DEMAND RESPONSE AS A COMMON POOL RESOURCE GAME: NUDGES OR PEAK PRICING

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Overview

The European Union has set ambitious targets to reduce greenhouse gas emissions, to increase the share of renewable energies in the production mix, and to achieve greater energy savings. As renewable energy is intermittent by definition and for energy savings to be realised, there is a need to have a more flexible residential energy demand, particularly during peak periods. Two methods used to incentivise households to reduce their energy consumption are dynamic pricing structures and nudge-based incentives. Under certain tariff structures consumers face financial incentives to reduce their electricity demand as during certain hours or on days when demand is particularly high, the price of electricity is greater than at off-peak times. This increased price reflects the higher production costs. Nudge based incentives go beyond providing households with information on the amount of electricity they have consumed by changing the way the information is presented in order to exploit behavioural biases (Thaler & Sunstein, 2008).

The principal objective of the present experiment is to use a contextualised common pool resource (CPR) game to compare the effects of nudges and price changes on subjects' electricity consumption choices in order to give an economic value to the nudge. Ostrom (1990) defines a common pool resource as a stock of a natural or man-made resource system from which a flow of resource units can be withdrawn. The stock of the CPR is renewable so the stock can be sustained so long as average withdrawal rates do not exceed average replenishment rates. Following Bäckman (2011), we consider electricity as a CPR: the electricity network (power stations, distribution centres, transmission lines) represents the resource system and the resource units are kilowatt hours. In the short run, we can consider that this system provides a stock of electricity units to househols which is renewable in the sense that once the electricity has been consumed it must be immediately reproduced in order to maintain supply and demand balance.

A key aspect of the CPR framework is that there is a social dilemma; individuals wish to withdraw (or in the case of electricity, consume) more resource units than the sustainable amount. There is a conflict between personal interest and collective interest. This can be translated to the context of electricity consumption during periods of peak demand, for example, when there are extreme weather events and when renewable energy is supplying the electricity. During such periods, there is a possibility of demand outstripping supply which implies a need for a reduction in household demand for electricity.

Methods

In this experiment, subjects are randomly assigned to a group of four households with whom they play during 10 periods. Each period represents a peak period of electricity demand. Each subject has an endowment of 100 Experimental Currency Units (ECU) and must decide how many electricity units (EU) to consume by choosing whether to use five different sets of electricity consuming equipment (heating, water heating, cooking equipment, washing equipment, and entertainment equipment). Each unit a subject chooses to consume increases their utility, however every unit consumed by a subject in their group reduces all subjects' utility regardless of who consumed it. At the end of each period subjects see, in terms of ECU, the level of utility their consumption choice resulted in.

In the base game, each EU costs 1 ECU and individuals maximise their individual profit at the Nash equilibrium of 25 electricity units. However, it is socially optimal for subjects to consume 15 electricity units. In one treatment, we apply a nudge to encourage subjects to reduce their consumption: if a subject consumes less than, or the socially optimal amount, they see a smiley face. If they consume more than the social optimal amount they see a sad face. In the price treatment, the cost of the electricity units is tripled, from 1 ECU in the base game to 3 ECU. This increase is the amount that aligns the Nash equilibrium consumption amount with the average consumption level observed in the nudge treatment. By setting the price to give the consumption amount observed in the nudge treatment, the goal is to compare whether the price increase results in the same level of consumption as the nudge when that is its objective.

Results

In the first period, all groups begin at a similar level of consumption. Overall and for periods 2-10, average consumption by treatment is significantly different. From period 2 onwards, average consumption is significantly lower in the nudge treatment, and higher for control groups (absent of any policies). There is a significant and permanent effect of the nudge policy on subjects' consumption decisions. Overall, average consumption in the price treatment is significantly different from the nudge treatment and the control groups; consumption remains between the two at or slightly above the Nash equilibrium target of 20 units. As the price is calculated according the result observed in the nudge treatment, we do not expect to see significant differences between the average group consumption of the nudge and price treatment groups from the second period onwards. The average consumption is significantly different in the price treatment compared to the nudge treatment in periods 2 and 3, and significantly different from 20 units in period 2.

Group and individual consumption choices are estimated using panel data random-effects estimation as this allows us to model the time-invariant between-subject treatment variables (Moffat, 2015). The estimates show a significant treatment effect of both the nudge and price policy. The effect of group and individual levels of consumption in the previous period are estimated. At the group level there is no significant effect on consumption due to under- or over-consuming in the previous period. At the individual level, subjects who under-consumed in the previous period continue to do so, as do subjects who overconsume when compared to optimally consuming subjects. We find that the nudge has the effect of reinforcing subjects' behaviour: those who under-consume (receive smiley face feedback) continue to do so, and those that over-consume (sad face feedback) also continue to do so, compared to optimally consuming groups.

Conclusions

The principal result of this experiment is that both treatments, a nudge and a price increase, result in a reduction in consumption compared to when no policy is present. Subjects choose to consume the lowest amount in the nudge treatment, followed by the price treatment, as expected in the experimental design. The design of the experiment allows for an estimation of the economic value of the nudge compared to its equivalent price increase. We conclude that the nudge treatment performs as well as an equivalent price increase without the implied loss of consumer welfare.

Given that it is not until the third period of play that average consumption is not significantly different from the target level in the price treatment, we conclude that the subjects take longer to integrate the price change into their decision making than for the nudge. Subjects' responses to the nudge is immediate in the second period after receiving feedback on their consumption choice. Concerning the feedback received by individuals, we find that the nudge serves to reinforce existing consumption behaviour; those who under (over) consume continue in that direction. The nudge has the effect of reducing electricity consumption at the group level but does not have the desired effect at the individual level. The results of the present experiment may be of interest to policy makers when considering the implementation of a nudge of price-based policy designed to reduce households' electricity consumption.

References

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