there is no difference  
 695 according to their level of altruism.

696

## 697 6 Discussion

698 We shall now discuss how the results of the experiment may be of interest to  
 699 policy makers considering the implementation of a nudge or a price-based inter-  
 700 vention designed to reduce households' energy consumption during peak periods.  
 701 Nudges may be a particularly interesting policy tool in situations in which indi-  
 702 viduals are unable to pay higher rates as a means to encourage them to lower their  
 703 consumption.

704 The implementation of such a nudge system at the level of a group of consumers  
 705 may be questioned. However, the development of smart meters and especially of  
 706 increasingly fine control devices via AI suggests, in the very near future, possibilities  
 707 for implementing such systems at very fine levels (for example at the level of a build-

708 ing or a neighbourhood). Pilot experiments are already under way, where localised  
709 devices grouping relatively similar households (with regard to the composition of  
710 households, electrical equipment, initial consumption levels, etc.) are being tested  
711 by integrating normative and/or informative nudges<sup>14</sup>.

712 Our experiment shows that in the absence of policies, individuals do not achieve  
713 the socially optimal level of consumption. We find that they consume, on average,  
714 slightly below the NE amount. This corroborates previous experimental evidence  
715 which shows that individuals tend to find a balance between their own private in-  
716 terest and the collective interest of the group, or that they display other-regarding  
717 preferences with regard to their choices (Ostrom and Walker, 1991, Davis and Holt,  
718 1993, Kagel and Roth, 2016).

719 When a policy is introduced, a nudge or a price, individuals significantly reduce  
720 their consumption and it remains lower than that of individuals who do not exper-  
721 ience any policy measures. In the nudge treatment, individuals make the greatest  
722 reduction efforts, on average, relative to control groups. This is line with the efforts  
723 of environmentally sensitive individuals in Boun My and Ouvrard (2019).

724 Under the price increase, individuals also lower their consumption relative to  
725 control groups and achieve an average level of consumption which is closer to its  
726 objective than the nudge treatment<sup>15</sup>. Delaney and Jacobson (2015) also find that  
727 their subsidy achieves a level of common pool extraction which is much closer to its  
728 objective than do their non-monetary interventions.

729 Both the nudge and the price increase result in a level of consumption that is  
730 halfway towards the optimal level compared to no policies. The price increase was  
731 designed to be approximately equivalent to the nudge, i.e.: the target consumption  
732 of the price increase is approximately equal to the observed consumption of the

---

<sup>14</sup>For example, the local authority in Grenoble has implemented a nudge-based energy conser-  
vation programme <https://www.grenoblealpesmetropole.fr/621-metro-energies.htm> which  
compares individual household consumption to that of similar households.

<sup>15</sup>We remind the reader that the objective of the nudge treatment is to reduce consumption to  
15 EU, and the price treatment to 20 EU

733 nudge treatment. The price increase is thus more efficient at achieving its target  
734 consumption than the nudge. However, under the price increase there is a loss of  
735 individual welfare due to a higher price which is not present under the nudge. We  
736 conclude that while the nudge does not achieve the SO, it is equivalent to the price  
737 increase without the loss of welfare the higher price implies.

738 Interestingly, we find a reversed effect between our two treatments: in the nudge  
739 treatment, individuals consume between the SO and the NE, whereas in the price  
740 treatment subjects consume above the NE, and thus above the SO. [Cornes and Sand-](#)  
741 [ler \(1983\)](#) suggest that individuals' perceptions and beliefs of how their actions affect  
742 others' actions can lead to a more pessimistic situation than would be achieved if  
743 individuals consumed at the NE, which in our case equates to more overconsumption  
744 than at the NE.

745 [Maldonado and Moreno-Sanchez \(2016\)](#) suggest that an abundance of a resource  
746 leads to greater cooperation, whereas resource scarcity can lead to a reduction in  
747 cooperation, and even inefficient private decisions above the NE. It can be argued  
748 that in our price treatment the resource is made more scarce by the increased price  
749 as individuals can afford to buy fewer energy units.

750 An alternative explanation to our above NE result in the price treatment is that  
751 the social dilemma is made weaker by the rapprochement of the NE and SO solutions  
752 ([Isaac and Walker, 1998](#)). In a public good game, [Isaac and Walker](#) find that when  
753 the NE is at 50% or 80% of the contribution space, players tend to contribute less  
754 than the Nash amount, whereas, when the NE is at 0%, or 20% of the contribution  
755 space, players tend to contribute above the Nash amount<sup>16</sup>. Furthermore, they  
756 find that the upward bias in contributions over the respective NE is greater than  
757 the downward bias. They conclude that contribution decisions are biased upwards  
758 (downwards) when the contribution space between the NE and the SO is large  
759 (small). In our experiment, the consumption space between the SO and NE in the

---

<sup>16</sup>The contribution space is between 0 and 248 tokens at the group level. [Isaac and Walker \(1998\)](#) run treatments with a NE of 0, 48, 124, and 200 tokens

760 nudge treatment is 25 and 15 EU. In the price treatment, this is reduced to 20 and  
761 12.5 EU. Thus in the price treatment, the contribution space is made smaller which  
762 may explain why we find average consumption to be above the NE.

763 When we examine individual behaviour, we find that subjects tend to continue  
764 to under (over) consume if they under (over) consumed in the previous period.  
765 This effect is particularly pronounced in the nudge treatment as a result of the  
766 message received by subjects. [Maldonado and Moreno-Sanchez \(2016\)](#) find that  
767 pro-social players tend to remain pro-social in their decisions regardless of whether  
768 they are in a group which tends to behave pro-socially or to free ride. In particular,  
769 [Cardenas \*et al.\* \(2002\)](#) find that players with a lower return on the private option  
770 tend to bear more of the burden of maintaining an environmental resource. Here  
771 we can draw parallels with the behaviour of underconsuming individuals in our  
772 nudge treatment who compensate for the behaviour of overconsuming individuals  
773 such that, on average, the nudge has the effect of lowering consumption at the group  
774 level.

775 Alternatively, it may be that overconsuming individuals see the nudge as a threat  
776 to their freedom to consume as they wish and so they react by demonstrating the  
777 discouraged behaviour ([Brehm, 1966](#), [Steindl \*et al.\*, 2015](#)). This is in contrast  
778 to the boomerang effect described in field experiments which find that households  
779 who consume less than the average of their neighbourhood tend to increase their  
780 consumption ([Schultz \*et al.\*, 2007](#), [Allcott, 2011](#)). In these cases, the inclusion of  
781 a smiley face to reward underconsuming households' behaviour has the effect of  
782 negating the boomerang effect.

783 It could be that the nudge in the present experiment is considered as an exogen-  
784 ous nudge; it is the experimenter who provides feedback in relation to an exogenously  
785 optimal level of consumption. The experimenter defines the parameters of the game  
786 and thus the optimal amount. Whereas in field experiments an endogenous nudge  
787 (household consumption in relation to the average of the neighbourhood) is tested

788 (Schultz *et al.*, 2007, Allcott, 2011). Given that nudges are a tool of “libertarian  
789 paternalism” and that it is a third party who is nudging individuals towards a de-  
790 cision that is in their best interest, further research should look into how individuals  
791 respond to exogenous and endogenous nudges. Given the reinforcement of existing  
792 behaviour found in our experiment, care should be taken when implementing such  
793 exogenous nudges as, in practice, this could lead to a situation where low consuming  
794 households are further reducing their consumption to compensate for the increasing  
795 consumption of high consuming households.

796 Concerning the levels of environmental sensitivity and altruism, in line with  
797 Boun My and Ouvrard (2019), we find that behaviour in the nudge treatment var-  
798 ies according to individuals’ level of environmental sensitivity. The same is true of  
799 individuals’ altruistic tendencies. Individuals who are more environmentally sens-  
800 itive and altruistic consumed less than their less environmentally sensitive and less  
801 altruistic counterparts. No such effect was found in the price treatment nor in the  
802 control groups.

803 There are of course other nudges that could be implemented to conserve energy.  
804 Defaults could be used to set thermostats at a lower temperature (Brown *et al.*,  
805 2013), or households could be opted-in to a green energy provider (Pichert and  
806 Katsikopoulos, 2008, Ghesla *et al.*, 2020). Research shows that individuals tend  
807 to stick with the default option, due to the endowment effect (Kahneman *et al.*,  
808 1990), or because defaults implicitly recommend a certain behaviour (McKenzie  
809 *et al.*, 2006), or because moving from a default is effortful (Kahneman, 2003). Thus  
810 if the green option, the less energy consuming option, is the default, then energy  
811 savings can be made. However, similarly to our nudge, there can be adverse effects of  
812 green defaults. Ghesla *et al.* (2020) find that while defaulting households to a green  
813 electricity provider reduces CO<sub>2</sub> emissions, it adversely affects poorer households  
814 who would be better off with a cheaper, grey electricity provider.

815 An alternative nudge that can be used to encourage energy savings, uses com-

816 mitment devices and goal setting. Households can commitment to lowering their  
817 consumption or can strive to attain a certain goal of energy savings (McCalley and  
818 Midden, 2002, McCalley *et al.*, 2011, Brandsma and Blasch, 2019). Again, goal set-  
819 ting nudges can have adverse effects: if the goal is too low, then energy savings are  
820 limited, if the goal is too high then households can be put off by the effort required  
821 to meet the goal. Realistic goals set by households themselves appear to be the most  
822 likely to encourage energy savings (Harding and Hsiaw, 2014).

## 823 **6.1 Limitations**

824 Our experiment contextualises CPR theory as a hypothetical energy consumption  
825 game. We do this in order to harmonise the context that individuals bring to  
826 the lab and to use evocative language to render the negative externalities more  
827 salient. Loewenstein (1999) suggests that the addition of context may improve  
828 an experiment’s external validity. However, we recognise that there is no actual  
829 consumption taking place as a result of subjects’ choices and so the external validity  
830 is limited.

831 Secondly, there are two effects at play in our nudge treatment: information as  
832 the nudging towards the SO creates a focal point threshold, and injunctive norms  
833 as the smiley or sad faces approve or disapprove of behaviour. While we never  
834 explicitly give the amount of consumption equal to the SO, in order to disentangle  
835 these potentially confounding effects would require further treatments which provide  
836 the focal point threshold without the smiley or sad face, and vice versa. We leave  
837 this to future research.

## 838 **7 Conclusion**

839 The experiment described in this paper explored subjects’ responses to a nudge  
840 and a peak price based intervention in a contextualised CPR game. Our contribu-

841 tion to the literature is that our experimental design allowed for a comparison of  
842 behaviour under a nudge policy and an equivalent price increase to an absence of  
843 policies thus enabling us to determine a monetary value of our nudge. The design  
844 of the game allowed us to determine whether a price increase designed to imitate  
845 behaviour under the nudge achieves that objective in order to obtain an equival-  
846 ent monetary valuation of our nudge. The nudge policy concerned feedback on an  
847 individual's consumption choice in the form of a happy face if they consume the  
848 socially optimal amount or less, and a sad face if they consume more than the  
849 socially optimal amount. We also explored how the use of different policy instru-  
850 ments to achieve hypothetical reductions in energy consumption affect individuals'  
851 perceptions of their own environmental sensitivity and altruism.

852 Our contribution to the literature is three-fold: (1) we show that individual  
853 behaviour under our nudge is matched by the behaviour of individuals under a  
854 prices that is three times the base price; (2) we find that individuals in the control  
855 group consume under the NE (as has been shown multiple times in the literature),  
856 however, when the price is implemented, they consume above the NE. This can be  
857 explained by a scarcity of the resource or by a weakened social dilemma in the price  
858 treatment compared to the control group. Finally, (3) we show that while the nudge  
859 improves the situation overall, it serves to reinforce individuals existing behaviour.  
860 Those who underconsume underconsume even more to offset the overconsumption  
861 of individuals who overconsume in the absence of the nudge. It is this final result  
862 which may be of most concern when implementing such nudges.

## 863 References

- 864 Alekseev, A., Charness, G., and Gneezy, U. (2017). “Experimental methods: When  
865 and why contextual instructions are important”. *Journal of Economic Behavior  
866 & Organization*, **134**:48–59.
- 867 Alexander, B. R. (2010). “Dynamic pricing? Not so fast! A residential consumer  
868 perspective”. *The Electricity Journal*, **23**(6):39–49.
- 869 Allcott, H. (2011). “Social norms and energy conservation”. *Journal of Public Eco-  
870 nomics*, **95**(9):1082–1095.
- 871 Allcott, H. and Kessler, J. B. (2019). “The welfare effects of nudges: A case study of  
872 energy use social comparisons”. *American Economic Journal: Applied Economics*,  
873 **11**(1):236–76.
- 874 Ambrosio-Albalá, P., Upham, P., and Bale, C. S. (2019). “Purely ornamental? public  
875 perceptions of distributed energy storage in the united kingdom”. *Energy Research  
876 & Social Science*, **48**:139–150.
- 877 Andor, M. A. and Fels, K. M. (2018). “Behavioral economics and energy  
878 conservation—a systematic review of non-price interventions and their causal ef-  
879 fects”. *Ecological Economics*, **148**:178–210.
- 880 Andor, M. A., Gerster, A., Peters, J., and Schmidt, C. M. (2020). “Social norms  
881 and energy conservation beyond the us”. *Journal of Environmental Economics  
882 and Management*, **103**:102351.
- 883 Andreoni, J. (1988). “Why free ride?: Strategies and learning in public goods ex-  
884 periments”. *Journal of public Economics*, **37**(3):291–304.
- 885 Antinyan, A., Horváth, G., and Jia, M. (2020). “Curbing the consumption of po-  
886 sitional goods: Behavioral interventions versus taxation”. *Journal of Economic  
887 Behavior & Organization*, **179**:1–21.

- 888 Ayres, I., Raseman, S., and Shih, A. (2012). “Evidence from two large field ex-  
889 periments that peer comparison feedback can reduce residential energy usage”.  
890 *Journal of Law, Economics, and Organization*, **29**(5):992–1022.
- 891 Bäckman, A. (2011). “The Nordic electricity system as a common-pool resource.”  
892 Dissertation.
- 893 Balijepalli, V. S. K. M., Pradhan, V., Khaparde, S. A., and Shereef, R. M. (2011).  
894 “Review of demand response under smart grid paradigm”. In “ISGT2011-India”,  
895 pages 236–243.
- 896 Ballard, C. L. and Medema, S. G. (1993). “The marginal efficiency effects of taxes  
897 and subsidies in the presence of externalities: A computational general equilibrium  
898 approach”. *Journal of Public Economics*, **52**(2):199–216.
- 899 Barron, K. and Nurminen, T. (2020). “Nudging cooperation in public goods provi-  
900 sion”. *Journal of Behavioral and Experimental Economics*, **88**:101542.
- 901 Bistline, J. E. (2017). “Economic and technical challenges of flexible operations under  
902 large-scale variable renewable deployment”. *Energy Economics*, **64**:363–372.
- 903 Boun My, K. and Ouyard, B. (2019). “Nudge and Tax in an Environmental Pub-  
904 lic Goods Experiment: Does Environmental Sensitivity Matter?” *Resource and*  
905 *Energy Economics*.
- 906 Brandsma, J. S. and Blasch, J. E. (2019). “One for all?—the impact of different  
907 types of energy feedback and goal setting on individuals’ motivation to conserve  
908 electricity”. *Energy Policy*, **135**:110992.
- 909 Brehm, J. W. (1966). *A theory of psychological reactance*. Academic Press.
- 910 Brent, D. A., Gangadharan, L., Mihut, A., and Villeval, M. C. (2019). “Taxation,  
911 redistribution, and observability in social dilemmas”. *Journal of Public Economic*  
912 *Theory*, **21**(5):826–846.

- 913 Brick, K., Visser, M., and Van der Hoven, Z. (2016). “Cooperation and climate  
914 change: can communication facilitate the provision of public goods in heterogen-  
915 eous settings?” *Environmental and Resource Economics*, **64**(3):421–443.
- 916 Brown, Z., Johnstone, N., Haščič, I., Vong, L., and Barascud, F. (2013). “Testing the  
917 effect of defaults on the thermostat settings of oecd employees”. *Energy Economics*,  
918 **39**:128–134.
- 919 Buckley, P. (2020). “Prices, information and nudges for residential electricity con-  
920 servation: A meta-analysis”. *Ecological Economics*, **172**:106635.
- 921 Bühren, C. and Daskalakis, M. (2020). “Which green nudge helps to save energy?  
922 experimental evidence”. Technical report, MAGKS Joint Discussion Paper Series  
923 in Economics.
- 924 Cardenas, J. C., Stranlund, J., and Willis, C. (2002). “Economic inequality and  
925 burden-sharing in the provision of local environmental quality”. *Ecological Eco-*  
926 *nomics*, **40**(3):379–395.
- 927 Cherry, T. L., Kallbekken, S., and Kroll, S. (2014). “The impact of trial runs on  
928 the acceptability of environmental taxes: Experimental evidence”. *Resource and*  
929 *Energy Economics*, **38**:84–95.
- 930 Cialdini, R. B. (2003). “Crafting normative messages to protect the environment”.  
931 *Current Directions in Psychological Science*, **12**(4):105–109.
- 932 Cialdini, R. B., Kallgren, C. A., and Reno, R. R. (1991). “A focus theory of normative  
933 conduct: A theoretical refinement and reevaluation of the role of norms in human  
934 behavior”. In “Advances in experimental social psychology”, volume 24, pages  
935 201–234. Elsevier.
- 936 Cochard, F., Willinger, M., and Xepapadeas, A. (2005). “Efficiency of nonpoint

- 937 source pollution instruments: An experimental study”. *Environmental and Re-*  
938 *source Economics*, **30**(4):393–422.
- 939 Cornes, R. and Sandler, T. (1983). “On commons and tragedies”. *The American*  
940 *Economic Review*, **73**(4):787–792.
- 941 Costa, D. L. and Kahn, M. E. (2013). “Energy conservation “nudges” and environ-  
942 mentalist ideology: Evidence from a randomized residential electricity field exper-  
943 iment”. *Journal of the European Economic Association*, **11**(3):680–702.
- 944 Costa, P. T. and McCrae, R. R. (1992). *Revised NEO Personality Inventory (NEO-*  
945 *PI-R) and NEO Five Factor Model (NEO-FFI)*.
- 946 Croson, R. and Marks, M. (2001). “The effect of recommended contributions in the  
947 voluntary provision of public goods”. *Economic Inquiry*, **39**(2):238–249.
- 948 Croson, R. T. (1996). “Partners and strangers revisited”. *Economics Letters*,  
949 **53**(1):25–32.
- 950 Dal Bó, E. and Dal Bó, P. (2014). ““Do the right thing:” The effects of moral suasion  
951 on cooperation”. *Journal of Public Economics*, **117**:28–38.
- 952 Davis, D. D. and Holt, C. A. (1993). *Experimental economics*. Princeton university  
953 press.
- 954 Delaney, J. and Jacobson, S. (2015). “Payments or persuasion: Common pool re-  
955 source management with price and non-price measures”. *Environmental and Re-*  
956 *source Economics*, pages 1–26.
- 957 Dincer, I. and Acar, C. (2018). “Smart energy solutions with hydrogen options”.  
958 *International Journal of Hydrogen Energy*, **43**(18):8579–8599.
- 959 Eckel, C. C. and Grossman, P. J. (1996). “Altruism in anonymous dictator games”.  
960 *Games and economic behavior*, **16**(2):181–191.

- 961 EDF (2016). “Grille de prix de l’offre de fourniture d’électricité”. Accessed 30 May  
962 2017.
- 963 Elliott, C. S., Hayward, D. M., and Canon, S. (1998). “Institutional framing:  
964 Some experimental evidence”. *Journal of Economic Behavior & Organization*,  
965 **35**(4):455–464.
- 966 Eriksson, K. and Strimling, P. (2014). “Spontaneous associations and label framing  
967 have similar effects in the public goods game.” *Judgment & Decision Making*,  
968 **9**(5).
- 969 Fanghella, V., Ploner, M., and Tavoni, M. (2021). “Energy saving in a simulated  
970 environment: An online experiment of the interplay between nudges and financial  
971 incentives”. *Journal of Behavioral and Experimental Economics*, **93**:101709.
- 972 Farrow, K., Grolleau, G., and Ibanez, L. (2017). “Social norms and pro-  
973 environmental behavior: a review of the evidence”. *Ecological Economics*, **140**:1–  
974 13.
- 975 Faruqui, A. and Sergici, S. (2013). “Arcturus: international evidence on dynamic  
976 pricing”. *The Electricity Journal*, **26**(7):55–65.
- 977 Faul, F., Erdfelder, E., Buchner, A., and Lang, A.-G. (2009). “Statistical power ana-  
978 lyses using g\* power 3.1: Tests for correlation and regression analyses”. *Behavior*  
979 *research methods*, **41**(4):1149–1160.
- 980 Fehr, E. and Schmidt, K. M. (1999). “A theory of fairness, competition, and cooper-  
981 ation”. *The Quarterly Journal of Economics*, **114**(3):817–868.
- 982 Ferraro, P. J. and Price, M. K. (2013). “Using nonpecuniary strategies to influence  
983 behavior: Evidence from a large-scale field experiment”. *Review of Economics and*  
984 *Statistics*, **95**(1):64–73.

- 985 Fischbacher, U. (2007). “z-tree: Zurich toolbox for ready-made economic experi-  
986 ments”. *Experimental Economics*, **10**(2):171–178.
- 987 Friedman, D. and Cassar, A. (2004). “Economics lab”. *An intensive course in*  
988 *experimental economics*. London y New York: Routledge.
- 989 Gächter, S. and Fehr, E. (1999). “Collective action as a social exchange”. *Journal*  
990 *of economic behavior & organization*, **39**(4):341–369.
- 991 Ghesla, C., Grieder, M., and Schubert, R. (2020). “Nudging the poor and the rich–  
992 a field study on the distributional effects of green electricity defaults”. *Energy*  
993 *Economics*, **86**:104616.
- 994 Goldthau, A. (2014). “Rethinking the governance of energy infrastructure: Scale,  
995 decentralization and polycentrism”. *Energy Research & Social Science*, **1**:134–140.
- 996 Gollwitzer, L., Ockwell, D., Muok, B., Ely, A., and Ahlborg, H. (2018). “Rethink-  
997 ing the sustainability and institutional governance of electricity access and mini-  
998 grids: Electricity as a common pool resource”. *Energy Research & Social Science*,  
999 **39**:152–161.
- 1000 Hagmann, D., Ho, E. H., and Loewenstein, G. (2019). “Nudging out support for a  
1001 carbon tax”. *Nature Climate Change*, page 1.
- 1002 Harding, M. and Hsiaw, A. (2014). “Goal setting and energy conservation”. *Journal*  
1003 *of Economic Behavior & Organization*, **107**:209–227.
- 1004 Harrison, G. W. and List, J. A. (2004). “Field experiments”. *Journal of Economic*  
1005 *literature*, **42**(4):1009–1055.
- 1006 Hausman, D. M. and Welch, B. (2010). “Debate: To nudge or not to nudge”. *Journal*  
1007 *of Political Philosophy*, **18**(1):123–136.

- 1008 Hennig-Schmidt, H., Sadrieh, A., and Rockenbach, B. (2010). “In search of work-  
1009 ers’ real effort reciprocity—a field and a laboratory experiment”. *Journal of the*  
1010 *European Economic Association*, **8**(4):817–837.
- 1011 Heres, D., Kallbekken, S., and Galarraga, I. (2013). “Understanding public support  
1012 for externality-correcting taxes and subsidies: A lab experiment”. Basque Centre  
1013 for Climate Change Working Papers.
- 1014 Holländer, H. (1990). “A social exchange approach to voluntary cooperation”. *Amer-*  
1015 *ican Economic Review*, pages 1157–1167.
- 1016 Holt, C. A., Laury, S. K., *et al.* (2002). “Risk aversion and incentive effects”. *Amer-*  
1017 *ican Economic Review*, **92**(5):1644–1655.
- 1018 Hsiao, Y.-C., Kemp, S., and Servátka, M. (2020). “On the importance of context in  
1019 sequential search”. *Southern Economic Journal*, **86**(4):1510–1530.
- 1020 Isaac, R. M. and Walker, J. M. (1998). “Nash as an organizing principle in the volun-  
1021 tary provision of public goods: Experimental evidence”. *Experimental economics*,  
1022 **1**(3):191–206.
- 1023 Kagel, J. H. and Roth, A. E. (2016). *The Handbook of Experimental Economics*,  
1024 volume 2. Princeton University Press.
- 1025 Kahneman, D. (2003). “Maps of bounded rationality: Psychology for behavioral  
1026 economics”. *American economic review*, **93**(5):1449–1475.
- 1027 Kahneman, D., Knetsch, J. L., and Thaler, R. H. (1990). “Experimental tests of  
1028 the endowment effect and the coase theorem”. *Journal of Political Economy*,  
1029 **98**(6):1325–1348.
- 1030 Kaiser, F. G. (1998). “A general measure of ecological behavior”. *Journal of Applied*  
1031 *Social Psychology*, **28**(5):395–422.

- 1032 Kallbekken, S., Kroll, S., and Cherry, T. L. (2011). “Do you not like Pigou, or do  
1033 you not understand him? Tax aversion and revenue recycling in the lab”. *Journal*  
1034 *of Environmental Economics and Management*, **62**(1):53–64.
- 1035 Kasperbauer, T. (2017). “The permissibility of nudging for sustainable energy con-  
1036 sumption”. *Energy Policy*, **111**:52–57.
- 1037 Keser, C. and Van Winden, F. (2000). “Conditional cooperation and voluntary  
1038 contributions to public goods”. *scandinavian Journal of Economics*, **102**(1):23–  
1039 39.
- 1040 Lavrakas, P. J. (2008). *Encyclopedia of Survey Research Methods*. SAGE Publica-  
1041 tions.
- 1042 Lehner, M., Mont, O., and Heiskanen, E. (2016). “Nudging—a promising tool for  
1043 sustainable consumption behaviour?” *Journal of Cleaner Production*, **134**:166–  
1044 177.
- 1045 Lenth, R. V. (2001). “Some practical guidelines for effective sample size determina-  
1046 tion”. *The American Statistician*, **55**(3):187–193.
- 1047 Loewenstein, G. (1999). “Experimental economics from the vantage-point of beha-  
1048 vioural economics”. *The Economic Journal*, **109**(453):F25–F34.
- 1049 Maldonado, J. H. and Moreno-Sanchez, R. d. P. (2016). “Exacerbating the tragedy of  
1050 the commons: Private inefficient outcomes and peer effect in experimental games  
1051 with fishing communities”. *PloS one*, **11**(2):e0148403.
- 1052 Marks, M. B., Schansberg, D. E., and Croson, R. T. (1999). “Using suggested con-  
1053 tributions in fundraising for public good”. *Nonprofit Management and Leadership*,  
1054 **9**(4):369–384.
- 1055 McCalley, L., de Vries, P. W., and Midden, C. J. (2011). “Consumer response

- 1056 to product-integrated energy feedback: Behavior, goal level shifts, and energy  
1057 conservation”. *Environment and Behavior*, **43**(4):525–545.
- 1058 McCalley, L. and Midden, C. J. (2002). “Energy conservation through product-  
1059 integrated feedback: The roles of goal-setting and social orientation”. *Journal of*  
1060 *Economic Psychology*, **23**(5):589–603.
- 1061 McKenzie, C. R., Liersch, M. J., and Finkelstein, S. R. (2006). “Recommendations  
1062 implicit in policy defaults”. *Psychological Science*, **17**(5):414–420.
- 1063 Melville, E., Christie, I., Burningham, K., Way, C., and Hampshire, P. (2017). “The  
1064 electric commons: A qualitative study of community accountability”. *Energy*  
1065 *Policy*, **106**:12–21.
- 1066 Moffatt, P. G. (2015). *Experimetrics: Econometrics for experimental economics*.  
1067 Palgrave Macmillan.
- 1068 Noussair, C. and Tucker, S. (2007). “Public observability of decisions and voluntary  
1069 contributions in a multiperiod context”. *Public Finance Review*, **35**(2):176–198.
- 1070 Ostrom, E. (1990). *Governing the commons*. Cambridge University Press.
- 1071 Ostrom, E., Gardner, R., Walker, J., Walker, J. M., and Walker, J. (1994). *Rules,*  
1072 *games, and common-pool resources*. University of Michigan Press.
- 1073 Ostrom, E. and Walker, J. (1991). “Communication in a commons: cooperation  
1074 without external enforcement”. *Laboratory research in political economy*, pages  
1075 287–322.
- 1076 Pevnitskaya, S. and Ryvkin, D. (2013). “Environmental context and termination  
1077 uncertainty in games with a dynamic public bad”. *Environment and Development*  
1078 *Economics*, **18**(1):27–49.

- 1079 Pichert, D. and Katsikopoulos, K. V. (2008). “Green defaults: Information present-  
1080 ation and pro-environmental behaviour”. *Journal of Environmental Psychology*,  
1081 **28**(1):63–73.
- 1082 Plott, C. R. (1983). “Externalities and corrective policies in experimental markets”.  
1083 *The Economic Journal*, **93**(369):106–127.
- 1084 Pratt, R. G. and Fuller, J. C. (2016). *Smart Grid Handbook*, chapter Demand  
1085 Response, pages 1253–1292. Wiley.
- 1086 Rege, M. and Telle, K. (2004). “The impact of social approval and framing on  
1087 cooperation in public good situations”. *Journal of Public Economics*, **88**(7):1625–  
1088 1644.
- 1089 Rommel, J., Hermann, D., Müller, M., and Mußhoff, O. (2019). “Contextual framing  
1090 and monetary incentives in field experiments on risk preferences: Evidence from  
1091 german farmers”. *Journal of Agricultural Economics*, **70**(2):408–425.
- 1092 Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., and Griskevicius, V.  
1093 (2007). “The constructive, destructive, and reconstructive power of social norms”.  
1094 *Psychological Science*, **18**(5):429–434.
- 1095 Skatova, A., Bedwell, B., and Kuper-Smith, B. (2016). “When push comes to shove:  
1096 Compensating and opportunistic strategies in a collective-risk household energy  
1097 dilemma”. *Frontiers in Energy Research*, **4**:8.
- 1098 Smith, V. L. (1976). “Experimental economics: Induced value theory”. *The American*  
1099 *Economic Review*, **66**(2):274–279.
- 1100 Spraggon, J. M., Sobarzo, L. A. V., and Stranlund, J. K. (2015). “A note on  
1101 stochastic public revelation and voluntary contributions to public goods”. *Eco-*  
1102 *nomics Letters*, **126**:144–146.

- 1103 StataCorp (2017). “Stata statistical software: Release 15”. College Station, TX:  
1104 StataCorp LLC.
- 1105 Steindl, C., Jonas, E., Sittenthaler, S., Traut-Mattausch, E., and Greenberg, J.  
1106 (2015). “Understanding psychological reactance: New developments and findings”.  
1107 *Zeitschrift für Pscyhologie*, **223**:205–214.
- 1108 Thaler, R. H. and Sunstein, C. R. (2008). *Nudge: Improving decisions about health,*  
1109 *wealth, and happiness*. New Haven, CT: Yale University Press.
- 1110 Zizzo, D. J. (2010). “Experimenter demand effects in economic experiments”. *Ex-*  
1111 *perimental Economics*, **13**(1):75–98.

1112 Appendix

1113 A English Translation of Experiment Instructions  
1114 concerning the Simulator

1115 Earnings simulator

1116 To assist you in making your decisions, you have at your disposal a simulator  
1117 with which you can simulate your earnings. You have 1 minute to do as many  
1118 simulations as you wish before making your final decision for the period. The use of  
1119 the simulator is described in the following slide. In addition to the simulator, there is  
1120 a table summarising all the possible earnings depending on your consumption choice  
1121 (by column) and the total consumption of the other three people in your group (by  
1122 row).

Choose the consumption level by clicking on the options next to each appliance type.

Time left

The screenshot shows the simulator interface for 'Période 1'. At the top, it says 'Période 1 de 1' and 'Temps restant [sec]: 37'. The main instruction is 'Choisissez les niveaux de consommation de vos principaux appareils électriques pendant la période de pointe. Lorsque vous avez fini vos simulations, confirmez votre choix de consommation et passez à la prochaine période en cliquant sur "Confirmer" en bas de l'écran.' There are three columns of appliance types: 'Machine à laver, lave vaisselle', 'Four, microondes, plaques de cuisson', and 'Télévision, ordinateur, musique'. Each has radio button options for 'Eteint (0 UE)' and 'Allumé (10 UE)'. Below these are 'Chauffage' and 'Chauffe-eau' with radio button options for different temperatures and states. A summary line says 'Avec ces choix, votre consommation totale est de (UE): 0 UE'. Below that is a slider for 'Ajoutez le niveau de consommation des 3 autres :' with values from 15 to 135. Another summary line says 'Avec ces données, votre gain serait de : 0 UME'. At the bottom, there is a 'Confirmer' button and a warning icon. Annotations include: 'Period number' pointing to '1 de 1'; 'Time left' pointing to '37'; 'Choose the consumption level...' pointing to the appliance options; 'Here, you can chose the consumption level of the three other consumers in your group.' pointing to the slider; 'Confirm your choice here. This is the consumption amount and the real choices of the three other consumers in your group will be used to calculate your earnings.' pointing to the 'Confirmer' button; 'The result of your simulation appears here.' pointing to the '0 UME' result; and 'This result is not necessarily the amount you will receive.' pointing to the '0 UME' result.

Here, you can chose the consumption level of the three other consumers in your group.

Confirm your choice here. This is the consumption amount and the real choices of the three other consumers in your group will be used to calculate your earnings.

The result of your simulation appears here.

This result is not necessarily the amount you will receive.

1123

## B Profit tables

		Your decision								
		5	10	15	20	25	30	35	40	45
The sum of the other three players	15	150	195	235	270	300	325	345	360	370
	20	148	190	228	260	288	310	328	340	348
	25	145	185	220	250	275	295	310	320	325
	30	143	180	213	240	263	280	293	300	303
	35	140	175	205	230	250	265	275	280	280
	40	138	170	198	220	238	250	258	260	258
	45	135	165	190	210	225	235	240	240	235
	50	133	160	183	200	213	220	223	220	213
	55	130	155	175	190	200	205	205	200	190
	60	128	150	168	180	188	190	188	180	168
	65	125	145	160	170	175	175	170	160	145
	70	123	140	153	160	163	160	153	140	123
	75	120	135	145	150	150	145	135	120	100
	80	118	130	138	140	138	130	118	100	78
	85	115	125	130	130	125	115	100	80	55
	90	113	120	123	120	113	100	83	60	33
	95	110	115	115	110	100	85	65	40	10
100	108	110	108	100	88	70	48	20	-13	
105	105	105	100	90	75	55	30	0	-35	
110	103	100	93	80	63	40	13	-20	-58	
115	100	95	85	70	50	25	-5	-40	-80	
120	98	90	78	60	38	10	-23	-60	-103	
125	95	85	70	50	25	-5	-40	-80	-125	
130	93	80	63	40	13	-20	-58	-100	-148	
135	90	75	55	30	0	-35	-75	-120	-170	

Table A1: Profit table in the control and nudge treatment

		Your decision								
		5	10	15	20	25	30	35	40	45
The sum of the other three players	15	140	175	205	230	250	265	275	280	280
	20	138	170	198	220	238	250	258	260	258
	25	135	165	190	210	225	235	240	240	235
	30	133	160	183	200	213	220	223	220	213
	35	130	155	175	190	200	205	205	200	190
	40	128	150	168	180	188	190	188	180	168
	45	125	145	160	170	175	175	170	160	145
	50	123	140	153	160	163	160	153	140	123
	55	120	135	145	150	150	145	135	120	100
	60	118	130	138	140	138	130	118	100	78
	65	115	125	130	130	125	115	100	80	55
	70	113	120	123	120	113	100	83	60	33
	75	110	115	115	110	100	85	65	40	10
	80	108	110	108	100	88	70	48	20	-13
	85	105	105	100	90	75	55	30	0	-35
	90	103	100	93	80	63	40	13	-20	-58
	95	100	95	85	70	50	25	-5	-40	-80
	100	98	90	78	60	38	10	-23	-60	-103
	105	95	85	70	50	25	-5	-40	-80	-125
	110	93	80	63	40	13	-20	-58	-100	-148
115	90	75	55	30	0	-35	-75	-120	-170	
120	88	70	48	20	-13	-50	-93	-140	-193	
125	85	65	40	10	-25	-65	-110	-160	-215	
130	83	60	33	0	-38	-80	-128	-180	-238	
135	80	55	25	-10	-50	-95	-145	-200	-260	

Table A2: Profit table in the price treatment

1125 **C Average consumption by group**

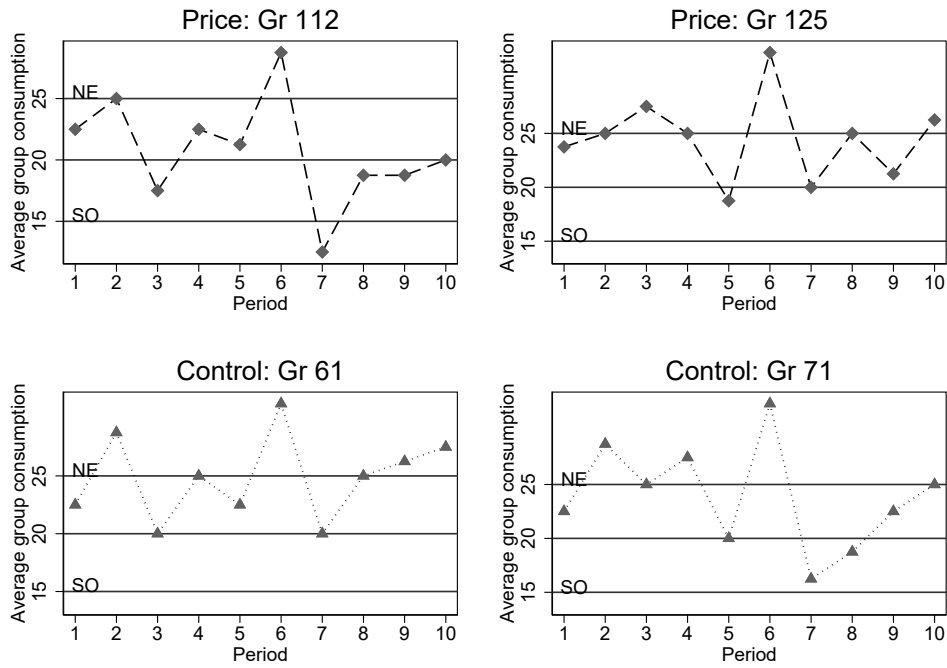


Figure 2: Average consumption by group

1126 **D Individual type (under, optimal or overconsum-**  
 1127 **ing)**

		Individual consumption			
		Under	Target	Over	Total
Treatment	Nudge	190	316	494	1,000
	Price	19.0%	31.6%	49.4%	100.0%
		234	295	271	800
	Control	29.3%	36.9%	33.9%	100.0%
75		79	446	600	
Total		499	690	1,211	2,400
		20.8%	28.7%	50.5%	100.0%

For the nudge and control groups, the target consumption equals the optimal level of consumption of 15. In the price treatment, the target consumption is equal to 20.

Table A3: Number of groups by consumption level (across all periods)