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Firm and Consumer Behaviour in Energy Markets

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Abstract

This dissertation consists of three essays on the study of firm and consumer behaviour motivated by the energy markets. The first chapter studies whether a firm with better information than their rivals about the customers in the market can use that information to earn more profits. The second chapter studies whether a profit-maximising firm would want to induce positive consumption to a consumer that has self-control issues. The third chapter analyses empirically whether self-control issues can explain the problem of self-disconnection that persists in prepayment energy meters.

Keywords: Energy markets; contracts; information asymmetry; self-control.

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Introduction

In many market situations, firms face the problem of the heterogeneity of consumers' tastes or types. Even if a firm knows the distribution, it does not know the type of any given customer. However, a firm can design a menu of contracts that is an incentive mechanism in which consumers are induced to reveal their type by their self-selection in the menu. This dissertation builds on incentive theory from different perspectives, although not being entirely in the area of incentive theory.

This dissertation uses energy markets as a motivation for the different issues analysed. Energy markets are surprisingly understudied from an economic point of view and have been evolving significantly with a number of new problems. Such an example is an emerging set of information and communication technologies in the electricity sector, called smart grid, that has allowed for innovative forms of metering. The debate over the smart grids has deserved a considerable engineering attention, but it is still an open issue in economic terms. In particular, there is still some debate around the sensitivity of data on consumers' energy usage and who should hold this data. Discussions about potential discriminatory behaviour have already been made by energy regulators. This raises the question whether it is, in fact, profitable for a firm that has access to consumers' data energy usage to share it with particular third parties.

In this context, the first essay, named "Contracting in a market with differential information", addresses whether a firm with better information than their rivals about the customers in the market can use that information to earn more profits. To study the role of information, we introduce a framework of two firms supplying a good composed of many commodities that compete in prices, which have access to the same technology and where customers have fixed demand. We are interested in the equilibrium outcomes under no differential information and under differential information. We show that, under no differential information, both firms equally share the customers and types of customers, charge the same payments and obtain zero profits. Under differential information, we assume that access to better information allows the better informed firm to attract specific customers. Access to better information gives the better informed firm a first customer contact advantage. The uninformed firm can only offer a menu of tariffs without being able to pre-identify the customer's type. Nonetheless, the uninformed firm can access the market, not allowing the better informed firm to make positive profits. We find that better information does not give a firm an advantage or disadvantage, that is, it obtains the same equilibrium profit as the uninformed firm.

Current energy meters, as opposed to smart meters, also present some issues. One of those is significantly related with prepayment meters which is a payment method where the payment is made before the actual consumption. That is, consumers have to pay for electricity and/or gas (immediate costs) before they consume it (delayed benefits). Moreover, consumers must plan in advance their future consumption. This planning, or lack of it, may lead to self-disconnection, which happens when consumers exhaust all available credit in their meter and are left without supply of energy for a certain period. Self-disconnection has serious consequences for the wellbeing of consumers. Likewise, it generates costs for the energy suppliers since it may contribute to lower energy consumption, higher debt levels, and higher costs related to reconnection of energy supply. This self-disconnection can be explained by the presence of self-control issues that can lead a consumer to under-consume.

Motivated by this problem, the second essay, "Contracting in a market with costly self-control", studies theoretically whether a profit-maximising firm would want to induce positive consumption to a consumer that is time-inconsistent and is unaware of his degree of time inconsistency. The literature on behavioural economics defines this type of consumer as naïve, in which differs from a sophisticated type in the sense that the latter is aware of his degree of time inconsistency. The firm/principal cannot observe the type of the consumer/agent at the contracting stage. In order to make any payment, the agent needs to make a saving decision and incur a savings effort cost. The agent's marginal utility of consumption is affected by a shock after the contracting stage. We study two specific contract forms: a pay-in-advance contract that involves a payment at date 0 and a payment at date 1, and a pay-in-advance contract that only involves a payment at date 1. We show that the principal can induce positive consumption to all types, but there is a trade-off between increasing efficiency and decreasing information rent when offering a menu of contracts. We also study the impact of the naïve type on the remaining types' utilities and on the principal's expected profit and show that the principal may have incentives to educate the naïve type.

The final essay, "Addressing self-disconnection among prepayment energy consumers: A behavioural approach", analyses empirically whether self-control issues can explain the problem of self-disconnection that persists in prepayment energy meters. We study a mechanism composed of a commitment contract and a reminder in order to minimise the number of self-disconnections. We design and implement a survey to energy consumers that use a prepayment meter in the UK. We show that self-control plays a role in self-disconnection and we are able to identify, in our sample, those consumers who benefit from a commitment contract. Moreover, we find a demand for commitment and an opportunity to save among those consumers who need a commitment contract.

This dissertation builds and expands on the economic literature in three ways. Chapter 1 contributes to the literature on the role of information in oligopolistic markets by analysing the impact of differential information about the types of customers on equilibrium profits in a one-stage Bertrand competition. Chapter 2 contributes to the literature on behavioural contract theory since it examines the impact of naiveté on the optimal contracts and profit when the agent can either be time-consistent, sophisticated or naïve and privately know his degree of inconsistency or believes to know it in case of the naïve type. Chapter 3 contributes to the empirical literature on behavioural economics and shows that self-disconnection can partially be explained by low self-control. This chapter suggests novel policy instruments that can help reduce the negative impact of self-disconnection. Overall, these chapters are motivated by issues in the energy markets and therefore, this dissertation contributes to the study of energy economics.

Chapter 1

Contracting in a market with differential information[1]

1.1 Introduction

The recent advanced infrastructures in the energy sector based on smart meters are now capable of real lifetime pricing and remote reading. This has generated a debate in relation to the potential sensitivity of data on customers' patterns that firms will be able to hold once smart meters are fully implemented. Indeed, the major players in the energy markets, such as network providers, suppliers, regulators and customers, recognise the potential sensitivity of data on customers' energy usage. The Council of European Energy Regulators has already made recommendations over potential discriminatory behaviour and potential measures of data security (CEER 2015).[2] Nevertheless, it is still not clear what is the impact of this new degree of information on competition in the energy markets.

[1]This is joint work with Thomas Greve.

[2]This potential discriminatory behaviour can come from a vertical connection between the distribution operator (upstream firm) and a retailer firm (downstream firm). This connection can particularly exist if the downstream firm was previously a de-integrated part of the upstream firm. Then, if the upstream firm has access to all customers' information in the market, there might be incentives for the upstream firm to give access to better data to its affiliated than to the remaining downstream firms in the market.

The key question posed in this paper is whether a firm with better information about the customers in the market than their rivals can use that information to earn more profit. Although, it might seem intuitive, one cannot claim under generality that access to better information leads to higher profits.

To study the role of information, we introduce a framework of two firms supplying a good composed by many commodities that compete in prices, which have access to the same technology and where customers have fixed demand. We are interested in the equilibrium outcomes under no differential information and under differential information. To answer our research question, we compare the equilibrium profits of both firms in two ways. First, we define information advantage as the difference between the equilibrium profits of the better informed firm and the uninformed firm in the differential information case. Second, we define information value as the difference between the equilibrium profits of the better informed firm under differential information and under no differential information.

We show that, under no differential information, both firms equally share the customers and types of customers, charge the same payments and obtain zero profits. Under differential information, we assume that access to better information allows the better informed firm to attract specific customers. Access to better information gives the better informed firm a first customer contact advantage. The uninformed firm can only offer a menu of price vectors without being able to pre-identify the customers' type. Consequently, access to better information leads to a change in the tie-breaking rule. The same result would hold if, for another reason other than better information, one firm would have first customer contact advantage. Nonetheless, the uninformed firm can access the market, not allowing the better informed firm to make positive profits. We find that better information does not give a firm an advantage or disadvantage, that is, the better informed firm obtains the same equilibrium profit as the uninformed one. We also show that there is no information value because the better informed firm has the same equilibrium profit under both cases.

We also analyse whether our results are robust to changes in the number of customers, number of firms and number of types. We show that as long as it is possible to equally divide the number of customers between firms, the symmetric Nash equilibria in pure strategies exist. Under differential information, the exclusionary Nash equilibria exist despite of the number of customers of each type. However, once we increase the number of better informed firms, the exclusionary equilibria exist as long as it is possible to equally divide the number of customers between the better informed firms.

1.2 Related Literature

This paper relates to two strands of literature. Firstly, it contributes to the literature on the role of information in oligopolistic markets by analysing the impact of differential information about the types of customers on equilibrium profits in a one-stage Bertrand competition. Though the literature on the role of information in oligopolistic markets under uncertain demand and incomplete information is quite broad (see for example Gal-Or (1987, 1988), Raith (1996), and Vives (1984)), there is a small literature on whether access to better information has a positive impact on the equilibrium profit. Further, there is not a general consensus on the result that it entails. This literature is especially small when competition is via prices. Vives (1990), using a two-stage model, shows that better informed firms have an incentive to invest more in the first stage which ends up fostering its competitive position and profitability. In Vives's framework, better information always increases expected profit of the better informed firm and it leads to an information advantage. Nevertheless, better information may enhance or diminish the rival's competitive position and profitability depending whether firms compete à la Bertrand or à la

Cournot. The consequences of differential information arise because the better informed firm can decide to invest more or less in the first stage.

A more related study to the present paper is Einy et al. (2002). It is shown that a better informed firm is rewarded, under Cournot competition, when firms' technology exhibits constant returns to scale. Chokler et al. (2006) challenge Einy et al. (2002) results and prove that in Cournot duopolies with differentiated products and linear demand and cost functions, the better informed firm earns less profit if both firms have symmetric demand functions. Consequently, one cannot claim, under generality, that better information leads to higher equilibrium profit for the better informed firm. Indeed, we show that in a one-stage Bertrand competition, differential information can lead to no information advantage or disadvantage.

Secondly, our paper contributes to the price discrimination literature and in particular, on competitive price discrimination and on personalised pricing, whereby firms charge different prices to different customers based on their willingness to pay. The literature on personalised pricing has been increasing due to the increasing ability of firms to collect customers' data and the ability to offer dynamic pricing. Some papers such as Choudhary et al. (2005) and Ghose and Huang (2009) have studied the competitive implications of personalised pricing in a model with product differentiation. Choudhary et al. (2005) show, in a model with vertical differentiation, that firms can be worse off when they offer personalised pricing. Ghose and Huang (2009) show, in a model of spatial differentiation, that firms are better off when they offer personalised pricing and quality compared to the case when they do not adopt customised pricing. This is because firms can offer higher qualities to each customer at higher rent extraction ability for each firm. Ghose and Huang (2009) assume that when a firm adopts personalised pricing and quality it can perfectly target customers in both price and quality. In our paper, we also assume that a firm that is better informed can perfectly target customers. We contribute to this literature by studying personalised pricing in a model with homogeneous goods and with differential information. In particular, we show that although, it is possible for the better informed firm to target customers, that does not allow it to charge higher prices.

The literature on privacy is closely related to the literature on competitive price discrimination and on personalised pricing. The literature on economics of privacy has analysed, for example, how firms use past behaviour of consumers to infer their taste and price (see e.g. Fudenberg and Tirole, 2000; Esteves, 2010); and how privacy actions are undertaken by consumers and how consumer information is sold to firms (see e.g. Casadeus-Masanell and Hervas-Drane 2015, Montes et al. 2016 and Taylor and Wagman 2014). This literature has been expanding significantly due to the rise of new technologies and online markets that are able to store consumers' personal information.[3] This also relates to the motivation of our paper in the sense that smart meters will allow for monitoring and recording of electricity consumption on a near real-time basis. Technology will also allow identifying the activities of consumers by matching data on their electricity usage with known appliance load signatures.[4]

1.3 The Model

Consider an industry where two firms compete in the production of $m > 1$ different commodities. There is a given finite set $A \subset \mathbb{R}^m_+$ of *types* of customers, where a type is a vector $a \in A$ specifying the demand for each of the m commodities. Assume that each commodity is homogeneous.

[3] For an overview of the literature on economics of privacy see Acquisti et al. (2016).

[4] See, for example, Figures 5-1 and 5-2 in NIST (2014) that show how nonintrusive appliance load monitoring techniques can be used to obtain information about individual consumption patterns.

Suppose that there are only two types of customers, $A = \{a_u, a_p\}$, where a_u is the uniform type and a_p is the peak type. There are four customers with two uniform customers, $n_u = 2$, and two peak customers, $n_p = 2$. Let $U_u = u_u - t_u$ and $U_p = u_p - t_p$ denote the utilities of uniform and peak types, respectively, and where t_u and t_p are the payments to the firm. We identify type a_u customers by the requirement that they consume all commodities of the good by the same amount (i.e. $a_{1u} = a_{2u} = ... = a_{mu}$), whereas the type a_p customers do not consume the same amount of each commodity.[5]

Firms, indexed by $l = 1, 2$, have access to the same technology, given by a cost function $C : \mathbb{R}^m_+ \to \mathbb{R}_+$, where $C(y)$ is the cost of producing the output vector $y = (y_1, \ldots, y_m) \in \mathbb{R}^m_+$. It is assumed throughout that

Assumption 1.1. *C is continuous and strictly quasi-convex, i.e. for each $c \in \mathbb{R}_+$, the lower contour set $L(c) = \{y \in \mathbb{R}^m_+ \mid C(y) \leq c\}$ is strictly convex.*

Assumption 1.2. *C exhibits constant returns to scale, that is $C(\lambda y) = \lambda C(y)$ for all $y \in \mathbb{R}^m_+$ and $\lambda \geq 0$.*

The assumption of quasi-convexity implies that if y' or y'', with $y' \neq y''$, can be produced at the same cost, then the production of $\frac{1}{2}y' + \frac{1}{2}y''$ will be less costly. For example, assume that $y' = (50, 0, 0)$ and $y'' = (0, 50, 0)$ can be produced at the same cost, then supplying $\frac{1}{2}y' + \frac{1}{2}y'' = (25, 25, 0)$ is less costly than producing y' and y''. In the context of energy supply, where the different commodities may be interpreted as consumption in different time intervals, it means that producing a constant flow over time is cheaper than changing it according to the time of the day.

[5]Take the following example. Let $a_1 = (0, 6, 0)$ means that a customer of type a_1 consumes 6 units of commodity 2 and 0 units of commodities 1 and 3. Similar for $a_2 = (2, 2, 2)$. The first type of customer represents the peak type and the second type of customer represents the uniform type. Our framework with a good that consists of different commodities allows us as well to have an example where we have 24 commodities. Electricity can be seen as a good that is composed of 24 commodities and so, each commodity in this case would represent the hourly electricity demand.

The assumption of constant returns to scale may seem less convincing, but its role is mainly to avoid too simplistic arguments for competition in cases where one firm in the market has a larger production than the others; under decreasing returns to scale this would by itself constitute an efficiency loss to society, and we exclude this case by our assumptions. Nevertheless, our motivation derives from the retail energy market where it is not conclusive from the literature that retailers' technology necessarily exhibits decreasing or increasing returns to scale as opposed to constant returns to scale.

The definition below states that an efficient allocation of production across suppliers is one that minimises production costs. That is, (y^1, y^2) being efficient means that a total output of $y = y^1 + y^2$ cannot be produced at a lower cost.

Definition 1.1. *The allocation of production* (y^1, y^2) *is efficient if and only if it minimises* $C(y') + C(y'')$ *over all* $(y', y'') \in \mathbb{R}^m_+ \times \mathbb{R}^m_+$ *with* $y' + y'' = y^1 + y^2$.

Since C is strictly quasi-convex (meaning that the sets $L(c)$ are strictly convex, so that a convex combination of two distinct points of $L(c)$ belongs to its interior), it is simple to see which allocations are cost minimising. That is, $y^1 = \lambda y$ and $y^2 = (1 - \lambda)y$ for $\lambda \in [0, 1]$ and some $y \in \mathbb{R}^m_+$. This means that, for a given y, the cost is minimised when firms produce the same combination of commodities.

Let x, y be two vectors that are not multiples of each other. In particular, this implies $C(x), C(y) > 0$. Let $\delta = C(x)/C(y)$, i.e. $C(x) = C(\delta y)$ by constant returns. Then,

$$C(x + y) = C\left(x + \frac{1}{\delta}(\delta y)\right),$$

from constant returns to scale:

$$= \left(1 + \frac{1}{\delta}\right) C\left(\frac{\delta}{\delta + 1}x + \frac{1}{\delta + 1}(\delta y)\right),$$

from $C(x) = C(\delta y)$, $x \neq \delta y$, and strict quasi-convexity (note that we must make use of the fact that we have a convex combination between x and δy):

$$< \left(1 + \frac{1}{\delta}\right) \left(\frac{\delta}{\delta + 1} C(x) + \frac{1}{\delta + 1} C(\delta y)\right),$$

multiply through with $\left(1 + \frac{1}{\delta}\right)$, using constant returns once again:

$$= C(x) + C(y).$$

Hence,

$$C(x + y) < C(x) + C(y). \tag{1.1}$$

For example, if $x = a_u$ and $y = a_p$, then $C(a_u + a_p) < C(a_u) + C(a_p)$. That is, the cost of supplying both types of customers is lower than separately supplying both types. Another case used in the paper is $x = 2a_u + a_p$ and $y = a_u + 2a_p$, then $C(3a_u + 3a_p) < C(2a_u + a_p) + C(a_u + 2a_p)$.[6]

Let $\mathbf{p} = (p^1, p^2)$ be two price vectors in $\mathbb{R}^m_+$.[7] Assume that prices are non-negative.[8] Recall that we are working in a context of fixed demand with a finite set of types of customers and firms compete to satisfy this fixed demand. Firms set simultaneously their prices, customers observe and buy from the firm that offers the lowest payment. That is, customers can only buy from one single firm.

[6] A similar result in Cambini and Martein (2009) shows that homogeneity of degree one combined with quasi-convexity produces convexity (Theorem 2.2.2).

[7] Each price is a vector, i.e. we have a price for each commodity, $p^l = (p^l_1, \ldots, p^l_m)$, for $l = 1, 2$. In the context of electricity, this means that we allow for "dynamic pricing" (i.e. time variant electricity prices). The application of more dynamic forms of prices has been limited in the domestic and small business sectors, however advanced metering solutions have made this possible (Haney et al. 2011).

[8] The reasonability on this assumption is based on the lack of evidence of negative electricity retail prices. Nevertheless, if this assumption were to be dropped, it would become easier not to violate the incentive compatibility constraints of customers' types.

1.3.1 No Differential Information

So far, we have only delineated the general features of our model, not going into informational problems. Consider first the case where no firm has access to better information. Firm l's problem is, for $l = 1, 2$,

$$\max_{p_u^l, p_p^l} \pi^l = n_u^l p_u^l \cdot a_u + n_p^l p_p^l \cdot a_p - C(n_u^l a_u + n_p^l a_p),$$

where n_u^l and n_p^l are, respectively, the number of uniform and peak types customers that firm l supplies. Customers buy the good if their utility of buying the good is non-negative. That is, for reasonable prices, customers buy the good and choose to buy from the firm that offers the lowest payment. Firms face the incentive compatibility (IC) constraints that require customers not to accept a different price vector other than the one that corresponds to their type.

$$u_u - p_u \cdot a_u \geq u_u - p_p \cdot a_u, \tag{1.2}$$

$$u_p - p_p \cdot a_p \geq u_p - p_u \cdot a_p. \tag{1.3}$$

These constraints can be re-written as

$$(p_p - p_u) \cdot a_p \leq 0 \leq (p_p - p_u) \cdot a_u. \tag{1.4}$$

Equation 1.4 has a geometrical interpretation in the sense that it indicates the space for non-binding IC constraints.

The IC constraints play an important role in finding potential equilibrium outcomes. Firms need to construct a menu of price vectors that ensures that the IC constraints are satisfied for the same total payment. Since demand vectors of both types are different and fixed, IC constraints can be satisfied by changing p_u in the following way: increasing the price of the commodities that the peak type customer consumes more and decreasing the price of the commodities that the peak type customer consumes less. This is illustrated in the example below.

Example 1.1. *Let* $a_u = (3, 3, 3)$ *be the demand of the uniform customer and* $a_p = (7, 1, 1)$ *be the demand of the peak customer with the following price vectors for each type,* $p_u = (1, 1, 1)$ *and* $p_p = (2, 1, 1)$*. The uniform customer pays a total payment equal to* 9*, whereas the peak customer pays a total payment equal to* 16 *if it accepts the peak payment and it pays a total payment equal to* 9 *if it accepts the uniform type payment. Thus, the IC constraint for the peak type is no longer satisfied. However, we can find a price that satisfies this condition. Take the price vector* $\hat{p}_u = (2.2, 0.4, 0.4)$*. This generates the same total payment for the uniform type. The peak type would need to pay a total payment equal to* 16.2 *in case it would accept the uniform type payment. Thus, it prefers to accept the peak type payment.*[9]

Both firms simultaneously set their prices, customers observe all posted prices and buy from the firm with the lowest payment. The lowest payments are

$$p_u \cdot a_u = \min\{p_u^1 \cdot a_u, p_u^2 \cdot a_u\},$$

$$p_p \cdot a_p = \min\{p_p^1 \cdot a_p, p_p^2 \cdot a_p\}.$$

If both firms post $p_u \cdot a_u$ and $p_p \cdot a_p$, then they equally split the customers (i.e. $n_u^l = 1$ and $n_p^l = 1$, for $l = 1, 2$) such that the IC constraints hold. We want to investigate Nash equilibria in which both firms are active in the market, set the same payments and supply the same composition of types. The set of such symmetric equilibria is characterised by

[9] This can also be achieved by allowing for negative prices in some commodities or by changing both price vectors. Further, the general case with m commodities makes the problem less restricted. That is, if the IC constraints are satisfied with three commodities, these will be satisfied as well with m commodities because there are more degrees of freedom for the firm to find different combinations of prices.

two conditions. First, both firms have in equilibrium $\pi^l \geq 0$. Second, unilateral price under-cutting should not be profitable. The next proposition shows existence of Nash equilibria with symmetric payments. All proofs are in the Appendix.

Proposition 1.1. *There are two classes of Nash equilibria with symmetric payments in pure strategies with* $\pi^l = 0$*,* $l = 1, 2$*, and with the following payments:*

(i) $p_u \cdot a_u = C(2a_u + a_p) - C(a_u + a_p)$ *and* $p_p \cdot a_p = 2C(a_u + a_p) - C(2a_u + a_p)$*,*

(ii) $p_u \cdot a_u = 2C(a_u + a_p) - C(a_u + 2a_p)$ *and* $p_p \cdot a_p = C(a_u + 2a_p) - C(a_u + a_p)$*.*

Proposition 1.1 shows that both firms can equally share the customers in terms of types while offering the same payment to each type. There is a continuum of Nash equilibria because for the same total payment there can be different prices for each commodity. Thus, there is symmetry in terms of payments, but there can be asymmetry in terms of prices. Proposition 1.2 considers the existence of equilibria with symmetric payments when firms make zero profits. It is important to consider a) the existence of an equilibrium with symmetric payments where at least one firm makes positive profit; and b) the existence of an equilibrium with asymmetric payments.

Proposition 1.2. *There is no Nash equilibrium with asymmetric payments or where at least one firm makes positive profit.*

Proposition 1.2 shows that there is no Nash equilibrium with asymmetric payments. Further, it will not be an equilibrium if one firm gains positive profit and the other makes zero profit. This is because if firms obtain different profits, then the firm with lower profit has an incentive to mimic the other firm's payments.

1.3.2 Differential Information

Assume that firms have different access to information about customers. Let firm 1 be better *informed* in the sense that it can see the types of all customers served by any firm in the industry, whereas firm 2 does not have access to this information. In connection with this difference in information, we assume that firm 1 can use the information on types to offer personalised payments, $w_a \in \mathbb{R}$, to customers of type $a \in A$, whereas firm 2 can only offer a menu of price vectors, $(p_u, p_p) \subset \mathbb{R}^m \times \mathbb{R}^m$. We assume the tie-breaking rule that customers buy from firm 1 in case of indifference.[10]

Given firm 2's payments, firm 1 can attract customers of type a, subject to a payment w_a, such that

$$w_a \leq p_a^2 \cdot a_a, \text{with } a = u, p. \tag{1.5}$$

If the payment offered by firm 1 is higher, then customers will not accept it. Firm 2 takes w_a as given and supplies the remaining customers as long as its profit is non-negative. Firm 2's problem is

$$\max_{p_u, p_p} \pi^2 = n_u^2 p_u^2 \cdot a_u + n_p^2 p_p^2 \cdot a_p - C(n_u^2 a_u + n_p^2 a_p). \tag{1.6}$$

Since firm 2 does not have access to the same information about customers as firm 1, firm 2's problem is subject to the IC constraints as in the no differential information case.

We can observe three potential equilibrium outcomes: (1) firm 1 sells only to uniform customers and firm 2 sells to peak customers, (2) firm 1 sells only to peak customers and firm 2 sells to uniform customers, and (3) firm 1 sells to both types of customers. We show that there is no equilibrium where the allocation of customers is as in (1) or (2), but there is an exclusionary equilibrium where the better informed firm sells to both types of customers. Further, the case where both firms equally split the customers cannot be an equilibrium due to the tie-breaking rule. The proposition below states this result.

[10]This tie-breaking rule makes sense in our framework because firm 1, the better informed firm, can approach each customer knowing beforehand its type, whereas firm 2 needs to wait for each customer to approach the firm.

Proposition 1.3. *(Exclusionary equilibria) First, there is no equilibrium where firms supply equally the customers or where each firm supplies a type of customer. Second, there is a continuum of equilibria, where the better informed firm sells to both types such that:*

(i) $w_u + w_p = C(a_u + a_p)$*,*

(ii) $w_u \leq C(2a_u + a_p) - C(a_u + a_p)$ *and* $w_p \leq C(a_u + 2a_p) - C(a_u + a_p)$*,*

(iii) $w_u = p_u^2 \cdot a_u$ *and* $w_p = p_p^2 \cdot a_p$*,*

with allocation $n_u^1 = 2$ *and* $n_p^1 = 2$*, thereby achieving profits* $\pi^1 = 0$*.*

Proposition 1.3 implies that holding better information about the customers in the market and the ability to contact customers before firm 2, does not translate into higher profit for firm 1. This is because positive profit would give firm 2 an incentive to undercut firm 1's payments.

1.3.3 Market Structure and Social Surplus

There is one possible market structure with differential information and one possible case without differential information. In each case, firms earn zero profits, with the difference that firm 2 is excluded from the market in the differential information case. This arises from our assumption of homogeneous commodities.

Proposition 1.2 shows that, under no differential information, there is no Nash equilibrium with asymmetric payments. This holds even when one firm in the market supplies both types of customers. This result is reversed once we introduce differential information. In fact, Proposition 1.3 shows that there is a continuum of Nash equilibria when the better informed firm supplies both types of customers. The tie-breaking rule plays a key role in this difference. Access to information about the types of customers in the market allows firm 1 a first customer contact advantage. Firm 2 can only offer a menu of price vectors without being able to pre-identify the customer's type.

We have defined information advantage as the difference between the equilibrium profits of the better informed firm and the uninformed firm in the differential information case. In this case, firm 2 is excluded while firm 1 supplies all customers. There is no information advantage because firm 1 is excluded from the market.

We have defined information value as the difference between the equilibrium profits of the better informed firm in the differential information case and in the no differential information. There is no information value because the better informed firm has the same equilibrium profit in both cases.

These results contrast to the literature that says that there is an information advantage or disadvantage depending on the firms' information setup (Chokler et al. 2006). This result is explained by two main reasons. First, the presence of competition because the residual customer can switch to the other firm, it is not possible for the better informed firm to extract surplus from the customers through its access to information about the customers. Second, firm 2 is allowed to offer a menu of two price vectors (i.e. one for each type). The price vectors allow firm 2 to avoid giving an information rent that induces the customers to reveal their private information regarding their types. If, instead of offering a menu of price vectors, firm 2 could only offer one price vector to all customers, then firm 1 would be able to charge higher prices and enjoy an information advantage.

This conclusion holds in the short-run where the uninformed firm imposes a competitive constraint to the better informed firm and therefore, the better informed firm gains zero profit despite of holding better information about all customers in the market. In the medium-run, the uninformed firm will not enter the market, or leave quickly, which leads to the possibility of the informed firm to be able to charge higher prices and enjoy an information advantage.

In each of the market structures mentioned above, social surplus equals the utility of customers less the operating cost. The social surplus is the same in all cases because there is no difference in terms of costs and the fixed demand is fully covered. The customer surplus will also be the same in both market structures. However, the surplus of each type may differ; in fact, each type may be better, worse or remain the same when we compare both market structures. The reason for this is that there are two classes of Nash equilibria for each market structure. For example, if under no differential information the set of equilibrium payments is $p_u \cdot a_u = C(2a_u + a_p) - C(a_u + a_p)$ and $p_p \cdot a_p = 2C(a_u + a_p) - C(2a_u + a_p)$, whereas in the differential information case the set of equilibrium payments is $p_u \cdot a_u = 2C(a_u + a_p) - C(a_u + 2a_p)$ and $p_p \cdot a_p = C(a_u + 2a_p) - C(a_u + a_p)$. Then, the uniform type will be better off and the peak type will be worse off when firm 1 is better informed. Nevertheless, the customer surplus will remain the same.

Based on definition 1, the allocation of production is efficient in both market structures. This is because a combination of different types is supplied by a given firm.

1.4 Robustness Analysis

To this point, we have assumed that there are two firms and two types of customers. We are now interested in examining the robustness of the results to small changes in the number of customers, firms and types.

1.4.1 Number of customers

So far, we have assumed that there are a total of four customers, two of each type. Suppose now that there are n_u uniform customers and n_p peak customers, with $n_u, n_p \in \mathbb{Z}^+$ and finite numbers. Suppose that no firm has access to better information.

If for at least one type $\frac{n_a}{2} \notin \mathbb{Z}^+$, $a \in A$, then it is no longer possible to split each type of customers equally between firms. Consequently, production is not efficient. By (1), combining all customers in one single firm leads to cost savings and so, higher profit. The same applies for a situation with asymmetric payments. Hence, the result of Proposition 1.1 will not hold if it is not possible to equally share each type of customers between both firms.

Furthermore, under differential information the same result holds. That is, the better informed firm has incentives to supply both types of customers, independently of the number of customers of each type. Thus, the result of no information advantage and no information disadvantage holds if it is possible to equally split the customers between firms.

1.4.2 Number of firms

We are now interested in analysing the impact on the market outcomes once we add one more firm. Assume that there are three firms and consider three customers of each type instead of two in order to avoid the unequal split. As shown above, if it is not possible to equally split the customers between firms, then Nash equilibria with symmetric payments in pure strategies under no differential information no longer exist.

If we add one more uninformed firm, then this firm will behave as firm 2 above because it is not a profitable deviation to decrease (or increase) the payment for the peak type or uniform type. The payments will remain the same and the same Nash equilibria with symmetric payments exist.

Assume now that firm 1 and firm 3 are equally informed, whereas firm 2 remains uninformed. Since firms 1 and 3 cannot equally split the customers of each type, then the exclusionary outcome under differential information will no longer hold. As before, the result of no information advantage and no information disadvantage holds if it is possible to equally split the customers between firms.

1.4.3 Number of types

The number of types increases the complexity in setting a menu of price vectors. Consider three types, a_u, a_r, and a_p. In order to avoid the unequal split, assume that there are two customers of each type. Now, we have the following additional IC constraints to those already mentioned before: $p_u \cdot a_u \leq p_r \cdot a_u$, $p_p \cdot a_p \leq p_r \cdot a_p$, $p_r \cdot a_r \leq p_u \cdot a_r$ and $p_r \cdot a_r \leq p_p \cdot a_r$. Example 1.2 shows that if there are not enough degrees of freedom to find different combinations of prices (i.e. three types and three commodities), then it is not possible to adjust the payments such that the IC constraints are satisfied.

Example 1.2. *Consider the following consumption profiles of three different types of customers:* $a_u = (3, 3, 3)$*,* $a_r = (3, 3.5, 2.5)$ *and* $a_p = (7, 1, 1)$*. Consider the following price vectors for each type,* $p_u = (1, 1, 1)$*,* $p_r = (1, 1.5, 1)$ *and* $p_p = (2, 1, 1)$*. In this case, both types* a_r *and* a_p *would prefer to accept the payment offered to the uniform type because they would pay less. Even by considering changes in all price vectors, in order to maintain the same total payment, no solution exists with non-negative prices. Thus, the IC constraints would not be satisfied.*

If the IC constraints are not satisfied, the result stated in Proposition 1.1 would no longer hold as one firm can offer a higher price and enjoy profits. However, this problem can be solved by adding enough commodities. The example below shows that the IC constraints are satisfied once we add two more commodities. Note that, as before, we imposed a non-negativity constraint in the price vectors. Without such constraint, the problem in Example 1.2 would be possible to solve without the violation of the IC constraints.

Example 1.3. *Consider the following consumption profiles of three different types of customers:* $a_u = (2.5, 2.5, 2.5, 2.5, 2.5)$*,* $a_r = (3, 2.5, 2.5, 2.5, 2)$ *and* $a_p = (7, 1, 1.5, 1.5, 1.5)$*. Consider the following price vectors for each type,* $p_u = (1, 1, 1, 1, 1)$*,* $p_r = (1.5, 1, 1, 1, 1)$ *and* $p_p = (1.5, 1, 1, 1, 1)$*. As before, types* a_r *and* a_p *would prefer to accept the payment offered to the uniform type because they would pay less. If we change the price vectors as follows:* $p_u = (3, 2, 0, 0, 0)$*,* $p_r = (1.8, 3.4, 0, 0, 0)$ *and* $p_p = (1.8, 3.4, 0, 0, 0)$*, then the same total payments remain the same and the IC constraints are satisfied.*

In order to find different combinations of prices that ensure the IC constraints to hold, we need to have a large number of commodities that is greater than the number of types. Under that case, the result of no information advantage or disadvantage is robust to changes in the number of types.

1.5 Conclusion

We have analysed whether there is an information advantage or disadvantage in a market where firms compete in prices with a good composed by homogeneous commodities. We have assumed that if one of the firms knows the corresponding type of all customers in the market, then this firm can offer personalised payments. Even though it is possible for the better informed firm to select its own customers as opposed to the uninformed firm, it obtains the same equilibrium profit as the uninformed firm and as in the case with no differential information.

While the literature does not generally conclude that better information entails higher profits, from our knowledge it only shows cases where there is information advantage or disadvantage. Indeed, this paper presents a game where the equilibrium profits for both firms (better informed and uninformed) remains the same.

Furthermore, we show that it is not the additional ability to price discriminate that leads the better informed firm being able to exclude the uninformed firm from the market; but rather the first customer contact advantage. The uninformed firm can only offer a menu of price vectors without being able to pre-identify the customer's type.

We have assumed in our model that there are two types of customers with fixed demand. This may not be satisfactory if we would like to model a market such like electricity, where demand for electricity in the industrial segment is elastic (as opposed to the current residential segment). An extension of the model would be to have the subset of types that, for example, represents the residential segment with inelastic demand and another subset of types representing the industrial one with elastic demand.

Furthermore, electricity can be sold as a differentiated good if, for example, we consider reliability, which may be crucial in case there is a positive probability of power blackouts. In this case, each contract offered to a given customer would specify the price and the customer's service order or priority. Thus, another extension of the paper would be to allow for differentiation and to analyse the robustness of the results.

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1.7 Appendix

PROOF OF PROPOSITION 1.1:

Let prices be as in (i) stated in Proposition 1.1, then $\pi^l = 0$, $l = 1, 2$, with corresponding allocation of customers $n_u^l = 1$ and $n_p^l = 1$. Further, we can assume that prices are in the interior of the feasible set given by the IC constraints and that small unilateral changes on prices do not violate these constraints. This means that the following conditions need to hold:

$$p_u \cdot a_u \leq p_p \cdot a_u,$$

$$p_p \cdot a_p \leq p_u \cdot a_p,$$

$$\text{and } p_u \cdot a_u + p_p \cdot a_p = C(a_u + a_p).$$

Given that a_u and a_p are not multiples of each other, firms can adjust the payments such that the IC constraints are satisfied. That is, p_u can be adjusted such that $p_u \cdot a_u$ changes but $p_u \cdot a_p$ remains constant. Thus, we can move any price vector from the boundary into the interior of the feasible set. Hence, payments set in (i) can be implemented while IC constraints are satisfied. The same applies for the payments set in (ii) stated in Proposition 1.1.

Even with IC constraints being satisfied, there are several ways in which a firm could deviate.

(a) If one firm increases the price of the uniform type, then it loses the uniform customer and obtains

$$\begin{aligned}\hat{\pi} &= p_p \cdot a_p - C(a_p) \\ &= 2C(a_u + a_p) - C(2a_u + a_p) - C(a_p) < 0,\end{aligned}$$

where the inequality in the second line comes from (1.1). Thus, increasing the price of the uniform type is not a profitable deviation. Similarly, if one firm increases the price of the uniform customer and decreases the price of the peak type customer, then it loses the uniform type and attracts one more peak type at $\hat{p}_p \cdot a_p < p_p \cdot a_p$. Then, $\hat{\pi} = 2(\hat{p}_p \cdot a_p) - C(2a_p) = 2(\hat{p}_p \cdot a_p - C(a_p))$, where the second equality comes from constant returns to scale. However, $\hat{\pi} = 2(\hat{p}_p \cdot a_p - C(a_p)) < 0$ because $\hat{p}_p \cdot a_p < p_p \cdot a_p = 2C(a_u + a_p) - C(2a_u + a_p) < C(a_p)$.

(b) By the same reasoning, if firm one decreases the price of the uniform customer and increases the payment of the peak type customer, then it loses the peak type customer and attracts one more uniform type customer at $\hat{p}_u \cdot a_u < p_u \cdot a_u$. By (1.1), $p_u \cdot a_u = C(2a_u + a_p) - C(a_u + a_p) < C(a_u)$, then $\hat{\pi} < \pi = 0$. By the same reasoning, increasing the price of the peak type is not a unilateral profitable deviation.

(c) If one firm slightly decreases the price of the uniform type (i.e. $\hat{p}_u \cdot a_u < p_u \cdot a_u$), then it supplies both uniform customers and one peak customer and it obtains $\hat{\pi} = 2(\hat{p}_u \cdot a_u) + p_p \cdot a_p - C(2a_u + a_p) < 2p_u \cdot a_u + p_p \cdot a_p - C(2a_u + a_p) = 0$. Therefore, decreasing the price of one of the commodities of the uniform type is not a profitable deviation.

(d) If one firm slightly decreases the price of the peak type (i.e. $\hat{p}_p \cdot a_p < p_p \cdot a_p$), it supplies one uniform type and two peak type, obtaining $\hat{\pi} = p_u \cdot a_u + 2(\hat{p}_p \cdot a_p) - C(a_u + 2a_p) < p_u \cdot a_u + 2p_p \cdot a_p - C(a_u + 2a_p) = 3C(a_u + a_p) - C(2a_u + a_p) - C(a_u + 2a_p) < 0$, by (1.1). Hence, decreasing the price of the peak type is not a profitable deviation.

(e) If one firm increases the price of both peak and uniform types, then loses all customers and therefore, it is not a profitable deviation.

(f) If one firm decreases the price of both peak and uniform types, such that $\hat{p}_p \cdot a_p < p_p \cdot a_p$ and $\hat{p}_u \cdot a_u < p_u \cdot a_u$, then revenue falls below total cost of supplying peak and uniform type customers, i.e. $\hat{\pi} < \pi = 0$.

We conclude that it is not profitable for a firm to unilaterally deviate. Similarly, it is not profitable for a firm to unilaterally deviate if $p_u \cdot a_u = 2C(a_u + a_p) - C(a_u + 2a_p)$

and $p_p \cdot a_p = C(a_u + 2a_p) - C(a_u + a_p)$. $\square$

PROOF OF PROPOSITION 1.2:

As shown in the proof of proposition 1.1, we can assume that unilateral small changes in prices do not violate IC constraints. There are different cases that need to be analysed.

Case 1. Assume that $\pi^1 = 0$ and $\pi^2 > 0$. Then, firm 1 has an incentive to mimic firm 2's payments and increase profit. The same reasoning applies to the reverse case.

Case 2. Let payments be symmetric such that $\pi^l > 0$, $l = 1, 2$. As shown in case 1, profits of both firms need to be equal. It is a profitable deviation to slightly decrease both payments, $\hat{p}_u \cdot a_u < p_u \cdot a_u$ and $\hat{p}_p \cdot a_p < p_p \cdot a_p$, such that IC constraints still hold. Then, the firm that deviates gains $\hat{\pi} = 2\hat{p}_u \cdot a_u + 2\hat{p}_p \cdot a_p - C(2a_u + 2a_p) = 2(\hat{p}_u \cdot a_u + \hat{p}_p \cdot a_p - C(a_u + a_p))$ (by constant returns to scale). Given that demand is fixed and unilateral changes are very small, we can say w.l.o.g. that $p_u \cdot a_u \approx \hat{p}_u \cdot a_u$ and $p_p \cdot a_p \approx \hat{p}_p \cdot a_p$. Then, $\hat{\pi} \approx 2(p_u \cdot a_u + p_p \cdot a_p - C(a_u + a_p)) = 2\pi > \pi > 0$.

Case 3. Let payments be asymmetric such that $\pi^l = 0$, $l = 1, 2$. Again, we can assume that unilateral small changes in prices do not violate IC constraints. There are several cases that need to be analysed. In all these cases, one firm will offer a lower payment than the other firm for at least one type. Then, that firm has an incentive to slightly increase the payment without matching the other firm's offer and hence, without losing customers.

Case 4. Let payments be asymmetric such that $\pi^l > 0$, $l = 1, 2$.

(i) Suppose that $p_u^1 \cdot a_u = p_u^2 \cdot a_u$ and $p_p^1 \cdot a_p < p_p^2 \cdot a_p$ (the same applies if $p_u^1 \cdot a_u = p_u^2 \cdot a_u$ and $p_p^2 \cdot a_p < p_p^1 \cdot a_p$). Then, $\pi^1 = \pi^2$ because otherwise any firm could deviate to the same allocation of types and charge the same payment as the other firm and increase profit. We can then use $\pi^1 = \pi^2$ to obtain $p_p^1 \cdot a_p = \frac{1}{2}C(a_u + 2a_p) - \frac{1}{2}C(a_u)$. If firm 2 decreases the price of the peak type such that it attracts one peak type customer, it obtains

$\hat{\pi}^2 = p_u \cdot a_u + p_p \cdot a_p - C(a_u + a_p)$. By $\frac{1}{2}C(a_u) > C(a_u + a_p) - C(\frac{1}{2}a_u + a_p)$ (that follows from (1)), we know that $\hat{\pi}^2 > \pi^2$. Thus, decreasing the price of the peak type is a unilateral profitable deviation.

(ii) By same reasoning, there is a profitable deviation if $p_u^1 \cdot a_u < p_u^2 \cdot a_u$ and $p_p^1 \cdot a_p = p_p^2 \cdot a_p$ while $\pi^l > 0$ (the same applies if $p_u^2 \cdot a_u < p_u^1 \cdot a_u$ and $p_p^1 \cdot a_p = p_p^2 \cdot a_p$).

(iii) Suppose that $p_u^1 \cdot a_u < p_u^2 \cdot a_u$ and $p_p^1 \cdot a_p > p_p^2 \cdot a_p$. If firm 1 matches the same peak payment as firm 1, it obtains $\hat{\pi}^1 = 2p_u \cdot a_u + p_p \cdot a_p - C(2a_u + a_p) > \pi^1 + \frac{1}{2}\pi^2 = 0$.

(iv) Suppose that $p_u^1 \cdot a_u < p_u^2 \cdot a_u$ and $p_p^1 \cdot a_p < p_p^2 \cdot a_p$. Then, firm 2 is not supplying any customers and therefore, firm 2 can match exactly the same as firm 1 and supply equally uniform and peak type customers as firm 1.

We conclude that there is no equilibrium with asymmetric payments and $\pi^l > 0$. □

PROOF OF PROPOSITION 1.3:

In order to analyse the potential outcomes of introducing differential information, we need to consider an equilibrium where firm 1 sells to both uniform customers and firm 2 sells to peak customers (case 1), or firm 1 sells to peak customers and firm 2 sells to uniform customers (case 2), and an exclusionary equilibrium where firm 1 sells to all customers (case 3). The case where both firms supply equally the customers is ruled out because of the tie-breaking rule.

Case 1. Consider the requirements for a situation in which firm 1 sells to type a_u customers and firm 2 sells to type a_p customers. Both customers and firms must be satisfied with this split. For customers, this requires that type a_u prefers to buy from firm 1,

$$w_u \leq p_u^2 \cdot a_u, \tag{1.7}$$

and that type a_p prefers firm 2,

$$w_p > p_p^2 \cdot a_p. \tag{1.8}$$

Then, firm 2 has an incentive to slightly increase $p_p^2 \cdot a_p$ and increase profit. Therefore, this cannot be an equilibrium.

Case 2. By the same token, there is no equilibrium if firm 1 sells only to a_p customers and firm 2 sells only to a_u customers.

Case 3. Now, we consider the requirements for a situation in which firm 1 sells to both types a_u and a_p customers. That is, firm 1 excludes firm 2 serving both customer types at payments that do not allow firm 2 to cover the cost of attracting any type of customers. For this to be an equilibrium, it is necessary that firm 1's profit is non-negative and the payments of both firms are identical. The latter condition is needed because otherwise firm 1 could increase the payments up to firm 2's offers without losing the customers and gain profit under the assumption that IC constraints hold. Furthermore, firm 1's profit must be zero, otherwise firm 2 could undercut and increase profit, i.e. $w_u + w_p = C(a_u + a_p)$.

For firm 1, this requires that supplying both types of customers at w_u and w_p is more profitable than selling only to type a_u. Further, firm 1 must prefer supplying all customers rather than competing only for the peak type customers or leaving one peak customer to firm 2 or to compete for both peak type customers and leaving one uniform type for firm 2.

$$2w_u + 2w_p - C(2a_u + 2a_p) \geq 2w_u - C(2a_u), \tag{1.9}$$

$$2w_u + 2w_p - C(2a_u + 2a_p) \geq 2w_p - C(2a_p), \tag{1.10}$$

$$2w_u + 2w_p - C(2a_u + 2a_p) \geq 2w_u + w_p - C(2a_u + a_p), \tag{1.11}$$

$$2w_u + 2w_p - C(2a_u + 2a_p) \geq w_u + 2w_p - C(a_u + 2a_p). \tag{1.12}$$

Simplifying equations (1.9) -(1.10) and using $w_u + w_p = C(a_u + a_p)$, we obtain the following conditions:

$$w_a \leq C(a_a), \text{for } a = u, p, \tag{1.13}$$

$$w_u \leq C(2a_u + a_p) - C(a_u + a_p), \tag{1.14}$$

$$w_p \leq C(a_u + 2a_p) - C(a_u + a_p). \tag{1.15}$$

Further, (1.14) and (1.15) are stricter than (1.13) by strict quasi-convexity.

We suffice to show that $w_u + w_p = C(a_u + a_p)$, (1.14) and (1.15) is non-empty. By summing equations (1.14) and (1.15), we obtain $C(3a_u + 3a_p) \leq C(2a_u + a_p) + C(a_u + 2a_p)$. By (1.1) we know that the resulting condition is strictly satisfied.

There will be different combinations of (w_u, w_p) that satisfy these conditions and therefore, we can have a continuum of equilibria. □

Chapter 2

Contracting in a market with self-control

2.1 Introduction

In many domains of life, individuals set goals and make promises, but potentially postpone actions and fail to achieve goals. This can have impact on decisions that individuals face as consumers. For example, consumers may need to produce forecasts of their future preferences at the time they decide to enter a contract with a firm. If consumers have dynamically inconsistent preferences that affect consumption and saving decisions, then this can have significant effects in the design of optimal contracts.

An example of this environment stems from the energy sector where prepayment meters allow consumers to pay for electricity and/or gas before they consume it. Consumers must plan in advance their future consumption. This may lead to self-disconnection, which happens when the credit runs out and energy supply is stopped. This can be particularly costly for a specific type of consumer that is not aware of his degree of time inconsistency at the contracting stage. The behavioural economic literature defines this type of consumer as naïve. This type differs from a sophisticated type in the sense that a sophisticated type is fully aware of his inconsistency and so, he correctly predicts how his future self will behave.[1]

The key question of this paper is whether a profit-maximising firm would want to induce the naïve type to consume the good. To answer this question, this paper develops a model of monopolistic contracting in a two selves framework. The model has an agent and a principal and two dates/periods. The agent can be time-consistent, sophisticated or naïve. The principal cannot observe the type of the agent at date 0 (i.e. the contracting stage). At date 0, the principal offers the agent a menu of contracts or a single contract. Each contract involves a quantity and a non-negative payment to the principal. We focus our attention to specific contract forms: a pay-in-advance (hereafter, PIA) contract that involves a payment at date 0 and a payment at date 1, and a pay-in-advance (hereafter, PAD) contract that only involves a payment at date 1. In order to make any payment, the agent needs to make a saving decision and incur a savings effort cost. At date 1, the agent's marginal utility of consumption is affected by a shock, good or bad, and consumption is only efficient in the good state. This together with the need to save in order to make a payment generates demand for flexibility. In addition, the self-0 sophisticated type values commitment because via a commitment contract, the self-0 is able to commit the self-1 to the self-0's desired consumption.

Under unobservability of time inconsistency, an adverse selection problem arises because the time-consistent type values flexibility more than a sophisticated type. Naiveté introduces a further complication because the self-0 naïve type behaves as the time-consistent type and hence, perfect self-selection at the contracting stage is not possible.

[1] Another example stems from the use of fertiliser in developing countries. The use of fertilisers has been incentivised (until a certain point) by agricultural experts because fertilisers generate positive agricultural yields. However, evidence shows an under-utilisation of fertiliser in African countries. Duflo et al. (2010) analyse this puzzle and argue that behavioural biases limit profitable investments in fertiliser by farmers in developing countries. It is further argued that this happens in a similar way that behavioural biases limit investment in attractive financial investments in pension plans by workers in the United States.

We find that by restricting the number of contracts to a single PIA contract that induces the self-1 sophisticated type to consume the good, the principal also induces the self-1 naïve type to consume in the good state. However, this is achieved at the expense of flexibility given that the agent needs to incur a savings effort cost even if no consumption is made (i.e. in the bad state).

We also show that if we do not impose the naïve type's consumption constraint, the principal can offer a menu of contracts composed of a PIA and a PAD contracts while extracting all rents from the remaining types. Once we add the naïve type's consumption constraint, the self-0 naïve type behaves as the time-consistent type and so, the principal needs to decrease the payments sufficiently to induce consumption. Hence, there is a trade-off between increasing efficiency and decreasing information rent that occurs partially at date 0 preferences and partially at date 1 preferences. We also study the conditions under which it is profit-maximising for the principal to offer a menu of contracts and a single PIA contract that induce positive consumption to all types.

Lastly, we study the impact of the naïve type on the remaining types' utilities and the principal's expected profit. We show that the principal may have incentives to educate the naïve into a sophisticated type because it can generate greater profits. The reason for this is that the principal needs to decrease the payments sufficiently to induce positive consumption from the naïve type. Once a naïve type becomes a sophisticated type, the principal can offer a different contract than the time-consistent type and extract rents. Therefore, the sophisticated and the time-consistent types are better off with the presence of the naïve type if the principal offers a menu of contracts.

2.2 Related literature

Our model follows the literature on the problem of contracting with time-inconsistent agents or boundedly rational consumers. We focus on the design of optimal contracts that can induce the naïve type to consume while inducing the time-consistent and the sophisticated types to consume.

Our paper belongs to the literature on contracting with time inconsistency, which includes the seminal paper by DellaVigna and Malmendier (2004) that studies optimal contracts in a complete information setup and quasi-hyperbolic discounting. The authors show that for time-inconsistent agents, a monopoly under a two-part pricing scheme and offering an "investment good" will charge a per-usage price below the marginal cost and a higher lump-sum fee. Two rationales are given for explaining such result: commitment and consumer overconfidence.[2] In the same framework, Li et al. (2014) extend DellaVigna and Malmendier's model by introducing private information on the consumer's benefit from the good while assuming that agents are sophisticated. They show that there is an important threshold value of short-run patience, such that below it time-inconsistent preferences hurt the firm's profits. By contrast, in this paper, private information is on the consumer's time preferences and the agent can be time-consistent, sophisticated or naïve type.

Closest to our work, Galperti (2015) shows that the principal can implement the first-best under complete information, but under unobservable time inconsistency a screening issue arises. It is shown that an efficient savings device for a time-inconsistent agent rewards savings and penalises withdrawals. However, if a time-consistent agent takes such a device, he does so expecting to receive more rewards and fewer penalties than otherwise. To lower the time-consistent agent's information rent, the principal curtails

[2]Indeed, the literature on behavioural industrial organisation with self-control problems can be usefully grouped with works from the overconfidence literature. For more information, see Grubb (2015).

the flexibility below efficiency. Galperti (2015) builds from the formulation of Amador et al. (2006) that also studies the presence of temptation for current consumption with a taste shock in each period. In Galperti (2015) the agent can only be time-consistent or -inconsistent, where time-inconsistent corresponds to a full sophisticated type. In our model, the agent can be time-consistent, sophisticated or naïve. Although, Galperti (2015) has a small discussion about the introduction of a naïve type, it does not explain how this would be formulated into the model and how exactly that would affect the results. Furthermore, Galperti's motivation stems from the consumption-saving decisions where the principal can be a profit-maximising firm or a welfare-maximising planner and hence, the agent can save different amounts each leading to a tax penalty or a subsidy. The motivation for our model comes from a profit-maximising firm that offers a contract to a consumer, where payments are usually non-negative. We do not allow for negative payments, which translate into less flexibility into the model since the principal is not allowed to give a penalty at date 1 in case the agent does not consume. Further, in the present paper a payment requires a savings effort cost from the agent.

Within this literature, other papers have focused attention on cases where the naïve consumer underestimates the cost and consumes too much. For example, Eliaz and Spiegler (2006) study a principal-agent problem under the assumption that agent's types differ in preferences while considering a principal that offers a menu of exploitative and non-exploitative contracts. The principal has an incentive to induce naïve types to sign up for the exploitative contracts. These agents will accept under the belief that they will be the ones to extract rent from the principal. Esteban et al. (2007) study nonlinear pricing schemes for a monopoly when self-control is costly using temptation preferences as in Gul and Pesendorfer (2001). As in Eliaz and Spiegler (2006), the firm acts optimally taking advantage of the consumers' temptation, however it is also shown that it is possible that the presence of temptation does not raise the firm's maximal profits. Grubb

(2009) considers contracting with consumers who overestimate the extent to which they can predict their demand for a product. Heidhues and Kőszegi (2010) study a similar problem, but specific to the credit market while analysing welfare-increasing interventions. Different from these papers, we study the case where the naïve type's unawareness increases the likelihood of under consumption that can harm both the consumer and the firm.

2.3 Model

Consider a monopolistic firm (the principal, P) who sells a good, $q \in \{0,1\}$, to a consumer (the agent, A). All parties are risk neutral. The agent can have dynamically inconsistent preferences, whereas the principal is time-consistent. The type of the agent is unobservable to the principal. Moreover, the agent can choose to exert a savings effort cost, which is necessary to be able to consume at all.

Agent. In order to model time inconsistency we follow the two-selves framework, where the agent has a self-0 who lives during date 0 and chooses the contract (or rejects it) and self-1 who lives during date 1 and chooses to consume or not. The agent can be time-consistent or time-inconsistent. The time-inconsistent can be sophisticated or naïve type. Let θ measure the degree of time consistency, where $\theta \in \Theta = \{\underline{\theta}, 1\}$, with $\underline{\theta} \in (0,1)$. Let $\tilde{\theta}$ be an agent's belief about his true type. Thus, there are three different types of agent each with a pair $(\theta, \tilde{\theta})$, with $(\theta, \tilde{\theta}) \in \{(1,1), (\underline{\theta}, \underline{\theta}), (\underline{\theta}, 1)\}$. The time-consistent type has $\theta = \tilde{\theta} = 1$. The sophisticated type has inconsistent preferences, and is aware of it, $\theta = \tilde{\theta} = \underline{\theta}$. The naïve type has inconsistent preferences, $\theta = \underline{\theta}$, but is unaware of it, $\tilde{\theta} = 1$. The principal does not observe the agent's type, but believes that the agent is time-consistent, sophisticated or naïve with respective probabilities ν_1, ν_2, and $(1 - \nu_1 - \nu_2)$.

Assume that the agent's marginal utility of consumption, ϕ_s, is affected by a shock, where s denotes the state of nature, $s = g$ (for good) and $s = b$ (for bad), with $0 < \phi_b < \phi_g$. Let the probability of the good state be p and the probability of the bad state be $(1 - p)$. Shocks are neither observable nor verifiable by the principal. The realised shock is only observable to the agent's self-1.

In order to make any payment and to consume the good, $q = 1$, the agent needs to make a saving decision and incur savings effort cost ψ. We assume that ψ is equal for all types and that saving can occur either at date 0 or at date 1, $S_0, S_1 \in \{0, 1\}, S_0 + S_1 \leq 1$. Assume that S_0 and S_1 are not contractible.

Assumption 2.1. *(Efficiency) The following holds:* $\phi_g > c + \psi > \phi_b$*,*

where $c > 0$ is the marginal cost of producing good q. This assumption means that, from a date-0 perspective, it is efficient that the agent chooses to consume in the good state and not to consume in the bad state. We also assume that the marginal benefit of consumption in the bad state for the time-consistent type is lower than the marginal benefit of consumption for the time-inconsistent types in the good state, i.e. $\phi_b < \phi_g \underline{\theta}$. We introduce this assumption to avoid those cases where the degree of time inconsistency is so low that any contract that induces the time-inconsistent types to consume would automatically induce the time-consistent type to consume in both states.

The shock that affects the marginal utility of consumption is only observed by the self-1 agent. This together with consumption being efficient only in the good state and the need to incur savings effort cost generate demand for flexibility. In addition, the self-0 sophisticated type values commitment, because via a commitment contract, the self-0 is able to commit the self-1 to the self-0's desired consumption. This introduces a trade-off between commitment and flexibility from the point of view of the self-0 sophisticated type. This trade-off is not perceptible for the self-0 naïve type, because he is not aware of his lack of self-control; or in other words, the self-0 naïve type values flexibility as the self-0 time-consistent type does, which is more than the self-0 sophisticated type. Flexibility plays a key role, because otherwise the principal would offer only contracts that involve a commitment from the agent.

Contracts. The principal offers a menu of contracts or payment options $T = \{t(\hat{\theta})\}_{\hat{\theta}\in\Theta}$, where $\hat{\theta}$ is the type reported by the agent when accepting the contract and $t(\hat{\theta}) = \{t_0(\hat{\theta}), t_1(\hat{\theta}, q)\}$ where t_0 and t_1 are the payments made during date 0 and date 1, respectively, and t_1 depends on consumption. The menu of contracts has to induce savings effort if it is to ensure positive consumption. The principal is assumed to be always committed to fulfil the rights and obligations in the contract.

Once contracts are offered, the agent evaluates the quantity and payment of any given contract, with respect to his belief about his own type. The agent's utility is normalised to zero if he refuses the contract with the principal. Assume that the agent is budget-constrained and thus, it will not be possible for the principal to include penalties. This assumption rules out contracts where the agent would need to pay a penalty at date 1 in case he would not consume, i.e. we must have $t_1(\hat{\theta}, 0) = 0$.

Two kinds of contracts are possible: pay-in-advance and pay-after-delivery. The pay-in-advance contract will take the form of a payment option that permits an early payment that can only be used to consume the good in the future without allowing for withdrawals. This is outlined in the definition below.

Definition 2.1. *A pay-after-delivery (PAD) contract is a payment schedule that does not involve any payment at date 0:* $t_0(\hat{\theta}) = 0$*. A pay-in-advance (PIA) contract is a payment schedule that involves a payment at date 0 (upfront payment):* $t_0(\hat{\theta}) > 0$*.*

In a full PIA contract, the agent needs to pay the full payment at date 0 in order to consume the good at date 1, but choice $q = 0$ is always possible. However, the closer to a full PIA contract, the greater will be the cost associated with the loss of flexibility.

From the literature on behavioural economics, sophisticated agents search for commitment devices in order to induce themselves to make certain future choices. A commitment device has a cost associated with losing flexibility. A PIA contract can be seen as a commitment device if the agent is willing to pay something simply to gain the commitment without any other benefit (Bryan et al. 2010).

We are particularly interested in studying two potential outcomes: (1) all types accept a PIA contract, and (2) the sophisticated type accepts the PIA contract and the time-consistent and the naïve types accept a PAD contract. Importantly, the case where the sophisticated and naïve types accept a PIA contract and the time-consistent type accepts a PAD contract is not achievable, because the self-0 naïve type behaves as the time-consistent type. Furthermore, we are particularly interested when all types consume the good only in the good state and so, efficiency is reached.

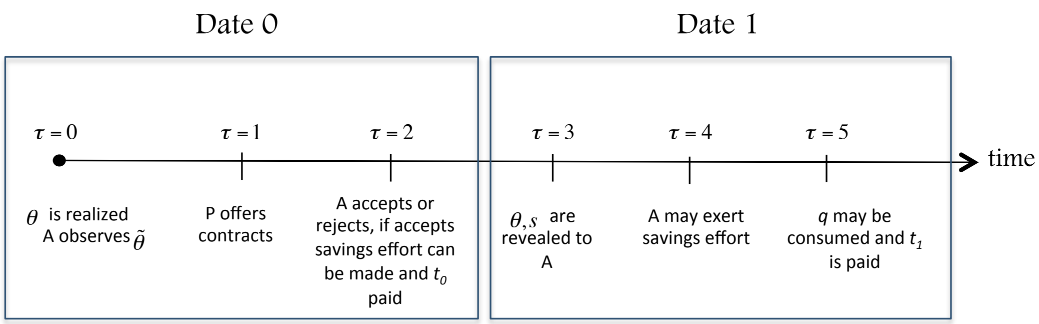
Principal. Assume that there is only one single profit-maximising principal that only cares about his profit, is time consistent and risk-neutral. If the agent of reported type $\hat{\theta}$ consumes q, the principal's profit is given by:

$$\pi = t_0(\hat{\theta}) + t_1(\hat{\theta}, q) - cq,$$

where $t_0(\hat{\theta}) + t_1(\hat{\theta}, q)$ is the total payment received.

Timing. The timing of contracting is illustrated in Figure 2.1.

FIGURE 2.1: Timing of Contracting



At $\tau = 0$, belief $\tilde{\theta}$ is revealed to the agent and so, after this period there is asymmetric information between the principal and the agent. At $\tau = 1$, the principal offers a contract or a menu of contracts to the agent. At $\tau = 2$, the agent accepts or rejects the offer and if accepts it also chooses the contract. If savings effort cost is incurred at date 0, then a payment t_0 can be made. At $\tau = 3$, θ and s are revealed to the agent. At $\tau = 4$, the agent chooses whether to exert savings effort cost or not. At $\tau = 5$, the good q may be consumed and conditional payment t_1 is made.

2.4 Analysis

2.4.1 Agent's choices

The self-1 type θ chooses whether to consume the good or not. Let V_{1s} denote the value of self-1 for $s \in \{b, g\}$:

$$\begin{aligned} V_{1s}(\theta, t(\hat{\theta}), S_0) &= \max_{q \in \{0,1\}} [(\phi_s \theta - (1 - S_0)\psi)q - S_0\psi - t_0(\hat{\theta}) - t_1(\hat{\theta}, q)] \\ &= \max\{\phi_s\theta - (1 - S_0)\psi - t_1(\hat{\theta}, 1), -t_1(\hat{\theta}, 0)\} - S_0\psi - t_0(\hat{\theta}), \end{aligned} \tag{2.1}$$

where $q^*_{s\theta}(S_0, t(\hat{\theta}))$ is the maximiser of the right-hand side.

Equation (2.1) considers the following cases: incurring the savings effort cost at date 0 ($S_0 = 1$) or not incurring at date 0 ($S_0 = 0$). If $S_0 = 0$ and $q = 1$, the consumer needs to save at date 1 ($S_1 = 1$). Note that when the consumer saves at date 0, the savings effort cost is sunk for self-1.

Let $V_0(\hat{\theta}, \tilde{\theta})$ denote the value of the self-0 of a type $\tilde{\theta}$ who pretends to be $\hat{\theta}$.

$$V_0(\hat{\theta}, \tilde{\theta}) = \max_{S_0 \in \{0,1\}} E_s[(\phi_s - (1 - S_0)\psi)q^*_{s\tilde{\theta}}(S_0, t(\hat{\theta})) - S_0\psi - t_0(\hat{\theta}) - t_1(\hat{\theta}, q^*_{s\tilde{\theta}}(S_0, t(\hat{\theta})))], \tag{2.2}$$

where $S^*_0(\hat{\theta}, \tilde{\theta})$ is the maximiser of the right-hand side.

Note that the self-0 has valuation $\theta = 1$. The agent's type is only present in the self-1 utility in order to capture the idea of time inconsistency. Consequently, for the sophisticated and naïve types there is a disagreement between the self-0 and the self-1 in terms of time preferences (θ). There is nevertheless an agreement between the self-0 and the self-1 about the utility shock (although there is a asymmetry of information, because the self-1 knows the utility shock as opposed to the self-0).[3]

2.4.2 Consumption constraints

As a preliminary step in our analysis, we find the agent's consumption constraints. We use backward induction to find when it will be optimal for the agent to consume the good. If the self-0 type $\tilde{\theta}$ has chosen $S_0 = 0$, then it will be optimal for the self-1 type θ to choose:

$$q^*_{s\theta}(0, t(\hat{\theta})) = \begin{cases} 1 & \text{if } \phi_s\theta \geq \psi + t_1(\hat{\theta}, 1) \\ 0 & \text{otherwise} \end{cases},$$

[3]This agreement regarding shocks and disagreement on time preferences follows the utility specification of Amador et al. (2006). Other authors, such as Galperti (2015), also use this specification.

where $t_1(\hat{\theta}, 0) = 0$ by assumption. That is, consumption will be chosen if the marginal benefit of consuming the good is greater or equal to the sum of the effort cost of saving and the payment. If the self-0 type $\tilde{\theta}$ has chosen $S_0 = 1$, then it will be optimal for self-1 type θ to choose:

$$q^*_{s\theta}(1, t(\hat{\theta})) = \begin{cases} 1 & \text{if } \phi_s\theta \geq t_1(\hat{\theta}, 1) \\ 0 & \text{otherwise} \end{cases}.$$

Exploiting when it will be optimal for an agent to consume will help us substantially, in the next subsections, to find the optimal contract(s). Suppose that the sophisticated type accepts a PIA contract and the time-consistent and the naïve types accept a PAD contract. A PIA contract requires a payment at date 0. Thus, the self-0 sophisticated type needs to save at date 0 to pay $t_0(\underline{\theta})$. In order to induce the self-1 sophisticated type to consume, the principal needs to set

$$t_1(\underline{\theta}, 1) \leq \phi_s\underline{\theta}.$$

That is, if the principal wants to induce consumption in the good state, then he needs to set a payment at most equal to $\phi_g\underline{\theta}$.

The time-consistent and the naïve types will prefer to save at date 1 in the good state only, because saving earlier requires a savings effort cost at date 0, which leads to a loss of flexibility. That is, both types will prefer to save and consume in the good state only because $\phi_b < c + \psi$ which leads to a real welfare cost if the good is consumed in the bad state. In order to induce the time-consistent type to consume in the good state, the principal needs to set

$$t_1(1, 1) \leq \phi_g - \psi.$$

However, at this payment, the self-1 naïve type will choose not to consume. In order to induce the naïve type to consume in the good state, the principal needs to decrease the payment to at most $\phi_g\underline{\theta} - \psi$. Therefore, the naïve type will restrict the principal when choosing the payment of a PAD contract. The reason for this is that the self-1 naïve type values the good less than the time-consistent type (and the self-0 naïve type).

If the principal cares about the agent's consumption regardless of the type, then the naïve type's consumption constraint will be crucial in the maximisation problem. If the principal cares only about the expected profit, then we need to analyse whether the principal is better off by not inducing the naïve type to consume, even in the good state. Thus, the naïve type's consumption constraint can be ignored if the profit gained by inducing the naïve type to consume does not compensate the cost of lowering the payment. The incentives for the principal to induce the naïve type to consume decrease with the degree of time inconsistency. That is, the principal needs to lower the payment of a PAD contract to at most $\phi_g\underline{\theta} - \psi$. Thus, the closer $\underline{\theta}$ is to zero (i.e. the more severe the degree of time inconsistency), the lower the payment needed to induce the naïve type to consume the good.

In standard models of price discrimination, the "high" value consumers receive informational rents to prevent them from mimicking the "low" value consumers. In this model, the self-0 time-consistent type is the high type because the self-1 time-consistent type values the good more than the self-1 sophisticated and naïve types. If a menu of contracts enables the sophisticated type to reach his self-0's utility level, then it will also be the case for the time-consistent type. The flexibility plays an important role because it makes the time-consistent type better off by not choosing a contract that involves an earlier payment.

2.4.3 The principal's problem

The principal offers a menu of contracts before knowing the type of agent and the realised state. In order to maximise expected profit, the principal will construct a direct-revelation mechanism where participation and truth-telling about the agent's type belief are individually rational. The principal's problem can be written as follows:

$$\begin{aligned}
&\max_{T} E_{(\theta,\tilde{\theta}),s}[t_0(\tilde{\theta}) + t_1(\tilde{\theta}, q^*_{s\theta}(S_0(\tilde{\theta},\tilde{\theta}), t(\tilde{\theta}))) - cq^*_{s\theta}(S_0(\tilde{\theta},\tilde{\theta}), t(\tilde{\theta}))] \\
&\qquad \text{s.t. for all } (\tilde{\theta},\hat{\theta}) \in \Theta^2: \\
&\qquad \text{PC}_{\tilde{\theta}}: \quad V_0(\tilde{\theta},\tilde{\theta}) \geq 0 \\
&\qquad \text{IC}_{\tilde{\theta}}: \quad V_0(\tilde{\theta},\tilde{\theta}) \geq V_0(\hat{\theta},\tilde{\theta}).
\end{aligned} \tag{2.3}$$

PC are the participation constraints and IC are the ex-ante incentive compatibility constraints. The IC constraints mean that an agent of type $\tilde{\theta}$ cannot not be worse off by pretending to be of type $\hat{\theta} \neq \tilde{\theta}$ and signing the contract assigned to that type. When we rewrite the IC constraints for each type, the sophisticated type should be better off accepting a contract $t(\underline{\theta})$ than accepting a contract $t(1)$ and the reverse for the time-consistent and the naïve types. Note that the IC constraint for the naïve type is based on a wrong belief because the self-0 naïve type thinks that he is time-consistent. Given his belief $\tilde{\theta}$, he must think that he will prefer the contract assigned to the time-consistent type. Heidhues and Kőszegi (2010), in a different setup, have a similar condition that is called *perceived-choice constraint*. This applies to our naïve type's IC constraint.

2.4.3.1 Single contracts

To better understand the solution to the problem in (3), it is useful to solve the maximisation problem for a single contract before solving it for the menu of contracts. When only one contract is offered, the IC constraints are satisfied; only the PC and the consumption constraints matter. We are most interested in the outcome when the agent consumes in the good state only.

Proposition 2.1 shows that if the principal offers a single contract, then a single PIA contract is profit-maximising when imposing consumption in the good state to all types of agent and given $\phi_g \geq \max\{\frac{\psi}{p} + c, \frac{(1-p)}{p(1-\underline{\theta})}\psi\}$. The condition $\phi_g \geq \frac{\psi}{p} + c$ guarantees that the expected profit when offering a single PIA contract is non-negative and $\phi_g \geq \frac{(1-p)}{p(1-\underline{\theta})}\psi$ guarantees that the principal's expected profit is greater when offering a single PIA contract than a single PAD contract.

Proposition 2.1. *Suppose the principal offers a single contract $\{t_0, t_1(q)\}$ such that consumption in the good state is incurred. Then, for $\phi_g \geq \max\{\frac{\psi}{p} + c, \frac{(1-p)}{p(1-\underline{\theta})}\psi\}$, the profit-maximising single contract is a PIA contract. Further,*

- *The expected profit of the principal is*

$$E(\pi)^{PIA} = p(\phi_g - c) - \psi.$$

- *The payments are $pt_1(1) + t_0 = p\phi_g - \psi$, with $\phi_b < t_1(1) \leq \phi_g\underline{\theta}$ and $t_0 > 0$.*

PROOF: (i) Suppose the principal offers a single PAD contract that does not involve any earlier payment and hence, it is optimal for the agent to incur the savings effort cost with probability p (i.e. $S_0 = 0$). In order to induce the time-inconsistent types to consume in the good state, the principal needs to set $\phi_b - \psi < t_1(1) \leq \phi_g\underline{\theta} - \psi$. The principal wants to extract the maximum rent while inducing consumption in the good state. Hence, $t_1(1) = \phi_g\underline{\theta} - \psi$. The time-consistent type consumes in the good state only because $\phi_g\underline{\theta} > \phi_b$. At this payment and optimal consumption and saving decisions, the principal's expected profit is given by $E(\pi)^{PAD} = p(\phi_g\underline{\theta} - \psi - c)$.

(ii) Suppose the principal offers a single PIA contract that involves an earlier payment and hence, $S_0 = 1$. All types will consume only in the good state if $\phi_b < t_1(1) \leq \phi_g \underline{\theta}$. The principal sets a payment that extracts rent as much as possible while inducing all types to consume in the good state. That is, $V_0(\underline{\theta}, \underline{\theta}) = 0 \Leftrightarrow pt_1(1) + t_0 = p\phi_g - \psi$, given that the time-inconsistent types' consumption constraints are satisfied (i.e. $t_1(1) \leq \phi_g \underline{\theta}$) and $t_0 > 0$. The principal's expected profit is given by

$$E(\pi)^{PIA} = p(t_1(1) - c) + t_0 = p(\phi_g - c) - \psi,$$

which by assumption is non-negative. Further, by $\phi_g \geq \frac{(1-p)}{p(1-\underline{\theta})}\psi$, $E(\pi)^{PIA} \geq E(\pi)^{PAD}$.
□

The proposition shows that by restricting the number of contracts to a single PIA contract that induces the self-1 sophisticated type to commit to consumption in the good state, the principal also induces the naïve type to consume in the good state. However, this is achieved at the expense of flexibility. Whilst in a PAD contract the savings effort cost is incurred with probability p, in a PIA contract the savings effort cost is incurred with probability 1.

Furthermore, the closer $\underline{\theta}$ is to zero, the more likely it is for the condition $\phi_g \geq \frac{(1-p)}{p(1-\underline{\theta})}\psi$ to hold. That is, the higher the degree of time inconsistency, the better is for the principal to offer a single PIA contract. This is because, under a PAD contract, the principal would need to lower the payment enough such that the time-inconsistent types would be induced to consume in the good state without being able to extract rent at date 0. Consequently, under a certain degree of time inconsistency, it is better for the principal to offer a single PIA contract. This shows that if the principal does not take into consideration that the agent might have dynamically inconsistent preferences when designing a contract, the result can be inefficient. Hereafter, we will focus on inducing the sophisticated type to accept a PIA contract.

Proposition 2.1 imposes the consumption constraints to the problem in (3). If the consumption constraints of the naïve and the sophisticated type are ignored, then a single PIA contract may not be profit-maximising. Indeed, Proposition 2.2 examines under what condition will be profit-maximising to offer a single PIA contract that imposes consumption in comparison to a case where the consumption constraints are not imposed.

Proposition 2.2. *Suppose the principal offers a single contract. Then, for* $\phi_g \geq \frac{(1-\nu_1 p)}{(1-\nu_1)p}\psi + c$*, the profit-maximising contract is a single PIA contract that induces all types to consume in the good state and the consumption constraints are not imposed.*

PROOF: As shown in Proposition 2.1, the expected profit when offering a single PIA contract that induces consumption only in the good state to all types is $E(\pi) = p(\phi_g - c) - \psi$. Now, we drop the consumption constraints. If the principal sets payments such that no type of agent consumes in the good state, then the expected profit is zero. Further, optimal consumption decisions for the sophisticated and the naïve types will be the same in a single contract. Hence, it is enough to analyse the case where only the time-consistent type consumes. In this case, the principal offers a single PAD contract since it does not involve a welfare loss. The principal needs to set $t_1(1) \leq \phi_g - \psi$ to induce consumption. Therefore, $t_1(1) = \phi_g - \psi$ and the expected profit is given by $E(\pi) = \nu_1 p(\phi_g - \psi - c) \geq 0$ (by $\phi_g > \psi + c$). Hence, a single PIA contract is profit-maximising if $p(\phi_g - c) - \psi \geq \nu_1 p(\phi_g - \psi - c) \Leftrightarrow \phi_g \geq \frac{(1-\nu_1 p)}{(1-\nu_1)p}\psi + c$. □

Proposition 2.2 shows that if the probability of the agent being time-consistent type is low enough (i.e. ν_1 is low enough) and the probability of the good state is high enough, then it is optimal for the principal to offer a single PIA contract.

2.4.3.2 Menu of contracts

Now we are interested in solving the maximisation problem in (2.3) when the principal offers a menu of contracts composed of a PIA and a PAD contracts. The following proposition identifies two possible cases that arise when the principal offers a menu of contracts.

Proposition 2.3. *Suppose the principal offers a menu of contracts $\{t(\underline{\theta}), t(1)\}$. Let $t(\underline{\theta})$ be a PIA contract and $t(1)$ be a PAD contract. Two possible cases arise.*

- *If the naïve type's consumption constraint is ignored, then only the sophisticated and the time-consistent types consume. The payments are $t_1(1,1) = \phi_g - \psi$ and $pt_1(\underline{\theta}, 1) + t_0(\underline{\theta}) = p\phi_g - \psi$, with $\phi_b < t_1(\underline{\theta}, 1) \leq \phi_g\underline{\theta}$ and $t_0(\underline{\theta}) > 0$. The expected profit of the principal is*

$$E(\pi)^1 = \nu_1 p(\phi_g - \psi - c) + \nu_2(p(\phi_g - c) - \psi).$$

- *If the naïve type's consumption constraint is imposed, then all types consume. The payments are $t_1(1,1) = \phi_g\underline{\theta} - \psi$ and $pt_1(\underline{\theta}, 1) + t_0(\underline{\theta}) = p\phi_g\underline{\theta} - \psi$, with $\phi_b < t_1(\underline{\theta}, 1) \leq \phi_g\underline{\theta}$ and $t_0(\underline{\theta}) > 0$. The expected profit of the principal is*

$$E(\pi)^2 = p(\phi_g\underline{\theta} - \psi - c) - (1-p)\nu_2\psi.$$

When $\phi_g \geq \frac{(1-\nu_1-\nu_2)}{(\underline{\theta}-\nu_1-\nu_2)}(\psi + c)$, it is profit-maximising for the principal to offer a menu of contracts where all types consume: $E(\pi)^2 \geq E(\pi)^1$.

PROOF: (i) Suppose that the naïve type's consumption constraint is ignored. First, we want to show that the menu of contracts with payments $t_1(1,1) = \phi_g - \psi$ and $pt_1(\underline{\theta}, 1) + t_0(\underline{\theta}) = p\phi_g - \psi$, with $\phi_b < t_1(\underline{\theta}, 1) \leq \phi_g\underline{\theta}$ and $t_0(\underline{\theta}) > 0$, satisfies PC and IC constraints.

If the self-0 time-consistent type accepts $t(1)$, then it is only induced to consume in the good state and it chooses to incur the savings effort cost at date 1 with probability p, obtaining $V_0(1,1) = p(\phi_g - \psi - t_1(1,1)) = 0$. If it accepts $t(\underline{\theta})$, it consumes only in the good state (by $\phi_b < \phi_g\underline{\theta}$) and incurs the savings effort cost at date 0, obtaining utility $V_0(\underline{\theta},1) = p(\phi_g - t_1(\underline{\theta},1)) - \psi - t_0(\underline{\theta}) = 0$. The self-0 utilities are the same, meaning that the self-0 time-consistent type is indifferent and hence, the IC_1 is satisfied.

If the self-0 sophisticated type accepts $t(\underline{\theta})$, then it is induced to consume in the good state only and it obtains $V_0(\underline{\theta},\underline{\theta}) = p(\phi_g - t_1(\underline{\theta},1)) - \psi - t_0(\underline{\theta}) = 0$. If it accepts $t(1)$, it does not consume and obtains $V_0(1,\underline{\theta}) = 0$ because $t_1(1,1) > \phi_g\underline{\theta} - \psi$. The self-0 utilities from both contracts are the same, meaning that the self-0 sophisticated type is indifferent and so, the $\text{IC}_{\underline{\theta}}$ is satisfied.

Consequently, PC and IC constraints are satisfied. Note that the self-0 naïve type behaves as the time-consistent type by accepting $t(1)$, but does not consume at date 1. The principal's expected profit is $E(\pi)^1 = \nu_1 p(\phi_g - \psi - c) + \nu_2(p(\phi_g - c) - \psi)$. Since the principal extracts full rent from the sophisticated and time-consistent types, the expected profit cannot be increased. The expected profit could be increased if it was possible to reduce two inefficiencies, which are that the sophisticated type saves at date 0 and the naïve type does not consume. The only way of avoiding the sophisticated type not to save at date 0 is by inducing it to accept a PAD contract or by simply offering a single PAD contract to all types as analysed in Proposition 2.1. We rule out this case as we are analysing the case where the principal offers a menu of contracts.

(ii) Now we add the naïve type's consumption constraint to the problem in (2.3). In order to induce positive consumption, the principal needs to set: $\phi_b < t_1(\underline{\theta},1) \leq \phi_g\underline{\theta}$ and $t_1(1,1) = \phi_g\underline{\theta} - \psi$. If the self-0 sophisticated type accepts $t(\underline{\theta})$, then $V_0(\underline{\theta},\underline{\theta}) = p\phi_g - \psi - t_0(\underline{\theta}) - pt_1(\underline{\theta},1)$. If it accepts $t(1)$, then $V_0(1,\underline{\theta}) = p(\phi_g - \psi - t_1(1,1)) = p\phi_g(1-\underline{\theta})$. Using $\text{IC}_{\underline{\theta}}$, $V_0(\underline{\theta},\underline{\theta}) \geq V_0(1,\underline{\theta}) \Leftrightarrow pt_1(\underline{\theta},1) + t_0(\underline{\theta}) \leq p\phi_g\underline{\theta} - \psi$. To extract maximum rent, the principal sets $pt_1(\underline{\theta}, 1) + t_0(\underline{\theta}) = p\phi_g\underline{\theta} - \psi$. Under $t(1)$ and $t(\underline{\theta})$, $V_0(\underline{\theta}, \underline{\theta}) \geq V_0(1, \underline{\theta}) \Leftrightarrow -(1-p)\psi \leq 0$, and hence, the IC$_{\underline{\theta}}$ is satisfied. The time-consistent and the naïve types accept $t(1)$ as it involves a savings effort cost with probability p, obtaining $V_0(1, 1) = p\phi_g(1 - \underline{\theta})$. Hence, all types enjoy the same positive rent at date 0. The principal's expected profit is $E(\pi)^2 = p(\phi_g\underline{\theta} - \psi - c) - (1-p)\nu_2\psi$.

Finally, $E(\pi)^2 \geq E(\pi)^1 \Leftrightarrow p(\phi_g\underline{\theta} - \psi - c) - (1-p)\nu_2\psi \geq \nu_1 p(\phi_g - \psi - c) + \nu_2(p(\phi_g - c) - \psi)$ which holds when $\phi_g \geq \frac{(1-\nu_1-\nu_2)}{(\underline{\theta}-\nu_1-\nu_2)}(\psi + c)$. □

Proposition 2.3 shows that if we do not impose the additional naïve type's consumption constraint, the principal can offer a menu of contracts composed of a PIA and a PAD contracts while extracting all rents from the sophisticated and the time-consistent types. Once the naïve type's consumption constraint is added to the maximisation problem, the self-0 naïve type behaves as the time-consistent type and hence, the principal needs to lower $t_1(1, 1)$ enough to induce the naïve type to consume. In addition, if we were to impose a binding PC$_{\underline{\theta}}$, then IC$_{\underline{\theta}}$ would not be satisfied and the sophisticated type would be better off with a PAD contract. The principal also needs to decrease the sum of payments $pt(\underline{\theta}, 1) + t_0(\underline{\theta})$ in order to satisfy IC$_{\underline{\theta}}$. Therefore, all types enjoy a positive rent from date 0 perspective. Hence, there is a trade-off between increasing efficiency and decreasing information rent. This is similar to the trade-off in standard contract theory. However, in our model this trade-off occurs partially at date 0 preferences and partially at date 1 preferences. The self-0 utilities of all types of agent are the same, but the self-1 utilities differ. In particular, the self-1 time-consistent type's utility is $\phi_g(1-\underline{\theta}) > 0$ if the good state realises and zero otherwise, whereas the self-1 naïve type's utility is zero in both states and the self-1 sophisticated type's utility will depend on the payments, but it is smaller than the self-1 time-consistent type's utility. Further, the self-1 time-consistent type's utility is zero in both states if the principal offers a menu of contracts where the naïve type does not consume.

Proposition 2.3 also compares the expected profits of both cases. If the probability of the naïve type is high enough, then it is profit-maximising to the principal to decrease the payments even if that implies a positive rent. The closer $\underline{\theta}$ is to one, the more likely is for the condition $\phi_g \geq \frac{(1-\nu_1-\nu_2)}{(\underline{\theta}-\nu_1-\nu_2)}(\psi + c)$ to hold. That is, the lower the degree of time inconsistency, the better is for the principal to offer a menu of contracts that induces positive consumption to all types. This is because the lower the degree of time inconsistency, the greater $t_1(1,1)$ and the lower the information rent. Further, the principal gains from the naïve type's positive consumption.

Given that we are interested in the outcome where the agent consumes in the good state, it is natural to ask under what condition will a single PIA contract generate greater (or lower) expected profit than a menu of contracts that induces all types to consume. Proposition 2.4 compares the expected profit obtained when offering a single PIA contract (i.e. $E(\pi)^{PIA} = p(\phi_g - c) - \psi$) with the expected profit obtained when offering a menu of contracts (i.e. $E(\pi)^2 = p(\phi_g\underline{\theta} - \psi - c) - (1-p)\nu_2\psi$).

Proposition 2.4. *When $\phi_g \geq \frac{(1-p)(1-\nu_2)}{p(1-\underline{\theta})}\psi$, it is profit-maximising for the principal to offer a single PIA contract instead of a menu of contracts that imposes positive consumption to all types.*

A single PIA contract involves a welfare loss since the time-consistent and the naïve types have to incur savings effort cost with probability one. Whilst the menu of contracts does not involve the same welfare loss for the time-consistent and the naïve types, it requires a positive rent. The closer ν_2 is to one (i.e. the greater the probability of the sophisticated type) and the closer $\underline{\theta}$ is to zero, the more likely is for the condition $\phi_g \geq \frac{(1-p)(1-\nu_2)}{p(1-\underline{\theta})}\psi$ to hold. This is because the greater the degree of time inconsistency, the lower $t_1(1,1)$ in the menu of contracts and consequently, the lower the respective expected profit. Further, a single PIA contract becomes more relevant the greater the probability of the sophisticated type.

In addition, if the probability of the naïve type is zero, the principal could offer a menu of contracts without giving a positive rent, as shown in Proposition 2.3. Thus, the presence of the naïve type has implications on the optimal contract. We analyse this in more detail in the next section.

2.5 Discussion

In this section, we analyse the impact of naiveté on the optimal contract, principal's expected profit, consumption and savings decisions and agent's consumer surplus. In particular, we compare the results above with the same model but without the naïve type or more precisely where the naïve type is now a fully sophisticated type. Furthermore, we have our attention to those contracts that induce positive consumption in the good state.

2.5.1 Model without the naïve type

Assume that the agent is time-consistent or sophisticated with respective probabilities, $\nu_1' = \nu_1$ and $\nu_2' = \nu_2 + \nu_3$, with $\nu_1' + \nu_2' = 1$ and where $\nu_3 = 1 - \nu_1 - \nu_2$. That is, we have transformed the naïve type into a sophisticated type. If the principal offers a menu of contracts, the payments will be the same as in case 1 in Proposition 2.3, i.e. $t_1(1,1) = \phi_g - \psi$ and $pt_1(\underline{\theta}, 1) + t_1(\underline{\theta}) = p\phi_g - \psi$ with $t_0 > 0$ and $\phi_b < t_1(\underline{\theta}, 1) \leq \phi_g\underline{\theta}$ such that the sophisticated type accepts a PIA contract and the time-consistent type accepts a PAD contract. In this case, the principal's expected profit is $\nu_1' p(\phi_g - \psi - c) + \nu_2'(p(\phi_g - c) - \psi)$. If the principal offers a single PIA contract, then the payments and the expected profit will be as in Proposition 2.1, which is smaller than the expected profit obtained under a menu of contracts.

The principal can also offer a single PAD contract as before. Under such a contract, the payments and the expected profit will be as in Proposition 2.1. For $\phi_g \geq \frac{(1-p)(1-\nu_1')}{p(1-\underline{\theta})}\psi$, it is profit-maximising for the principal to offer a menu of contracts instead of a PAD contract. Hence, if the degree of time inconsistency is severe it is better for the principal to offer a menu of contracts. As before, we are most interested in the case where the difference between time-consistent and time-inconsistent types is significant and so, we are interested in comparing the case without the naïve type when the principal offers a menu of contracts with the case with the naïve type and where the principal might offer a single PIA contract or a menu of contracts.

2.5.2 Impact of naiveté on the principal's expected profit

We first analyse the impact of the naïve type on the principal's expected profits. If the principal offers a single PIA contract, the expected profit is $p(\phi_g - c) - \psi$, which is smaller than the expected profit without the naïve type. On the other hand, if the principal offers a menu of contracts, then, for $\phi_g \geq \frac{(1-p)(1-\nu_1-\nu_2)}{p(1-\underline{\theta})}\psi$, the expected profit obtained without the naïve type is greater. However, as shown in Proposition 2.4, when $\phi_g \geq \frac{(1-p)(1-\nu_2)}{p(1-\underline{\theta})}\psi$ it is profit-maximising for the principal to offer a single PIA contract instead of a menu of contracts. Given that the expected profit without the naïve type is greater than with the naïve type when offering a single PIA contract, the principal will be better off without the naïve type.

This finding raises an interesting point that we have not explored so far which is the source of consumer beliefs and whether it is possible for consumers to learn about their preferences from their own behaviour or from the firm. In our model, beliefs about the type are exogenous and hence, our model cannot easily accommodate learning. Nevertheless, our model shows that the principal may have incentives to educate the naïve type since it can increase expected profit if the naïve type behaves as the sophisticated type. This contrasts with a theoretical discussion in Spiegler (2011) about educating naïve consumers, focusing on the case where a firm does not have incentives to educate naïve consumers since it cannot generate increased profits. We note, however, that if the costs associated with educating the naïve type about his degree of time inconsistency are greater than the incremental profit, then the principal no longer has incentives to educate the naïve type into a sophisticated type. Nevertheless, exploring how the principal can increase the naïve type's awareness is outside of scope of this paper.[4]

2.5.3 Impact of naiveté on the agent's utility

We are now interested in the agent's utility and consumption and saving decisions. In terms of consumption, there is no impact of the naïve type on the remaining types because those types are always induced to consume in the good state. There is, however, a potential impact on the saving decision of the time-consistent type. If the principal offers a single PIA contract, then the time-consistent type needs to save in both states, which leads to a welfare loss. Whereas in a model without the naïve type, the principal offers a menu of contracts which allows the time-consistent type to save only in the good state.

Although there might not be an impact of the naïve type on the remaining types in terms of consumption and saving decisions, there might be an effect on the consumer surplus. In order to compare the consumer surplus of the non-naïve types with and without

[4]We note, however, that empirical literature has shown that feedbacks/reminders can be effective in increasing awareness in self-control (see e.g. Cadena et al. 2011, Karlan et al. 2016 and Kast et al. 2012). Further, the ability of firms collecting data about consumers' tastes and preferences, in particular information over past consumption and levels of satisfaction, is increasing in different markets. The access to more detailed information could allow a firm to send individualised feedbacks/reminders to those consumers closely related to a naïve type.

the naïve type, we need to decide which self to favour. Welfare judgements are conceptually problematic when agents have time-inconsistent preferences because there are two selves and it is not trivial which self to use. O'Donoghue and Rabin (1999) favours the long-run self, which in our case corresponds to the self-0 agent. The same is followed by DellaVigna and Malmendier (2004) and Galperti (2015). Although there is an open debate regarding welfare measures in non-standard models of choice, we follow the literature and analyse the agent's welfare from the perspective of self-0.

When the principal offers a single PIA contract, all types obtain $V_0 = 0$. The same does not apply if the principal offers a menu of contracts. In this case, all self-0 types obtain utility $p\phi_g(1 - \underline{\theta}) > 0$. Hence, all self-0 types are better off with a menu of contracts than with a single PIA contract. Furthermore, in a model without the naïve type, the principal extracts full rent from the self-0 sophisticated and time-consistent types via a menu of contracts. Therefore, both self-0 types are better off under the presence of the naïve type if it is profit-maximising for the principal to offer a menu of contracts.

2.6 Conclusion

In this paper, we have analysed the contract design of a profit-maximising principal that sells a good to an agent that can be time-consistent, sophisticated or naïve type. The self-0 naïve type behaves as the time-consistent type, but his self-1 values consumption less. The principal needs to decrease the payments sufficiently to attract the naïve type to consume. We focus our attention on specific contract forms, a pay-in-advance (PIA) and a pay-after-delivery (PAD) contracts. We conclude that a single PIA contract can induce positive consumption in the good state while extracting full information rent. However, it imposes a welfare loss given that all types of agent need to incur a savings effort cost even if the bad state realises. We compare this contract to a menu of contracts that also induces positive consumption to all types, however it requires an information rent that it increases with the severity of the degree of time inconsistency.

Finally, we analyse the impact of the naïve type on the expected profit and the remaining types' utilities. We show that the principal may have incentives to educate the naïve type since he can increase the expected profit if the naïve type is aware of his degree of time inconsistency. The reason behind this result is that in order to induce the naïve type to consume, the principal needs to decrease the payments sufficiently, which in turn leads to a positive information rent.

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Chapter 3

Addressing self-disconnection among prepayment energy consumers: A behavioural approach[1]

3.1 Introduction

Research in economics and psychology suggests that most choices involve intertemporal trade-offs between immediate and delayed costs or benefits (Frederick et al. 2002). In order to evaluate such trade-offs, decision makers compare the costs and the benefits that occur at different times. However, people can be impatient in the sense that they like to enjoy immediate rewards and to defer costs (O'Donoghue and Rabin 1999). Strotz (1956) was the first to model impatience for near-term trade-offs rather than for future ones, modelling it as a commitment device. He showed that under exponential discounting preferences are time consistent, but under non-exponential discounting agents may prefer to constrain their own choices.

Self-control plays an important role in explaining inconsistencies for the future over time and across activities (Lowenstein 2000). People with high levels of self-control are

[1]This is joint work with Michelle Baddeley and Michael Pollitt.

able to stay on diets, exercise regularly and to lead their lives within their means, whereas those that lack self-control end up not achieving their aims (Laibson 1997). In order to constrain future choices and to obtain a desired outcome, people impose commitment devices that facilitate the achievement of goals (Brocas et al. 2004; Bryan et al. 2010). It has been shown that commitment devices are effective in improving performance in school (Ariely and Wertenbroch 2002), in saving money (Ashraf et al. 2006; Benartzi and Thaler 2004), in the context of addictions (Bernheim and Rangel 2004), etc.

Prepayment metering is an interesting case to study intertemporal trade-offs. Prepayment is a payment method where the payment is made before the actual consumption; that is, consumers have to pay for electricity and/or gas (immediate costs) before they consume it (delayed benefits). Moreover, consumers must plan in advance their future consumption. This planning, or lack of it, may lead to self-disconnection, which happens when consumers exhaust all available credit in their meter and are left without supply of energy for a certain period. Self-disconnection has serious consequences for the well-being of consumers, such as lack of heating; impacts on food preparation; leisure and psychological impacts, e.g. shame or loss of self-esteem (Consumer Focus 2010). Likewise, self-disconnection generates costs for the energy suppliers since it may contribute to lower energy consumption, higher debt levels and higher costs related to reconnection of energy supply.

The aim of this paper is to propose a mechanism that minimises the number of self-disconnections through commitment and awareness. This paper has implications not only for the more efficient use of prepayment in energy, but has also implications for poverty. In fact, self-disconnection is especially pronounced among low-income households and has been linked to fuel poverty (Brutscher 2012b; O'Sullivan 2013). Fuel poverty is usually defined as the inability to keep an adequate level of warmth on 10% of household income and has been regarded as a likely contributor to increased winter mortality rates

(O'Sullivan et al. 2013). If we find a mechanism that minimises the number of self-disconnections, then we can contribute to a better energy comfort for those households who fall in the category of fuel poor, reducing the negative consequences of fuel poverty.

First, we design a mechanism that induces higher rates of savings committed to energy consumption and that decreases the likelihood of consumers to self-disconnect. Consumers differ in their degree of self-control and in their willingness to accept a commitment device. The energy supply firm does not know the different degrees of self-control amongst consumers and so needs to target consumers effectively. The mechanism is composed of a commitment contract and an energy consumption reminder in order to account for the heterogeneity of consumers and their private information. We propose a commitment contract for consumers who lack self-control but their awareness makes them sophisticated enough to engage in such a contract, and a feedback/reminder to those consumers who are not aware of their lack of self-control. Second, we empirically examine the determinants of self-disconnection and the choice of different commitment contracts using data from a representative survey that we have designed for this purpose. The survey was applied to a subset of British Gas consumers who use a gas prepayment meter. British Gas is one of the largest retailers in the UK, providing service to approximately 15.9 million energy households.

We find that self-control problems play a role in self-disconnection. We are able to identify those consumers who would benefit from a commitment contract. Moreover, we show that there is a demand for commitment and saving opportunities among consumers. These findings demonstrate that there is a scope to introduce a commitment contract. The prepayment meter can be used as a flexible self-commitment device and in fact a significant share of consumers use the prepayment meter as a device to control energy expenses. However, prepayment meters alone cannot prevent self-disconnection completely. This emphasises the need for a commitment contract that increases the control over energy expenses. Overall, we show that there is an interest over the different commitment saving contracts, and that a significant share of consumers would prefer to smooth their energy expenditures if a commitment contract enabled them to do so.

3.2 Background on prepayment energy

Prepayment consumers insert credit into their meters by the use of a key or card that is then used or spent when electricity or gas is consumed in the home. This allows the consumer to decide the amount of energy to be consumed beforehand, as happens commonly with mobile phone services.

Prepayment meters (PPMs) emerged as a mean of offering indebted domestic consumers the ability to pay their energy bills. Countries such as UK, South Africa, Mozambique, Canada, Australia, among others, offer this type of payment in the "energy sector". In Great Britain, the number of PPM customers increased, by 2012, to around 4.2 million household electricity customer accounts (15.5% of the total) and 3 million household gas customer accounts (13.3% of the total) (Ofgem 2015).[2]

One important feature of PPMs is that, when the credit is exhausted, the supply of energy can be interrupted. In a stricter definition, self-disconnection happens when the consumer has exhausted all the available credit, including the emergency credit. The emergency credit is a fixed value (usually £5 in UK) of gas or electricity that is made available, at no extra cost, when consumers run out of credit and was created to overcome self-disconnection. However, other alternatives are also offered. One example is friendly credit - certain periods over the day in which suppliers do not disconnect whatever the

[2] The number of PPMs continued to increase in 2014. There were 4.5 million electricity PPM customer accounts and around 3.4 million gas customer accounts in 2014. (Ofgem 2015).

consumer's usage or credit status. These options give more time for consumers to top up their card.

Different reasons have been given in order to explain self-rationing and self-disconnection: inconvenience/transport costs, forgetting to top up, financial constraints or coordination issues (Brutscher 2012b; O'Sullivan et al. 2013; Consumer Focus 2010). In situations in which the reasons are a lack of opportunity to go to an outlet; forgetting to top up; or coordination issues within the household - options like emergency credit or friendly credit are good solutions. Conversely, if we consider financial constraints, identified by Brutscher (2012b) as the main driver of self-disconnection, such solutions may just postpone the problem rather than fix it. On the one hand, it can provide more credit flexibility by providing additional help for those who do not have money available, but on the other hand, it does not help consumers with more severe problems and/or who lack self-control.

Self-disconnection implies that households opt to have discrete jumps in energy consumption rather than smoothing consumption throughout the year. Brutscher (2012b) analyses this puzzle and argues that a possible explanation is preference reversals (usually associated with self-control problems) that end up affecting consumers' ability to save. In the UK, self-disconnection happens mostly during the autumn/winter for gas consumption since energy expenditure tends to be greater than in the spring/summer due to heating. During the winter, consumers might realise that they need to save in order to avoid self-disconnection, but as soon as the summer arrives they have a different set of preferences. Those households who exhibit impatience during the summer can fail to have the sufficient liquidity to purchase enough credit during the winter, which affects their tendency to self-disconnect.

Building on Brutscher's (2012b) findings, we propose a mechanism composed of a commitment contract and a reminder to induce higher rates of savings and consequently, decrease the likelihood of self-disconnection.

3.3 A mechanism to minimise self-disconnection

We start by analysing the type of consumers that we need to target in order to reduce self-disconnections. In the literature on self-control, there is a major distinction between sophisticated and naïve agents. Sophisticated agents are aware of their lack of future self-control whereas naïve agents are unaware (O'Donoghue and Rabin 1999, 2001)[3]. Agents unaware of their self-control problems will repeatedly procrastinate believing that they will act tomorrow. This heterogeneity among agents, in our case consumers, complicates the incentive design since optimal incentives differ for different types of agents. Sophisticated consumers will easily accept an energy commitment contract. Naïve consumers are less likely to accept an energy commitment contract since they have incorrect perceptions about future behaviour. As Brutscher (2012a) points out household energy, like all household expenditure, may involve complicated family dynamics where the presence of a commitment device may allow a sophisticated agent within the family to prevent a naïve agent from acting inconsistently with family resources, e.g. a husband/wife spending money on summer time other than allowing the wife/husband to save for winter fuel. A firm serving a mixed group of consumers does not usually know the degree of self-control of the individual consumers and so, it needs to offer a different type of incentive for the naïve. In order to induce these consumers to accept a commitment contract or at least to increase their level of awareness, we propose an energy consumption reminder.

Overall, the consumers that we wish to target (1) are more likely to have self-control issues as opposed to consumers that do not act inconsistently; (2) can afford the spare cash required in order to increase their savings; and (3) have higher personal self-disconnection

[3] O'Donoghue and Rabin (1999, 2001) and Laibson (1997) analyse the existence of cognitive behavioural issues that lead for a need of a commitment device through a (quasi)-hyperbolic model. Other important works are based on temptation (Gul and Pesendorfer 2001), dual-self (Fudenberg and Levine 2006) and limited attention (Karlan et al. 2016).

or self-rationing costs than benefits, i.e. they, together with the firm, should benefit from minimising self-disconnection.

3.3.1 Commitment contract

The ideal commitment contract to offer to energy consumers would be one that provides maximal consumption smoothing. However, there are challenges when developing a contract that involves a commitment product.

First, one needs to consider the trade-off between commitment and flexibility. As pointed out in Ashraf et al. (2003), individuals demand highly liquid saving devices, but they also need a certain degree of commitment. Thus, there is a trade-off between flexibility and commitment that will vary according to the customer's self-control.

Second, we need to consider whether there is a concern about exploitation of consumers. From a consumer perspective, if a household accepts the commitment contract offered by a firm, then it is because it will benefit from it, otherwise it would not accept it. Interestingly, in the present case, a commitment contract, if successful, can decrease costs associated with self-disconnection for the consumers (in terms of energy discomfort) and the firm (in terms of the costs of dealing with disconnection/debt collection).[4]

Based on these concerns, we propose four types of commitment contracts that can work in the context of prepayment energy. As in Beshears et al. (2013), we consider different contracts with different degrees of flexibility and saving targets (see Table 3.1). The essence of these contracts is straightforward: households commit to allocate a portion of each top-up into savings to use in future energy expenditure. In the contracts'

[4]This is opposed to the literature on the exploitation of self-control problems of consumers by a firm. In this literature, a firm can extract rents from the consumers due to its cognitive issues, and consumer surplus is scaled down (see for example Eliaz and Spiegler, 2006). The intuition is that the agent who accepts an exploitative contract expects that he will extract rents from the principal and the principal expects the reverse. Naïve agents accept the exploitative contract and end up consuming more than they initially wanted. This is opposed to our case because initially the sophisticated and naïve want to consume more energy during the winter period than they actually end up consuming if no commitment contract is offered.

design, we have assumed two periods: period 0 corresponds to the spring/summer where the commitment is made, and period 1 corresponds to the autumn/winter where self-disconnection is reduced. The contracts here proposed are the following ones.

Regular payments throughout year. Based on a summary of the previous year's consumption, the customer agrees to an equal weekly/monthly amount and commits to a payment schedule through the year. This contract implies a significant loss of flexibility.

Voluntary savings target. The customer chooses a target amount that they feel comfortable/confident about saving. The customer is responsible for meeting this target and it is up to them whether it is achieved each month. The credit saved can be used to offset winter consumption. The customer is free to choose how much to save in each week, but postponing savings is allowed.

Ad-hoc extra payments. The customer makes additional payments as and when they can afford to do so. The customer would not have to nominate a target for savings, but the more that is saved the more winter consumption would be offset. This is the plan that offers the most flexibility of all commitment contracts, although it is not a real commitment, only an awareness device.

Summer fixed extra payments. The customer commits to additional fixed payments just during summer months. These additional payments could be calculated on the basis of wintertime gas consumption in the previous year, not necessarily equal payments throughout the year. The extra payments would be used to cover higher gas payments in the wintertime.

Table 3.1 shows the main differences in terms of flexibility and saving target for the four types of commitment contract. Flexibility is either low or medium because in all contracts, the consumer has to insert extra credit in the meter that can only be used for gas or electricity expenses. This is in contrast with the energy consumption reminder that, as we will discuss in the next section, has a high degree of flexibility and no-predefined saving target.

TABLE 3.1: Main features of the commitment contracts

	Regular payments throughout year	Voluntary savings target	Ad-hoc extra payments	Summer fixed extra payments
Flexibility	Low	Medium	Medium	Low
Saving target	Yes (set by the firm)	Yes (set by the consumer)	No	Yes (set by the consumer)

In order to avoid attrition, the following restriction could be imposed: "Savings can only be consumed in the following period". This can be done, if feasible in both technical and regulatory terms, through a second card used to insert and lock the savings or via an online "commitment store", e.g. stickK.com.[5] If consumers need to withdraw their savings, then they need to contact the firm. By creating more transaction costs, consumers have the incentives to break the commitment only for reasons such as unexpected shocks as opposed to procrastination or impulse/temptation.

It could be that fixing/locking an amount of credit in the prepayment card is not possible for technical reasons or simply not allowed by the authorities. In this case, one can minimise the number of withdrawals before time through a reward/incentive. In some of the proposed contracts, a minimum saving requirement is explicitly assumed. In order to emphasize the importance of such a requirement, a reward to save can be introduced. In the beginning of period 0, the consumer chooses a "fixed" goal amount of savings to accumulate during period 0. If, at the beginning of period 1, the goal has been reached, then the reward is given. We can also impose, if necessary, a further requirement: no

[5]stickK.com is a website that provides commitment contracts to the general public. The idea is that people choose a goal/target for changing an aspect of their behaviour (e.g. stop smoking), make a public commitment to change, and in some cases put up a financial stake that they are prepared to lose if they fail. Other websites of this type are fatbet.net and www.dietbetter.com.

self-disconnection. This can be achieved through the use of a reward that is offered to the customer if they do not self-disconnect during the winter.

Note that these rewards should not be very high/attractive for three reasons. First, consumers may just accept because the effective price of energy has been changed, rather than because of a "behavioural" change. Second, we want to ensure that those consumers whose costs (in terms of energy discomfort) are higher than the benefits of self-disconnection (in terms of extra money saved from not consuming energy during a certain period) are targeted to receive the commitment contract. Third, the reward implies costs to the firm that should not be exceeded by the benefits associated with the lower number of self-disconnections, otherwise the firm will not have an incentive to offer a commitment contract.

A further concern that may arise regards competition issues and lock-in effects (i.e. when the firm makes it extremely hard for the consumers to leave them). Given that the consumers are free to choose their type of contract, if the firm continues offering the conventional prepayment method (among others), then the consumers are always free to switch type of contract, besides being able to switch firm.

3.3.2 Reminder/Feedback on consumption

We suggest a reminder or feedback in order to attract consumers who do not accept a commitment contract due to their poor self-control. The idea is that the energy supply firm would increase consumers' awareness regarding the need to top up regularly.

So far, we have assumed that self-disconnection is associated with an incomplete task, where this task is the accumulation of savings for future energy expenditure. A commitment device is used to increase the chances of successfully completing the task. However, perhaps the problem is that, in certain periods, consumers forget that their energy expenditure in the winter is greater than in the summer, which, leads to over consumption or under saving. Then, when winter arrives, the consumer faces the second-best option of reducing energy consumption. It may also be that consumers do not recognize their future expenditure because they do not value heating as much as their future self does and so, they assume that energy expenditure will be roughly the same. Consequently, a further explanation for self-disconnection is that consumers may suffer from limited attention/memory.

A reminder can be effective because time inconsistency, under this argument, is derived from a failure to forecast future expenditure leading to less consumption smoothing than would occur under perfect foresight (Karlan et al. 2016). A reminder/feedback implies voluntary and selective attention from the consumer given that they want to save for future energy consumption.

In the prepayment energy context, a reminder on consumption could be as follows: "Last year you spent £20 on gas between July and September and you spent £120 on gas between October and December". The reminder/feedback can be extended by introducing a saving cue, e.g. "By saving extra £50 during the summer time, you can smooth your gas expenses throughout the year". The reminder could be sent by e-mail or mobile SMS during period 0. Interestingly, if the consumer does not wish to consume more energy during the winter, then self-rationing is not driven by reasons of dynamic inconsistency or by limited attention issues. The consumers who choose rationally to self-ration are those that we do not need to target since their benefits from self-rationing and self-disconnecting are greater than their costs. We want to target those consumers whose costs exceed benefits because they are the ones who will benefit from a commitment contract.

3.4 Data

The data source used for examining the mechanism is from a survey developed in collaboration with British Gas (BG) designed specifically for prepayment gas consumers. The survey was available online between January and February 2013 and was sent via email to 20,000 consumers (11% of surveys were undelivered). Surveys with a significant small number of responses were dropped from the database. In total, we obtained 1541 usable responses, however in certain questions we had a lower number of observations for estimation purposes.

The survey, designed to be representative of the prepayment consumers and fielded accordingly, included a series of detailed questions about the respondent's saving plan choice and demographics (age, gender, education, household size and income). A wide range of revealed preference questions to assess self-disconnection, saving behaviour, topping-up behaviour, opinions about the prepayment meter,[6] and questions to measure self-control were also included. For a summary of the main variables employed in the paper see appendix, Table A1.

Regarding the questions on the preferences about the saving plan, we did not ask open-ended questions (e.g. "Do you want to make more spread and similar payments throughout the year?"). Instead, we gave a specific text for each of the saving plans, similar to the contracts' description in section 3.3.1 and asked the respondents which of the plans they would prefer (see Appendix for the questions related to the saving plan choice). This type of questions is usually referred to as stated preference questions. Revealed preference data does not exist for new products, which is the case for the saving plans that we propose in this paper. Thus, stated preference questions can be used to obtain hypothetical data and estimate the attractiveness of the saving plans. Precisely

[6]Although, we have asked questions to assess their opinions over prepayment meter, we did not use them for the empirical analysis.

because this type of questions involve hypothetical scenarios they also involve some limitations: (1) respondents may find some trade-offs difficult to evaluate because they are unfamiliar with the suggested saving plans; and (2) once the number of attributes increases, the complexity and the number of comparisons increase, which may lead to a loss of interest from the respondent. For these reasons we took great care in explaining the different plans in detail and focus on differences in attribute levels. The attribute levels (i.e. level of flexibility and saving target) for the commitment contracts are presented in Table 3.1. The reminder/feedback has the following attribute levels: high level of flexibility and no saving target. We included in the survey one extra alternative ("none of the options") that we use as our main reference choice, which is valid as a constant for all respondents given that they were all using the same payment method at the moment of the survey and acts as a status quo alternative. The absence of a status quo alternative would bias interest in saving options upwards.

Socio-Economic Variables. Table 3.2 compares the age and gender of the respondents of the survey with the group of consumers who have a contract with BG for the supply of gas through a prepayment meter. Our sample is representative with small differences in the number of consumers aged between 22 and 34 years old and between 45 and 54 years old.

TABLE 3.2: Survey sample: control variables

	Category	**Survey sample (%)**	**PPM Gas in BG (%)[a]**
Gender	Male	37.8	39.4
	Female	62.2	59.4
Age	21 and Under	0.2	2.2
	22 to 34	5.6	25.9
	35 to 44	20.7	24.4
	45 to 54	38.5	24.7
	55 to 64	25	13.8
	65 and Over	9.9	9.1

[a] This information was made available by BG and corresponds to the same period as our survey.

Table 3.3 shows the means and standard deviations (in parenthesis) of the socio-economic variables. The consumers in the sample are, on average, between 45 and 54 years old, with basic and medium levels of education (around 31% and 34% respectively) and lower and medium levels of household income (approximately 33% and 33% respectively). The household is composed, on average, of two adults and one child. All variables are categorical except for the members of adults and children in the household. Information about household income and education are captured by a group of dichotomous variables, where the reference variables for each group are low income and none and basic education. We now turn to a discussion of the main variables of interest.

TABLE 3.3: Descriptive statistics: demographic characteristics

Measures	Total		Male		Female	
Income levels						
Low income (up to £1000)	.414	(.493)	.405	(.491)	.419	(.494)
Medium income (£1001 to £2000)	.406	(.491)	.393	(.489)	.415	(.493)
High income (over £2000)	.166	(.373)	.187	(.391)	.153	(.361)
Education levels						
None	.133	(.340)	.158	(.365)	.119	(.323)
Basic (O-levels)	.346	(.476)	.280	(.449)	.386	(.487)
Medium (A-levels + Technical education)	.377	(.485)	.406	(.491)	.360	(.480)
Higher (Undergraduate + Postgraduate degrees)	.166	(.373)	.156	(.363)	.136	(.343)
#Adults in the household	2.19	(1.05)	2.14	(1.08)	2.21	(1.04)
#Children in the household	.924	(1.11)	.636	(.989)	1.07	(1.14)
Observations	1541		583		958	

Notes: Standard deviations in parenthesis. Monthly household income includes any benefits. Low income and none and basic education will be used as benchmark categorical variables.

Self-disconnection and Emergency Credit. Table 3.4 shows our measures of self-disconnection and emergency credit. At least 62% of the sample stated that had already used the emergency credit and around 37% had already self-disconnected at some point.

TABLE 3.4: Distribution of emergency credit and self-disconnection

Answer	**Freq.**	**Percent.**	**Cum.**
Emergency Credit (stated), redefined			
To what extent do you agree with the following statement: I rarely use the emergency credit.			
(0) Strongly agree, agree	550	38.38	38.38
(1) Strongly disagree, disagree, neither agree nor disagree	883	61.62	100
Total	1,433	100	
Self-disconnection (stated), redefined			
To what extent do you agree with the following statement: Sometimes the emergency credit runs out.			
(0) Strongly disagree, disagree	828	60.61	60.61
(1) Strongly agree, agree, neither agree nor disagree	538	36.77	100
Total	1,366	100	

Notes: The variables are redefined since the original ones are in a scale from "Strongly agree" to "Strongly disagree", including a "Don't know" option that was dropped in the redefined variables.

Inconvenience of Top-up. A possible explanation for a household using the emergency credit or self-disconnecting is that it is inconvenient to top-up, for example due to transaction costs. Every time consumers need to top-up, they have to go to an outlet or if the payment can be made through an online account, the consumers still need to have access to internet. Other reasons may include liquidity constraints or lack of income. In order to take into account this factor, we have asked the respondents to answer, on a scale from "strongly disagree" to "strongly agree" including a "don't know" option, the sentence *"Pay As You Go makes it easy to pay for my gas"*. From this, we constructed the binary variable *inconvenience of top up* that is zero if the customer had answered "strongly agree" or "agree" to the question or one otherwise. In all redefined variables throughout the analysis, the "don't know" option was dropped. Interestingly, the majority of the respondents have stated that a prepayment meter does make it easy to pay for gas (see Table A2 for a cross-tabulation with self-disconnection).

Topping Up Behaviour. The consumers were asked to state whether they top up more over the winter or roughly the same over the year. This is summarised in the variable *top up all year* that equals to one if consumer i tops up roughly the same all year around and zero if consumer i tops up much more over the winter. The majority of the consumers choose to top up according to their needs, and so their top-ups were more frequent over the winter. From the consumers who top up roughly the same all year round, only 29% had self-disconnected; whereas 40% of those who top up more during the winter had already self-disconnected (see Table A3 in the Appendix). Although consumers who self-impose a personal rule or internal commitment mechanism, such as topping up the same every week, are less exposed to self-disconnection, there are still consumers that top up regularly and self-disconnect. This suggests that current regular top-up behaviour is not sufficient in preventing self-disconnection for all type of consumers.

Saving Behaviour. Consumers may have not been using the meter as a commitment device via regular top-ups, but still saved for the increase in energy spending. One question asked, on a scale from “strongly disagree” to “strongly agree”, was *“When I’m using less gas in warmer months I like to add any spare cash to my savings”*. 24% of the consumers that answered this question, answered “strongly agree” or “agree” against 76% who answered “strongly disagree” or “disagree” or “neither agree nor disagree”. This is a redefined variable: *saving behaviour* equals one if the customer answered “strongly agree” or “agree” and zero otherwise. Moreover, the relationship between *saving behaviour* and *self-disconnection* is not statistically significant (see Table A4). This suggests that consumers use the accumulated savings during the summer for expenses other than energy.

Spare Cash. Self-disconnection is associated with poverty. Following Bryan et al. (2010), behavioural anomalies significantly affect consumers with less disposable income. At this point, a relevant question is: do low-income consumers who self-disconnect have the opportunity to accumulate savings during the summer? When answering the question *“I have spare cash in warmer months as I don’t have to spend so much on gas”*, 20% of the consumers who have answered “strongly agree” or “agree” are in the low-income category (see Table A5). Eight percent out of those 20% had already self-disconnected. Consequently, a proportion of low-income consumers affected by self-disconnection also had opportunities to use a commitment contract. Banerjee and Mullainathan (2010) argue that low-income people consume relatively more temptation goods. Temptation and self-control problems affect both the rich and the poor though they influence and/or matter more for the poor. Therefore, through the decrease of temptation and increase in self-control, one may induce greater savings.

Self-control. We constructed a measure to assess the level of goal achievement of the individuals as a proxy for self-control. Psychologists have considered the impact of conscientiousness on self-control and goal achievement can be seen as one facet of conscientious trait (see the literature on the Big Five personality traits, e.g. Costa and Widiger 1994). We decided to focus on goal achievement since it is the most relevant facet of conscientious trait in explaining self-control in the context of self-disconnection. Due to the limit number of questions in the survey, we have a single question to assess goal achievement and thus, our question does not assess completely goal achievement but rather focuses on goal task, planning and procrastination issues.

Which of the following statements best describe you? (Choose two responses at most)

a) I usually achieve my goals.

b) I usually avoid or delay a task that requires a lot of thinking.

c) I have difficulties in completing a task that requires organization.

d) I usually set-up weekly or monthly goals that I wish to achieve.

e) I don't usually achieve my goals.

In order to construct an index for "goal achievement" from this question, we delineated three different levels: *high, medium*, and *low goal achievement* (see Table A6 in the Appendix). Individuals who usually achieve their goals (answered point a) have a high level of goal achievement. In contrast, individuals who usually do not achieve their goals

(e) are seen as having a low level of goal achievement. The intermediate concept targets those individuals who have difficulties in achieving their goals (b, c and d). The majority of the respondents, 63%, answered one option only. However, respondents could select two options, and so we need to define a rule to divide the answers between the three subsets (high, medium and low). Those that have answered options (a) and (d) are considered as high because (d) is stronger in terms of goal achievement than (b) or (c), whereas those that have answered (a) and (b) or (a) and (c) are considered as medium. These answers represent so far 90% of the total answers for this question. The remaining answers that have included (e) are considered as low type. Overall, the majority of the respondents (around 60%) are considered as *high goal achievement* types against 10% of the sample that were considered as *low goal achievement* and 30% as *medium goal achievement*.

This index has a major limitation for firms and/or decision makers since information on attitudes, personality traits and/or behaviour is generally not available. In order to better understand how the information on *goal achievement* correlates with other easily observable variables, we conducted a correlation analysis (see Table 3.5).

TABLE 3.5: Correlations between variables characterising individual heterogeneity

	1	2	3	4	5	6	7	8	9	10	11	12
1. Household size	1											
2. Female	.12***	1										
3. Low income	-.29***	.01	1									
4. Medium income	.16***	.02	-.71***	1								
5. High income	.16***	-.04	-.38***	-.37***	1							
6. Basic education	.07*	.11***	.00	-.02	.03	1						
7. Medium education	-.06	-.05*	-.04	.07**	-.03	-.57***	1					
8. High education	.03	-.03	-.09***	.02	.09***	-.30***	-.32***	1				
9. Low goal achievement	-.06	-.04	.03	-.02	-.03	.02	-.01	-.06**	1			
10. Medium goal achievement	-.06	.12***	.06*	-.02	-.04	.04	-.03	-.01	-.22***	1		
11. High goal achievement	.09**	-.09***	-.07**	.03	.06*	-.05*	.04	.04	-.41***	-.80***	1	
12. Self-disconnection	.10***	.03	-.00	.02	-.03	.01	.03	-.02	.01	.12***	-.12***	1

Notes: ***, **, * stand for 1, 5, and 10 percent significant levels, respectively; GA stands for goal achievement.

Interestingly, education is related only to the extremes with the other variables. There is a negative correlation between *basic education* and *high goal achievement* and a negative correlation between *high education* and *low goal achievement*. Additionally, *high goal achievement* is significant negatively correlated with *low income* and *female*. The former result deserves special attention because those consumers that have *low goal achievement* levels and are *low-income* are precisely those consumers that can take advantage of a commitment contract. The latter correlation is more ambiguous since it might be explained either because female respondents in our sample have lower levels of goal achievement when compared to male respondents or because female reported goal achievement in a less confident manner. Nevertheless, the magnitude of correlation is quite small, around 9%.

Further, we find that *self-disconnection* is significant negatively correlated with a *high goal achievement*. This is relevant in light of the discussion above that self-disconnection is affected by cognitive biases. In fact, this finding seems to clearly identify those consumers who do not need a commitment contract or a reminder, thus our non-target group of consumers. We also find a positive and statistically significant relationship between *self-disconnection* and *medium goal achievement*. Given this positive correlation, it cannot be said that these consumers are truly consistent and one can say that there is a sign that these consumers lack self-control. But the question is, will these consumers accept a commitment contract? Are they sophisticated enough to be aware of their lack of self-control? We have introduced a question in the survey that we will use to inspect this point in the next section: *"To what extent do you agree with the following statement*, on a scale from strongly disagree to strongly agree: *I get worried about running out of credit"*. In fact, 52% of those that have answered "strongly agree" or "agree" in this question *and* have been considered as *medium goal achievement*, have already self-disconnected.

A further relevant question is: assuming that those respondents with *medium goal* *achievement* levels are a good proxy for those consumers that would accept a commitment contract, how could a firm identify them without the availability of information on self-control? Table A8 in the Appendix shows the mean characteristics of those respondents that were indexed as *medium goal achievement*. These respondents are more likely to be between 34 and 54 years old, to have low and medium levels of income, to have basic and medium education and top-up more during the winter. Table A7 and A9 show the mean characteristics of those respondents that were indexed as *low* and *high goal achievement*, respectively.

Saving Plans. Table 3.6 shows the distribution of the choices that consumers made with regard to the commitment contracts that were introduced in the previous section and the reminder. Interestingly, when asked to choose between the different commitment contracts, the reminder or none, 36% of the consumers have chosen the regular payments throughout the year, followed by almost 15% choosing the reminder option whereas the voluntary savings and the summer fixed payments received least interest.

TABLE 3.6: Distribution of the different plans

Preferred saving plan	Freq.	Percent	Cum.
Regular payments	457	36.44	36.44
Voluntary savings	106	8.45	44.9
Ad-hoc payments	131	10.45	55.34
Summer fixed payments	47	3.75	59.09
Reminder	187	14.91	74
None of the above	326	26	100
Total	1,254	100	

3.5 Estimation Strategy

First, our survey is designed to identify the type of consumers that would accept a commitment contract and/or a reminder. In order to increase consumer surplus, we need to target those consumers who actually need a commitment contract because, even though their costs of self-disconnection exceed the benefits, self-control issues constrain their ability to make a strictly rational choice predisposing them to relatively costly self-disconnection. For that purpose, we need to understand what are the determinants of self-disconnection. Second, we wish to know whether our proposed commitment contracts would be accepted by energy consumers and, if so, which contract they would prefer.

Testing for self-control problems in self-disconnection. It will be desirable to model stated emergency credit, ec_i, and stated self-disconnection, sd_i, at once in a seemingly unrelated regression set-up in which the dependent variables are generated by processes that are independent except for the correlated errors. Let us assume that stated emergency credit for individual i is identified by the latent variable ec_i^* and that sd_i^* is the latent variable measuring stated self-disconnection for individual i. The first model becomes:

$$ec_i^* = \boldsymbol{\gamma}_1 \boldsymbol{x}_{1i} + \boldsymbol{\gamma}_2 \boldsymbol{x}_{2i} + \mu_{1i}, \tag{3.1}$$

We observe ec_i:

$$ec_i = \begin{cases} 1 & \text{if } ec_i^* > 0 \\ 0 & \text{otherwise.} \end{cases}$$

The second model becomes:

$$sd_i^* = \boldsymbol{\alpha}_1 \boldsymbol{x}_{1i} + \boldsymbol{\alpha}_2 \boldsymbol{x}_{2i} + \alpha_3 GAl_i + \alpha_4 GAm_i + \mu_{2i}, \tag{3.2}$$

We observe sd_i:

$$sd_i = \begin{cases} 1 & \text{if } sd_i^* > 0 \\ 0 & \text{otherwise.} \end{cases}$$

where $\boldsymbol{x}_{1i}$ represents a vector of demographic and economic characteristics and $\boldsymbol{x}_{2i}$ represents a vector of variables that may help explaining self-disconnection. In the latter vector, we have included *top up all year, saving behaviour*, and *inconvenience of top up*. To measure self-control, we use our levels of goal achievement as dummy variables and use *high goal achievement* as a reference category in our estimations: $GAl_i = 1$ if *low goal achievement* and zero otherwise; $GAm_i = 1$ if *medium goal achievement* and zero otherwise; and $GAh_i = 1$ if *high goal achievement* and zero otherwise. The error structure can be described as follows:

$$\begin{pmatrix} \mu_{1i} \\ \mu_{2i} \end{pmatrix} \sim N \left\{ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right\},$$

where ρ captures the correlation in the error terms between *self-disconnection* and *emergency credit*.

Can we identify sophisticated and/or naïve consumers? A possible indication of this identification of types is to see whether consumers that have a low and/or medium levels of goal achievement are more likely to worry about running out of gas than the consumers with *high goal achievement*. A consumer can be worried about running out of credit for several reasons, but an interesting one is that they may already self-ration or even self-disconnect, *and* they are aware of their self-control issues. Thus, we expect that a sophisticated consumer is more likely to be worried about running out of gas, whereas the naïve is overconfident. We can use the dummy variable *worried*, that equals one if consumer i has "agreed" or "strongly agreed" with the statement *"I get worried about running out of credit"*, and zero otherwise. We use this dummy as a binary dependent variable in the following equation.

$$worried_i = \pi_0 + \boldsymbol{\pi}_1 \boldsymbol{x}_{1i} + \pi_2 GAl_i + \pi_3 GAm_i + \xi_i, \tag{3.3}$$

In order to test this hypothesis, we estimated a probit model where *worried* is the dependent variable; as explanatory variables we included a vector of demographic, including gender and economic variables and goal achievement. ξ_i is a stochastic disturbance.

Preferred Saving Plan. In the second step of our analysis, we show a theoretical framework for consumers choosing a certain commitment device. A consumer i is faced with a choice between the following alternatives or plans: (1) regular payments throughout year, (2) voluntary savings target, (3) ad-hoc extra payments, (4) summer fixed extra payments, (5) reminder, (6) none of the options.

Following the additive random utility model for multiple alternatives (see Cameron and Trivedi 2005), the individual utility associated with the jth choice can be represented as

$$U_{ij} = \boldsymbol{x}_i^{'} \boldsymbol{\beta}_j + \epsilon_{ij}, j = 1, ..., 6, \tag{3.4}$$

where U_{ij} represents the utility of consumer i of a plan j. ϵ_{ij} is the random component of utility that stands for the consumers unobserved characteristics. $\boldsymbol{\beta}_j$ is a vector of alternative-specific parameters.

Each consumer decision is based on choosing the plan that offers the highest utility level. A certain consumer i chooses plan j if the utility derived from it is higher than the utility that he had derived from choosing “none of the options” and from all other plans, $U_{ij} \geq U_{is}$, for all $j \neq s$. The choice s, “none of the options”, is used as the reference choice. Then, the probability for customer i to choose plan j is given by

$$\begin{aligned} \Pr(\mathrm{PP}_i = j) &= \Pr(U_{ij} \geq U_{is}, \forall j \neq s) \\ &= \Pr(\boldsymbol{x}_i^{'}\boldsymbol{\beta}_j + \epsilon_{ij} \geq \boldsymbol{x}_i^{'}\boldsymbol{\beta}_s + \epsilon_{is}, \forall j \neq s) \\ &= \Pr(\boldsymbol{x}_i^{'}\boldsymbol{\beta}_j - \boldsymbol{x}_i^{'}\boldsymbol{\beta}_s \geq \epsilon_{is} - \epsilon_{ij}, \forall j \neq s). \end{aligned} \tag{3.5}$$

We assume that the errors ϵ_{ij} are i.i.d. type-one extreme value, with density

$$f(\epsilon_{ij}) = \mathrm{e}^{-\epsilon_{ij}}\exp(-\mathrm{e}^{-\epsilon_{ij}}), j = 1, ..., 6.$$

This results in the multinomial logit $\Pr(\mathrm{PP}_i = j) = \frac{\mathrm{e}^{\boldsymbol{x}_i^{'}\boldsymbol{\beta}_j}}{\sum_{s=1}^{6}\mathrm{e}^{\boldsymbol{x}_i^{'}\boldsymbol{\beta}_s}}$. The model then takes the following form:

$$\Pr(\mathrm{PP}_i = j) = F(\beta_{0j} + \boldsymbol{\beta}_{1j}\boldsymbol{x}_{1i} + \boldsymbol{\beta}_{2j}\boldsymbol{x}_{2i} + \beta_{3j}sd_i + \beta_{4j}GAl_i + \beta_{5j}GAm_i + \epsilon_{ij}), \tag{3.6}$$

where PP_i represents a customer decision about plan j. As before, $\boldsymbol{x}_{1i}$ represents a vector of demographic and economic characteristics and $\boldsymbol{x}_{2i}$ includes *inconvenience of top up* and *saving behaviour*. This is estimated using a multinomial logit (MNL). By estimating equation (3.6) using a MNL model, we examine the direct impact of *self-disconnection, goal achievement, inconvenience of top up, saving behaviour* and individual socioeconomic characteristics on the probability of choosing between one of the commitment contracts, or the reminder against the reference category of not choosing any of the listed options.

The MNL has some limitations. The most criticised component of the MNL lies in its property known as independence of irrelevant alternatives (IIA). This property states that the ratio of the probabilities of choosing one alternative over another, with both alternatives having a non-zero probability of choice, is not affected by the presence or absence of any additional alternatives in the choice set (Louviere et al. 2000). This assumption is quite strong and in fact, it may not hold, for example when two or more alternatives are closer substitutes than the other alternatives. The Hausman test and the Small-Hsiao test are the standard procedures to test whether the IIA property in the MNL is violated.

3.6 Results

3.6.1 Self-disconnection and Emergency Credit

Estimation results for *emergency credit* and *self-disconnection* are obtained by estimating equations (3.1) and (3.2) through a seemingly unrelated bivariate probit model. Table 3.7 reports the average marginal effects and conditional probabilities. The two equations are statistically significantly correlated ($\rho = 0.258$). This result implies that the error terms of both equations are correlated and we gain a more efficient estimator by estimating the two equations jointly compared to estimating them separately.

Although income is significant in the emergency credit model, i.e. a lower income level increases the probability of using emergency credit; the same is not applied in the self-disconnection model. Education does not seem to affect the use of emergency credit or the tendency to self-disconnect. The *inconvenience of top-up* increases the predicted probability to self-disconnect by around 15%; whereas *top up all year* decreases the predicted probability of using the emergency credit and of self-disconnection by around 16%.[7] A regular top up seems to be effective in reducing self-disconnection, however, as discussed in the previous sections, it does not completely offset it. *Saving behaviour* (i.e.

[7] Notice that these are categorical variables and so, the marginal effects show how the probability of stated self-disconnection and stated emergency credit change as the categorical variable, e.g. inconvenience of top-up, changes from 0 to 1.

being more prone to save) affects significantly and negatively the use of emergency credit but is not significantly associated with self-disconnection. This emphasises the finding in the previous section that self-imposing a commitment mechanism such as saving during warmer months is not sufficient in minimising self-disconnection.

Result 1. *A self-commitment device such as saving during warmer months is not sufficient in minimising self-disconnection.*

We also find a significant relationship between *goal achievement* and *self-disconnection*. Note that we have used as a reference category the high level of goal achievement. Thus, moving from the high category to the medium one increases the predicted probability of *self-disconnection* by 10.6%. This emphasises our next result, that self-control, measured through *goal achievement*, plays a role in *self-disconnection*.

Result 2. *Self-control plays a role in self-disconnection.*

We control for self-control problems only in equation (3.2) since the use of emergency credit is not related to self-control issues. A household can use the emergency credit because it simply forgot to top up, or it may even be the case that the emergency credit is being used as a short small "loan" since it involves no interest payment, and hence its use is rational.

The last column reports the conditional predicted probability of *self-disconnection* given that *emergency credit* has been used. These effects are similar to the average marginal effects of *self-disconnection*, including the statistical significance of the variables. The reverse conditional probability does not make sense in our case because self-disconnection mostly happens once emergency credit runs out.

TABLE 3.7: Seemingly unrelated bivariate probit: emergency credit and self-disconnection

Seemingly unrelated bivariate probit	Average marginal effects Emergency Credit	Average marginal effects Self-disconnection	Conditional Probability $\Pr(sd = 1 \mid ec = 1)$
Age			
35 to 44	.055	-.092	-.104
	(.087)	(.085)	(.087)
45 to 54	.028	-.076	-.084
	(.084)	(.082)	(.083)
55 to 64	-.027	-.080	-.080
	(.088)	(.086)	(.090)
Over 65	-.093	-.166	-.161
	(.100)	(.102)	(.104)
Female	-.011	.008	.010
	(.037)	(.038)	(.040)
Education			
Medium	.049	.020	.014
	(.037)	(.038)	(.039)
Higher	.020	.006	.004
	(.050)	(.053)	(.055)
Income			
Medium	.112***	-.001	-.019
	(.037)	(.038)	(.039)
High	.059	-.028	-.004
	(.050)	(.051)	(.039)
Household adults	.029*	.025	.022
	(.017)	(.017)	(.018)
Saving behavior	-.124***	.010	.029
	(.039)	(.040)	(.042)
Top up all year	-.177***	-.162***	-.144**
	(.057)	(.062)	(.064)
Inconvenience of top up	.015	.147***	.152***
	(.037)	(.036)	(.037)
Goal Achievement			
Low		.098*	.102*
		(.057)	(.060)
Medium		.106***	.115***
		(.038)	(.039)
ρ	.258		
	(.057)		
LL	-996.23		
Wald χ^2(28)	87.95		
Prob $> \chi^2$	.000		
Observations	787		

Notes: Average marginal effects are reported. Standard errors calculated by the Delta method are in parenthesis. ***, **, * stand for 1, 5, and 10 percent significant levels, respectively. LL stands for log likelihood. Age under 22 and Age to 34, none and low education, low income and high goal achievement were used as reference categories.

Robustness Check. The model above relies greatly on the definition of the dependent variables. We tested the same model, seemingly unrelated bivariate probit, using a different definition of the dependent variables, *self-disconnection* and *emergency credit*, by dropping the “neither agree nor disagree” category. Table A10 reports the results. No sign and/or statistically significant changes happened in terms of *emergency credit*, only in terms of the magnitude of the coefficients. Regarding the *self-disconnection* model, the sign and significance of the main explanatory variables did not suffer change. The similarity between the models with the two different definitions suggests that our former definition is correct.

We also tested a seemingly unrelated bivariate ordered probit model. This estimation method also allows for correlation between the latent variables underlying the two dependent variables, even after controlling for observables. However, the latent variables are ordered in a scale from strongly disagree to strongly agree (“don’t know" answer is regarded as a missing value). Table A10 shows that the results remain significantly similar to the coefficients obtained through the seemingly unrelated bivariate probit model.

3.6.2 Worried

Table 3.8 shows the average marginal effects obtained through the probit estimation of equation (3.3). The low explanatory power (pseudo R^2) of the model suggests that factors other than those considered account for *worried.* This can also be explained by missing data. Therefore, a carefully analysis of the predicted probabilities should be considered.

Interestingly, *low goal achievement* increases the predicted probability of becoming worried about running out of credit. Moving from the high category to the low one increases the predicted probability of being *worried* by 22.7% in the first column model. This shows signs of awareness among those consumers who feel that they might run out of gas. Those consumers who know that they will not self-disconnect have no reason to be worried and so represent those consumers that we do not want to target with a commitment contract, or even a reminder. Nevertheless, this analysis is not sufficient to clearly identify sophisticated consumers and naïve consumers in our sample especially because naïve consumers tend to be overconfident and therefore, might have overstated their true level of goal achievement.

In the second column we add *top up all year* which leads to an improvement (i.e. the log-pseudo likelihood decreases around 4 points and the pseudo R^2 increases by 0.008 points). Trivially, a consumer that tops up throughout the year is less *worried* about running out of gas. *Low goal achievement* and *medium goal achievement* are still statistically significant in this model.

TABLE 3.8: Probit: self-control variables on worried

Average Marginal Effects, Probit	Dependent Variable: Worried	
Female	.101***	.105***
	(.097)	(.035)
Household adults	-.006	-.005
	(.045)	(.015)
Education		
Medium	-.018	-.011
	(.100)	(.035)
Higher	-.014	-.014
	(.136)	(.048)
Income		
Medium	-.038	-.041
	(.102)	(.035)
High	-.035	-.036
	(.135)	(.048)
Goal Achievement		
Low	.227***	.190***
	(.178)	(.038)
Medium	.077**	.073**
	(.104)	(.034)
Top up all year		-.161***
		(.056)
Constant[a]	.268**	.275
	(.251)	(.253)
Pseudo R^2	.036	.044
Observations	878	878
Log-pseudo likelihood	-517.78	-513.23
Prob > χ^2	.000	.000

Notes: Average marginal effects are reported. Robust standard errors are in parenthesis. ***, **, * stand for 1, 5, and 10 percent significant levels. Percent correctly predicted: 70.05. Age under 22 and Age to 34, none and low education, low income and high goal achievement were used as reference categories. [a]Coefficient estimates. Age categorical variables are here omitted.

3.6.3 Preferred Saving Plan

Though a significant percentage (around 36%) of consumers have chosen regular payments saving plan as their preferred option, as it is shown in Table 3.6, plenty of comments expressed some concern about the lack of flexibility. Thus, we will investigate deeper which type of customer chooses each plan.

Table 3.9 shows the estimation results for the choice of the preferred saving plan. All the saving plans are compared to the "none of the options" choice. We find that a higher age reduces the likelihood of choosing a saving plan (with the exception of the summer fixed payments plan, which is not statistically significant). Keeping all other variables at their means, the predicted probability of choosing a *regular payment* plan is 1.7% higher for those that had already self-disconnected and around 16% higher for those who find PPMs of not make it easier to pay. This contrasts with *ad-hoc payments* since having *self-disconnection* decreases the predicted probability of choosing *ad-hoc payments*.

For both plans *regular payment* and *reminder*, a higher income leads to a greater likelihood of choosing a saving plan instead of none. These results also suggest a relationship between self-disconnection and saving plans, which leads to the following result.

Result 3. *A household that stated that it had already self-disconnected has a higher probability of accepting a commitment device, especially for the contract with summer fixed payments.*

TABLE 3.9: Multinomial logit: preferred plan (base comparison: "None of the options")

Average Marginal Effects, Multinomial Logit	Regular payments	Voluntary savings	Ad-hoc payments	Summer fixed payments	Reminder
Age					
45 to 54	-.058	-.013	-.020	.038**	.008
	(.044)	(.025)	(.027)	(.014)	(.034)
55 to 64	-.073*	.004	-.051*	.006	.053
	(.050)	(.028)	(.032)	(.020)	(.036)
65 over	-.144**	-.068*	-.050*	.039	.093
	(.079)	(.053)	(.049)	(.019)	(.051)
Education					
Medium	-.053	.007	-.034*	.006	.030
	(.040)	(.022)	(.025)	(.010)	(.029)
Higher	-.092	-.018	-.011	.005	.087
	(.054)	(.033)	(.034)	(.014)	(.035)
Income					
Medium	.083**	-.048	-.015	.002	.045**
	(.040)	(.023)	(.024)	(.011)	(.029)
High	.094	-.014	-.079	.006	.020
	(.051)	(.028)	(.037)	(.013)	(.039)
Self-disconnection	.017*	.014	-.007	.019**	.026*
	(.037)	(.021)	(.024)	(.010)	(.027)
Inconvenience of top up	.164***	.004*	-.023	-.005	-.018
	(.038)	(.025)	(.026)	(.010)	(.029)
Saving Behaviour	.009	.004	-.004	.024**	-.039
	(.043)	(.025)	(.027)	(.010)	(.033)
Goal Achievement					
Low	-.073	-.021	.050	.023	.014
	(.063)	(.038)	(.033)	(.014)	(.045)
Medium	.008	.019	-.029	.005	.011
	(.040)	(.022)	(.027)	(.011)	(.029)
Constant[a]	.353	-.816***	-.184	-3.97***	-.984***
	(.291)	(.412)	(.372)	(.815)	(.376)
Pseudo R^2	.043				
Observations	811				
LL	-1222.8				
Prob > χ^2	.000				

Notes: Average marginal effects are reported. Standard errors calculated by the Delta method are in parentheses. ***, **, * stand for 1, 5, and 10 percent significant levels, respectively and the standard errors are in parenthesis. LL stands for log likelihood. "None of the options" is the base outcome. Age under 22, Age to 34 and Age to 44, none and low education, low income and high goal achievement were used as reference categories. [a]Coefficient estimates.

The Small-Hsiao test and the Hausman test of IIA assumption were computed and we cannot reject the null hypothesis of non-violation of IIA.

Overall, the above results demonstrate that there is scope to introduce a commitment contract. We show that an internal commitment/self-commitment device is not sufficient in eliminating self-disconnections. We find that a consumer/household who has already experienced self-disconnection has a greater probability of accepting a commitment contract. Although our multinomial logit model did not show a significant importance of our measure of self-control as a predictor of the different types of commitment contract and/or reminder, we find that self-control has a great importance in predicting self-disconnection.

3.7 Discussion

Both low-income households and households revealing that they have already suffered from self-disconnection deserve special attention. Tables 3.10 and 3.11 show the choices made by these two groups of households. For both groups, households prefer a regular payment throughout the year. Around 89 consumers who had self-disconnected preferred not to have a saving plan. One reason for this is that these consumers may be unaware of their self-control issues. In fact, 46% (35 out of 89) of the respondents that answered "none of the options" have self-disconnected, but also have stated that they usually achieve their goals. This shows a certain sign of naiveté. The reminder could help these consumers to be more aware of potential self-control issues and/or likely increases in consumption during the winter.

The other explanation, which may explain it, is a failure to understand the saving plan. In fact, 40% (41 out 89) of the respondents that answered "none of the options" have self-disconnected and have no or low education levels. This shows us that there is a need to explain the different saving plans more clearly and to use less formal educated language so as to reach all consumers.

A further explanation is that these 89 consumers may face extreme financial constraints and the complete lack of spare cash makes a saving plan not possible. In fact, 37% (33 out of 89) of the respondents that answered "none of the options" have self-disconnected and have low income.

TABLE 3.10: Cross tabulation: preferred saving plan vs. low-income

		Preferred saving plan						
		Regular payments	Voluntary savings	Ad-hoc payments	Summer fixed payments	Reminder	None	Total
Low inc.	0	252	43	59	26	96	127	603
	1	142	44	51	14	53	115	419
	Total	394	87	110	40	149	242	1,022

Notes: Pearson $chi2(5) = 15.2764$ ($p = .009$).

TABLE 3.11: Cross tabulation: preferred saving plan vs. self-disconnection

		Preferred saving plan						
		Regular payments	Voluntary savings	Ad-hoc payments	Summer fixed payments	Reminder	None	Total
Self-disc.	0	245	54	75	20	95	206	695
	1	178	41	48	20	74	89	450
	Total	423	95	123	40	169	295	1,145

Notes: Pearson $chi2(5) = 15.6226$ ($p = .008$).

Overall, consumers are interested in a saving plan and in general they agree that it would be a good way to spread the cost of seasonal changes in gas use.[8] We find that those households stating they have already self-disconnected would like to commit to a saving plan. When asked specifically about their preferred plan, a significant percentage of the consumers have chosen the regular payments saving plan as their preferred option, although many respondents commented on the lack of flexibility. In the survey, consumers could leave any comments with regards to the saving plans. The consumers showed some concerns regards to loss of flexibility, lack of spare cash, possible increases on the gas prices, loss of the interest during the summer, likelihood to forget to save, and also mistrust from the profit-maximising firm.

Moreover, consumers understand that a commitment contract can help them to control their gas bills, but do not fully understand the possibility of positive synergies in terms of avoiding temptations to spend on things that they do not need.

Based on our findings, we would choose a commitment contract that shares some of the characteristics of the regular payments, while allowing for a greater flexibility. For example, the customer can make extra payments when they prefer/can, but at the beginning of each summer the energy firm suggests an equal weekly/monthly amount (based on the previous year's consumption) that the customer can meet in order to smooth consumption through the year.

[8] Consumers were asked to answer in a scale from "strongly disagree" to "strongly agree" the following statements about their preferred saving plan: "It would be a good way to spread the cost of seasonal changes in gas use."; "It would help me focus on budgeting to cover my gas needs."; "It sounds too complicated."; "I'd worry about losing the credit I had saved."; and "It could help me reduce my spending on non-essential purchases".

3.8 Conclusion

In this paper, we designed different contracts to be offered by an energy firm that involve a commitment from the consumer. These contracts differ in terms of flexibility and saving target. We proposed also a reminder for consumers who do not wish to commit to a specific plan that involves savings, either because they do not think that they need it, although some of them might actually need it, or because they do not wish to commit to one firm. These interventions, under certain conditions, can lead to an increase in consumer surplus. Among these conditions are the correct identification of those consumers who need a commitment device and the “no introduction of extra switching costs” for the consumer of either changing tariff or firm. If overall firm costs also decrease as a result of our proposed mechanism, then there are compelling reasons to believe that our mechanism can lead to an increase in social welfare. Nevertheless, a deeper welfare analysis would need to be undertaken before reaching such a conclusion.

It is ambiguous whether an increase of the awareness of self-control issues can have an impact on other expenditures other than energy. Further, the empirical part of the study has a major limitation: we relied exclusively on a self-reported questionnaire. These limitations suggest that future research should experimentally test the effectiveness of a commitment contract and feedback/reminder to PPM gas consumers. A follow-up survey could then test whether there are any spillover effects of other types of expenditure.

Our analysis has implications for the policy debate on the role of the prepayment smart meter in the context of fuel poverty. This link to poverty emphasises the importance of the present study in providing specific and simple solutions to increase levels of energy comfort. The solution proposed in this paper does not demand any costs to the government, and, is likely to increase social welfare.

3.9 References

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3.10 Appendix

TABLE A1: List of main variables

Variable	Detailed Description
Age	Age of respondent. Categorical ordered variable.
Female	Dummy for the gender of the respondent, Female=1 and Male otherwise.
#adults household	No. persons with more than 16 years old in the household.
#children household	No. children in the household with less or equal to 16 years old.
Household size	No. people in the household
Household income	Household monthly income, including any benefits.
Low	=1 if household monthly income is up to £1000, and =0, otherwise.
Medium	=1 if household monthly income is £1001 to £2000, and =0, otherwise.
High	=1 if household monthly income is over £2000, and =0, otherwise.
Education	Education level of the respondent.
None	=1 if highest education obtained is lower than basic, and =0, otherwise.
Basic (O-levels)	=1 if the highest degree is basic education, and =0, otherwise.
Medium (A-levels & vocational)	=1 if the highest degree is medium education, and =0, otherwise.
Higher (University degree)	=1 if the highest degree is higher education, and =0, otherwise.
Emergency credit (stated)	To what extent do you agree with the statement: I rarely use the emergency credit. Strongly disagree=1, to Strongly agree=5. Redefined into dummy variable. =1 if ec=1 or =2 or =3, and =0, otherwise.
Self-disconnection (stated)	To what extent do you agree with the statement: Sometimes the emergency credit runs out. Strongly disagree=1, to Strongly agree=5. Redefined into dummy variable: =1 if sd=5 or =4 or =3, and =0, otherwise.
Top up all year	Which of the statements is most applicable to your spend on gas over the year? =0 if "I top up more on my gas meter over the winter than over the summer." =1 if "I top up roughly the same all year around."
Saving behaviour	To what extent do you agree with: When I'm using less gas in warmer months, I like to add any spare cash to my savings. Strongly disagree=1 to Strongly agree=5. Redefined into dummy variable. =1 if =5 or =4, and =0 otherwise.
Inconvenience of top up	To what extent do you agree with: Pay As You Go makes it easy to pay for my gas. Strongly disagree=1, to Strongly agree=5. Redefined into dummy variable. =1 if =1 or =2 or =3, and =0 otherwise.
Preferred Plan (PP)	Binary Variable. Regular payment throughout the year=1, Voluntary savings target=2, Ad-hoc extra payments=3, Summer fixed extra payments=4, Reminder on consumption=5, None=6
Worried	To what extent do you agree with: I'd worry about losing the credit I had saved. Strongly disagree=1 to Strongly agree=5. Redefined into dummy variable. =1 if =5 or =4, and =0 otherwise.
Spare Cash	To what extent do you agree with: I have spare cash in warmer months as I don't have to spend so much on gas. Strongly disagree=1 to Strongly agree=5.

TABLE A2: Cross tabulation between inconvenience of top up and self-disconnection

		Self-disconnection		
		0	1	Total
Inconvenience of top up, redefined	0	616	306	922
		45.46%	22.58%	68.04%
	1	203	230	433
		14.98%	16.97%	31.96%
	Total	819	536	1,355
		60.44%	39.56%	100%

Notes: Pearson $chi2(1) = 48.9422$ ($p = 0.000$).

TABLE A3: Cross tabulation between inconvenience of top up and self-disconnection

		Self-disconnection		
		0	1	Total
Top up all year	0	732	499	1231
		53.59%	36.53%	90.12%
	1	96	39	135
		7.03%	2.86%	9.88%
	Total	828	538	1,366
		60.61%	39.39%	100%

Notes: Pearson $chi2(1) = 6.9132$ ($p = 0.009$).

TABLE A4: Cross tabulation between saving behaviour and self-disconnection

		Self-disconnection		
		0	1	Total
Saving Behaviour, redefined	0	507	316	823
		46.34%	28.88%	75.23%
	1	154	117	271
		14.08%	10.69%	24.77%
	Total	661	433	1094
		60.42%	39.58%	100%

Notes: Pearson $chi2(1) = 1.9457$ ($p = 0.163$). The relation between saving behaviour and self-disconnection is not statistically significance.

TABLE A5: Cross tabulation between spare cash and low-income

		Low income		
		0	1	Total
Spare cash, redefined	0	312	258	570
		25.68%	21.23%	46.91%
	1	400	245	645
		32.92%	20.16%	53.09%
	Total	712	503	1215
		58.6%	41.4%	100%

Notes: Pearson $chi2(1) = 6.6079$ ($p = 0.010$).

Sample of question on saving plan choice

The following questions relate to how the payment plan may work and we are looking for your thoughts on what would be the most beneficial / easy to use. Before entering onto the payment plan, you would need to agree to a tailored quote detailing your consumption patterns and spend over the year - this would help you understand how you might manage the cost of your gas with different saving options that suit your lifestyle and income. Some of these options have been listed below and we'd like to know how these sound to you.

The following options are variants of the savings plan. We'd like to know how these saving plans A to E appeal to you. Please rate 1 - 5 where 1 is not appealing and 5 is extremely appealing.

A) **Regular payments throughout year**

Based on the summary of your previous year's consumption, you agree to an equal weekly / monthly amount that you commit to paying through the year. Regular equal payments would cover your consumption throughout the year.

B) **Voluntary Savings Target**

You chose a target amount that you feel comfortable / confident in saving. You're responsible for meeting this target and it would be up to you whether or not you achieved your target each month. The credit you saved would be used to offset your winter consumption.

C) **Ad-hoc Extra Payments**

You make additional payments as and when you can afford to do so. You would not have to nominate a target for your savings but the more you saved, the more of your winter consumption would be offset.

D) **Summer Fixed Extra Payments**

You commit to additional fixed payments just during summer months. These additional payments would be calculated on the basis of your winter time gas consumption in the previous year. The extra payments would be used to cover your higher gas payments in the wintertime.

E) **Feedback on Consumption**

Without changing your monthly payment plan, you receive regular feedback in the summer about your average gas payments. For example: "Last year you spent £20 on gas between July and September and you spent £120 on gas between October and December".

From the options listed in the question above which savings plan would you prefer? Choose one option only:

A) Regular payments throughout year

B) Voluntary Savings Target

C) Ad-hoc Extra Payments

D) Summer Fixed Extra Payments

E) Feedback on Consumption

F) None of the above

TABLE A6: Distribution of goal achievement questions

Answer	Freq.	Percent over all variables	Percent over groups
		Goal achievement	
High			
I usually achieve my goals	409	35.2	58.8
I usually set-up weekly or monthly goals that I wish to achieve and I usually achieve my goals	287	24.7	41.2
Total	696	59.9	100.0
Medium			
I usually set-up weekly or monthly goals that I wish to achieve	184	15.8	52.9
I have difficulties in completing a task that requires organization	31	2.7	8.9
I usually avoid or delay a task that requires a lot of thinking	68	5.9	19.5
I usually set-up weekly or monthly goals that I wish to achieve and I have difficulties in completing a task that requires organization	7	0.6	2.0
I usually set-up weekly or monthly goals that I wish to achieve and I usually avoid or delay a task that requires a lot of thinking	21	1.8	6.0
I have difficulties in completing a task that requires organization Iand I usually achieve my goals	5	0.4	1.4
I usually avoid or delay a task that requires a lot of thinking and I usually achieve my goals	32	2.8	9.2
Total	348	30	100.0
Low			
I don't usually achieve my goals	34	2.9	29.1
I usually set-up weekly or monthly goals that I wish to achieve and I don't usually achieve my goals	17	1.5	14.5
I have difficulties in completing a task that requires organization and I don't usually achieve my goals	17	1.5	14.5
I have difficulties in completing a task that requires organization and I usually avoid or delay a task that requires a lot of thinking	27	2.3	23.1
I don't usually achieve my goals and I usually avoid or delay a task that requires a lot of thinking	18	1.6	15.4
I don't usually achieve my goals and I usually achieve my goals	4	0.3	3.4
Total	117	10.1	100.0

TABLE A7: Low Goal Achievement: mean characteristics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Female	117	0.56	0.50	0	1
Age					
21 and Under	117	0.00	0.00	0	0
22 to 34	117	0.32	0.47	0	1
35 to 44	117	0.24	0.43	0	1
45 to 54	117	0.39	0.49	0	1
55 to 64	117	0.28	0.45	0	1
65 and Over	117	0.05	0.22	0	1
Top-up all year	117	0.09	0.28	0	1
Income					
Low	92	0.46	0.50	0	1
Medium	97	0.38	0.49	0	1
High	97	0.13	0.34	0	1
Education					
None	108	0.17	0.37	0	1
Basic	108	0.39	0.49	0	1
Medium	108	0.36	0.48	0	1
High	108	0.08	0.28	0	1

TABLE A8: Medium Goal Achievement: mean characteristics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Female	348	0.72	0.45	0	1
Age					
21 and Under	348	0.00	0.05	0	1
22 to 34	348	0.29	0.45	0	1
35 to 44	348	0.24	0.43	0	1
45 to 54	348	0.39	0.49	0	1
55 to 64	348	0.22	0.42	0	1
65 and Over	348	0.07	0.26	0	1
Top-up all year	348	0.09	0.28	0	1
Income					
Low	287	0.45	0.50	0	1
Medium	290	0.40	0.49	0	1
High	290	0.14	0.35	0	1
Education					
None	321	0.12	0.32	0	1
Basic	321	0.38	0.49	0	1
Medium	321	0.36	0.48	0	1
High	321	0.15	0.35	0	1

TABLE A9: High Goal Achievement: mean characteristics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Female	696	0.59	0.49	0	1
Age					
21 and Under	696	0.00	0.04	0	1
22 to 34	696	0.31	0.46	0	1
35 to 44	696	0.19	0.39	0	1
45 to 54	696	0.39	0.49	0	1
55 to 64	696	0.26	0.44	0	1
65 and Over	696	0.11	0.31	0	1
Top-up all year	696	0.11	0.31	0	1
Income					
Low	582	0.38	0.49	0	1
Medium	593	0.42	0.49	0	1
High	593	0.18	0.39	0	1
Education					
None	641	0.11	0.31	0	1
Basic	641	0.33	0.47	0	1
Medium	641	0.39	0.49	0	1
High	641	0.16	0.37	0	1

TABLE A10: Robustness check: SUBOP and SUBP

	SUBOP		**SUBP**	
	Coefficients		Average marginal effects	
	ec (ordered)	sd (ordered)	ec (redefined)	sd (redefined)
Age				
35 to 44	.040	-.083	.026	-.116
	(.191)	(.199)	(.098)	(.089)
45 to 54	-.019	-.062	.023	-.111
	(.183)	(.191)	(.093)	(.084)
55 to 64	-.146	-.119	-.075	-.119
	(.192)	(.200)	(.097)	(.088)
Over 65	-.299	-.287	-.122	-.220**
	(.224)	(.239)	(.113)	(.108)
Female	.041	.054	-.025	.041
	(.083)	(.089)	(.044)	(.042)
Education				
Medium	.117	-.017	.022	.001
	(.085)	(.090)	(.044)	(.042)
Higher	.040	-.011	.044	.013
	(.115)	(.121)	(.060)	(.056)
Income				
Medium	.151*	.078	.099**	.005
	(.086)	(.091)	(.045)	(.043)
High	.120	-.072	.021	-.037
	(.112)	(.121)	(.059)	(.056)
Household adults	.045	.042	.023	.018
	(.038)	(.040)	(.020)	(.019)
Saving behavior	-.275***	.044	-.125***	-.019
	(.092)	(.098)	(.047)	(.045)
Top up all year	-.415***	-.638***	-.196***	-.227***
	(.131)	(.153)	(.066)	(.072)
Inconvenience of top up	.067	.415***	.036	.161***
	(.084)	(.087)	(.043)	(.038)
Goal Achievement				
Low		-.068		.047
		(.054)		(.060)
Medium		-.082**		.109***
		(.037)		(.040)
ρ	.363		.384	
	(.039)		(.063)	
Observations	795		596	
LL	-2283.30		-740.13	
Wald chi2(13)	35.96			
Wald chi2(28)			71.33	
Prob $> \chi^2$	.000		.000	

Notes: SUBOP stands for seemingly unrelated bivariate ordered probit and SUBP stands for seemingly unrelated bivariate probit. In the SUBP, the dependent variables were redefined by dropping the “neither agree nor disagree" option whereas in the SUBOP we did not dropped this option in the dependent variables. Standard errors are in parenthesis. The standard errors in the average marginal effects are calculated by the Delta method. ***, **, * stand for 1, 5, and 10 percent significant levels, respectively. LL stands for log likelihood. Age under 22 and Age to 34, none and low education, low income and high goal achievement were used as reference categories.