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Optimal Nonlinear Pricing, Bundling Commodities and Contingent Services

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Abstract

In this paper, we propose to analyze optimal nonlinear pricing when a firm offers in a bundle a commodity and a contingent service. The paper studies a mechanism design where all private information can be captured in a single scalar variable in a monopoly context. We show that to propose the package for commodity and service is less costly for the consumer, the firm has lower consumers' rent than the situation where it sells their good and contingent service under an independent pricing strategy. In fact, the possibility to use price discrimination via the supply of package is dominated by the fact that it is costly for the consumer to sign two contracts. Bundling energy and a contingent service is a profitable strategy for a energetician monopoly practising optimal nonlinear tariff. We show that the rates of the energy and the contingent service depend to the optional character of the contingent service and depend to the degree of complementarity between commodities and services.

JEL Classification : D42, L12, Q4

Keywords : Bundling, Nonlinear pricing, Energy market

1 Introduction

Recently, a trend towards deregulation of utilities industries (as energy and telecommunications) has been observed worldwide and has an impact on market structures and pricing strategies. Hence, market structure has shifted from monopoly[1] to oligopoly and in these conditions, mainly historical incumbent need to diversify their offers to compete with their rivals. As a result, companies are multiplying their multiproduct offers but also bundles including commodities and contingent services [2].

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[1]Moreover, some administrative "principle of specialization" that formerly assigned public monopoly operators to produce only a single specialized good, have been removed.

[2]For instance for professionals in the energy sector, dominant operators propose bi-energy and service offers as "Provalys" for Gaz de France and "Essentiel Pro" for Electricté de France.

The aim of this paper is to analyze such bundling strategy and its impact on pricing for an incumbent in a monopolistic situation. The firm has the choice to sell a good and a service separately (independent pricing) or as a package (pure bundling) and, both with a nonlinear pricing. Pure bundling refers to the practice of selling two or more goods or services together in a package at a unique tariff. More precisely, this paper focuses on bundling for space heating needs for residents or professionals, where energy can be tied with a contingent service. The service for example may be technical maintenance or energy consultancy which enhances the gross utility for the good.

This paper deals with a private monopoly, mainly to depict a situation where market power is high. In this case, the optimal strategy is the mixed bundling for it obtains a maximum surplus from the consumers if the correlation of consumers' reservation values is negative (Adams and Yellen [1976], Schmalensee [1984], Mc Afee, Mc Millan and Whinston [1989]). Bundling is the fact of selling two or more goods together in a package and this practice has two effects: bundling increases the valuation of goods and allows to propose prices smaller than the case where a consumer buys the goods separately. Mixed bundling refers to the practice of offering to consumers the option of either buying two goods separately or else a package of both. In fact, bundling allows the monopolist to sort consumers better and consequently the firm extracts more consumer rent. So with the mixed strategy, the monopoly makes higher profits since the correlation of consumers' reservation values is negative. However as competition increased the results are reversed, in fact bundling can reduce the gains of the firm and can increase the rent of consumers.

The bundle pricing strategy for a complementary service is an issue that has not been analyzed in the general literature on bundling. This paper analyzes the package of a good and a contingent service in energy market, and more precisely which is the efficient pricing strategy when good and contingent service are complementary. We focus on the impact of the service on the nonlinear tariff under an independent pricing strategy and under a bundling strategy. The acknowledged fact is that the more a service is personalized the more its ex-ante valuation is difficult (Bateson [1995]). The valuation attributed to a good is superior than the valuation attributed to a service, it is the general situation for a service associated to a good. Thus, a consumer has more difficult to give a benchmark price for a service, in comparison with a good. The model focuses on nonlinear pricing which allows price discrimination against the consumers, so when the monopoly uses a bundling strategy the firm has an additional tool to practice price discrimination. Sorting customers with nonlinear pricing—generally referred to as second-degree price discrimination—is a practice commonly used in most markets. In fact, nonlinear pricing is widely used in energy markets for the supply of one or several goods. For example, for the gas supply, the industrial gas retailler uses a two-part tariff, it comprises a uniform price for each unit of gas purchased plus a fixed fee payable if any positive amount is purchased. This type of tariff allows firms to practice price discrimination offering a menu of tariff rates. Each consumer chooses the appropriate tariff, therefore this choice allows for the consumers to reveal their preferences and thus allows to the firm to extract more consumer rent.

Since consumers' willingness to pay is private information, the firm must condition the contract upon observable variables, it is most often assumed that the firm can observe only one variable. It is also common to assume that the observed variable is a single dimensional, this is quality in Mussa and Rosen [1978] and quantity in Maskin and Riley [1984]. Wilson [1993] provides definitions and examples of multidimensional goods and multidimensional pricing.

Martimort [1992] introduces the possibility for a common agent to contract with multiple principals. He compares the cooperative situation, this is the situation where firms can offer a package, and the situation with noncooperation under the hypothesis of nonlinear pricing. The results depend on the complementarity or the substituability between activities controlled by each principal. If the goods are complements thus the bundling strategy is an optimal strategy for the principals and the consumers. However, if the goods are substitutes the consumer's utility is better when there is noncooperation between the principals, but the profits are lower. He adds the hypothesis of multiple consumers [1996] and he finds the same results.

In our model, we use the analysis of Martimort [1992 and 1996] under the hypothesis of complementarity between a good and a contingent service. Contrary to the assumptions of Martimort's model, there is no symmetry between the good and the related service in our specified utility function. We show that the profitability of the bundling strategy depends to the optional character of the related service for space heating and the degree of complementarity between the good and the service.

This paper considers the case where the monopoly practices nonlinear pricing for both a good and a contingent service, the main issue is to determine the optimal pricing strategy for the seller. The monopoly has two shops and offers commodity and contingent service to the good. The model considers two cases: in the first case, the monopoly sells the good and the service under an independent pricing strategy and in the second case bundling is considered. In the bundling case both shops coordinate themself to use price discrimination and to capture a maximum of consumers' surplus with the help of the package. However, incomplete information upon the consumers' type implies that an incentive compatible nonlinear pricing schedule have to be designed in both cases. In this paper proposing the package for commodity and service is less costly for the consumer and the firm has lower consumers' rent than the situation where it sells their good and service under an independent pricing strategy. In fact, the possibility to use price discrimination via the supply of package is dominated by the fact that it is costly for the consumer to sign two contracts at two separating shops. Bundling associated to a nonlinear tariff is more efficient for the consumers' point of view. But for the monopoly profits the independent pricing strategy provides more consumers' rent.

The results are the following: with an independent pricing strategy the monopoly would be worse off to propose separating contracts. The monopoly proposes a contract for the gas and a contract for the service, so it captures more rent of consumer for each contract is signed. However, when the monopoly commits to a pure bundling strategy it cannot duplicate the independent contracts and proposes a package with commodities good and service so it captures only once the consumers' rent. Contrary to the authority recommendations, in this paper bundling are an optimal strategy for the consumers.

The rest of the article is organized as follow. The following section sets out the model. In the section 3 we consider the monopoly has a perfect information to the consumers' preferences. This section is the benchmark to analyze the effects of independent pricing strategy and bundling strategy in a context of imperfect information. The section 4 consider the case where the shops coordinate itself and propose a package. Afterwards in section 5 we remove this hypothesis to considers the two shops which provide commodity (gas) and service (technical maintenance or energy consultancy) separately. At last, the section 6 proposes few concluding remarks.

2 The model

The model focuses on gas demand for space heating needs. The firm offers a good (gas) and a contingent (complementary) service, for example technical consultancy. The gross utility is given by:

$$u(H, \theta)$$

where H is the level of heating achieved and θ the consumers' preference. Heating is obtained by a given technology which combined $x \geq 0$ is the quantity of gas consumed, and $s \geq 0$ is the contingent service level purchased. Hence, utility can be directly written as an increasing asymmetric function of x and s so that $u(H, \theta) = u(x, s, \theta)$ which satisfies the following requirements for all $y \geq 0$:

$$\forall y, u(y, 0, \theta) \geq u(0, y, \theta). \tag{H1}$$

Moreover the usual Spence-Mirless property is verified that is:

$$u_{\theta x}(x, s, \theta) > u_{\theta s}(x, s, \theta) \geq 0. \tag{H2}$$

where subscripts represent partial derivatives. The (energetic) good is intrinsically preferred to the service since the latter cannot provide heating alone. As a result, the technical service can be viewed as optional from the consumer's point of view. In the sequel we will mainly focus on the polar case for which $u_{\theta s}(x, s, \theta) = 0$, that is consumer's preferences are heterogeneous mainly from the energy use point of view but not from the contingent service.

We also assume strict concavity[3] and complementarity between gas and service such as:

$$u_{xs}(x, s, \theta) \geq 0. \tag{H3}$$

For instance, assumptions above are fulfilled by the following quasi-concave function, we will use in the sequel:

$$u(x, s) = \theta(x + \alpha s) + 2\beta xs - \frac{\gamma}{2}x^2 - \frac{\gamma}{2}s^2 \tag{H4}$$

where $0 \leq \alpha, \beta \leq 1$ and we set $\gamma = 1$.

The population of potential consumers have preferences which can be indexed by a single-dimensional parameter, $\theta \in \Theta \equiv [\underline{\theta}, \bar{\theta}] \subset \mathbb{R}_+$, which we take to be represented by with an everywhere non-negative density $f(\theta) = F'(\theta)$. In fact, the monopoly does not observe the buyer's valuation θ but it is common knowledge that the valuation θ is distributed according to a prior distribution function $F(\theta)$. We also define $\varphi(\theta) = \frac{1-F(\theta)}{f(\theta)}$, the hazard rate, which represents the information extraction cost for the firm, and it is decreasing[4] in θ so that $\varphi'(\theta) \leq 0$.

To simplify, firm costs are supposed to be identical and increasing convex for both service and good units produced, so we have:

$$C(x, s) = c(x) + c(s)$$

We will assume further that $c(y) = \frac{1}{2}y^2$ for $y \geq 0$.

Suppose that the monopolist sells its products using a nonlinear tariff T, the consumers' net utility is then given by:

$$U = \begin{cases} u(x, s, \theta) - T & \text{if } x, s > 0 \\ 0 & \text{if } x, s = 0 \end{cases}$$

where T is the total expenditure paid if consumers buy x units of good or/and s units of service, which can be divided in two respective parts $T = t + \tau$. The timing of the game of contract proposals is the following. First, principal offer the contracts, T under the bundling strategy and t for the gas and τ for the contingent service under the independent

[3] More precisely this implies that $u_{ss} < 0, u_{xx} < 0$ and $u_{ss}u_{xx} - (u_{xx})^2 > 0$. Moreover we assume $u_{\theta xx}(x, s, \theta) > 0$.

[4] This is a acceptable assumption as Bagnoli and Bergstrom [2005] have shown. As the type increases, the relative weight of types above θ decreases. The firm is more and more concerned about the rents left below θ.

pricing strategy, or equivalently the direct revelation mechanisms: $T(\hat{\theta})$ or $t(\hat{\theta})$ and $\tau(\hat{\theta})$. Second, agents simultaneously accept or refuse the proposal they respectively receive. Third, they make their reports to the principal. Finally, the tariff $T(\hat{\theta})$ and the good and the contingent service $\{x(\hat{\theta}), s(\hat{\theta})\}$ are implemented.

The tariff for the contrat depends on the monopoly pricing strategy. If the monopoly follows a bundling strategy, consumers choose a tariff for the bundle which include the good and the contingent service. Each consumer pays an overall tariff T for the package. On the contrary, if the monopoly follows an independent pricing strategy consumers choose a tariff for the good and a tariff for the contingent service. If a consumer applies to the energy retailler, he pays an overall tariff equal to t, for the service supply the overall price to pay is τ. Each tariff is a nonlinear one, with a fixed fee and a variable price.

In our setting, the firm only cares about its expected profits, and seeks to maximize $E(\pi)$. In addition, the buyer must have adequate incentives to reveal his type truthfully—incentive compatibility (IC)—and to participate in the mechanism voluntary—individual rationality (IR):

$$\begin{aligned} \max E(\pi) &= \int_{\underline{\theta}}^{\overline{\theta}} \{t(\theta) + \tau(\theta) - C(x(\theta), s(\theta))\} f(\theta) d\theta \\ U(\theta) &\equiv u(x(\theta), s(\theta), \theta) - t(\theta) - \tau(\theta) \geq u(x(\hat{\theta}), s(\hat{\theta}), \theta) - t(\hat{\theta}) - \tau(\hat{\theta}) \quad \text{(IC)} \\ U(\underline{\theta}) &\geq 0 \quad \text{(IR)} \end{aligned}$$

The incentive compatibility represents the fact that the firm lets a consumers' surplus higher when the consumer reveals their preferences and chooses an optimal price schedule than when the consumer lies about their preferences and he would like to be taken for an other type. With the IC constraint the monopoly encourages the consumers to reveal their preferences. With the IR constraint the firm must incite the consumers to consume by leaving a positive net surplus.

In the following section we consider that the monopoly knows each type of consumer θ. This situation is the benchmark to analyze the effects of price discrimination under a nonlinear pricing. In the following sections we remove this hypothesis to consider the case where the monopoly only knows the distribution of consumers' preferences.

3 Perfect Discrimination

As a benchmark, we first consider that the monopoly has perfect information to the consumers' preferences. Thus, it can fix a price equal to the consumers' willingness to pay and capture all the consumers' surplus. The tariffs for the good and service are such as the consumers' final rent is nil.

The firm only cares about its expected profits, and seeks to maximize the tariff minus its cost under the IC constraint:

$$\max_{T,x,s} T - C(x,s) \text{ s.t } u(x,s,\theta) - T \geq 0$$

The monopoly chooses at the equilibrium a tariff which depends to the gas quantity and the level of service according to each consumer's type such that $T = u(x,s,\theta)$. Denote $(x^F(\theta), s^F(\theta))$ the first-best solution[5] such as:

$$\begin{aligned} u_x(x^F, s^F, \theta) &= c'(x^F) \\ u_s(x^F, s^F, \theta) &= c'(s^F) \end{aligned}$$

Consequenty using concavity and the Spence and Mirlees conditions, one can directly see that $\dot{x}^F(\theta) > 0$ and $\dot{s}^F(\theta) > 0$. Optimal sales of energy and services are positively correlated with the consumer's preferences.

Explicitely with utility and cost functions previously defined, the quantity of gas and the level of service, in the perfect information, are given by:

$$x^F(\theta) = \frac{1+\alpha\beta}{2(1-\beta^2)}\theta \text{ and } s^F(\theta) = \frac{\alpha+\beta}{2(1-\beta^2)}\theta$$

The quantity of gas is positive as the level of service if $\beta \in [0,1[$. The quantities of gas and service are both increasing in relation to the consumers' willingness to pay. This means that a consumer who has a high preference for the good and the service has a more important demand than a consumer with a low preference.

The derivative of utility in relation to x gives the gas price fixed by the firm:

$$u_x(x(\theta), s(\theta), \theta) = c'(x(\theta)) = p^F(\theta)$$

Since in complete information the firm knows exactly each consumer's preference, it leaves any surplus for the price equal to the willingness to pay. In other words, the monopoly fixes a price equal to the marginal cost. With the specified utility function the gas price is given by:

$$p^F(\theta) = x^F(\theta)$$

When the consumer aimed at the shop 2 to buy the service contingent to the good, the price of the service is given by the derivative of the utility function in relation to s:

$$u_s(s(\theta), x(\theta), \theta) = c'(s^F(\theta)) = r^F(\theta)$$

[5]The global second-order condition implies that $(u_{ss} - c'')(u_{xx} - c'') - (u_{xs})^2 > 0$ must hold, that is cost convexity must not counterbalance concavity of utility.

The fixed price is equal to the marginal cost, the firm captures fully consumer's surplus. At the equilibrium, with the specified utility function, the price of the service is given by:

$$r^F(\theta) = s^F(\theta)$$

In the complete information case, the firm knows exactly each type of consumer and therefore can extract them the maximum of surplus. In fact, it fixes a tariff equal to the good reservation values of consumers. This case is similar to first-degree price discrimination since we assume that the monopoly has full information. This case is the benchmark to analyze the effects of price discrimination under a nonlinear pricing. To carry on the analyze we remove the hypothesis of perfect information and consider that the monopoly knows only the distribution of consumers' preferences. In the next section we look to the pure bundling strategy in a context of imperfect information.

4 Nonlinear pricing schedule and bundling

In this section we consider a monopoly which can offer a good (gas) and a contingent (complementary) service, for example technical consultancy, under a package form. The monopoly has two separated shops which coordinate themselves to propose a nonlinear tariff for the bundle.

Ex-post the tariff for the gas supply and for the service supply is implemented as a three-part schedule and has the following form:

$$T = Z + px + rs \Leftrightarrow Z = T - px - rs$$

where Z is the fixed fee of the tariff, p and r are respectively the gas and the service rates so T is the overall that consumers pay from purchasing the bundle.

The first and second order incentive compatibility constraints implemented with $T(\theta) = T(x(\theta), s(\theta))$ are given by:

$$\begin{aligned} u_x(x,s,\theta)\ \dot{x}(\theta) + u_s(x,s,\theta)\ \dot{s}(\theta) - \dot{T}(\theta) &= 0 \\ u_{\theta x}(x,s,\theta)\ \dot{x}(\theta) + u_{\theta s}(x,s,\theta)\ \dot{s}(\theta) &\geq 0 \end{aligned}$$

Which can allow us to write that $\dot{U}(\theta) = u(x(\theta), s(\theta), \theta)$, so with integration by parts the firm's objective can be implemented by:

$$\max E(\pi) = \int_{\underline{\theta}}^{\overline{\theta}} \left[u(x(\theta), s(\theta), \theta) - \varphi(\theta) u_\theta(x(\theta), s(\theta), \theta) - C(x(\theta), s(\theta))\right] f(\theta) d\theta$$
$$\text{s.t. } u_{\theta x}(x(\theta), s(\theta), \theta)\dot{x}(\theta) + u_{\theta s}(x(\theta), s(\theta), \theta)\dot{s}(\theta) \geq 0$$

At the equilibrium, the couple $\{x^B(\theta), s^B(\theta)\}$ satisfies the system;

$$\begin{cases} u_x(x,s,\theta) - \varphi(\theta)u_{\theta x}(x,s,\theta) = c'(x) \\ u_s(x,s,\theta) - \varphi(\theta)u_{\theta s}(x,s,\theta) = c'(s) \end{cases} \quad (1)$$

Invoking strict concavity of $u(\cdot)$ in (x,s) and negativity $\varphi'(\theta)$, one can directly show that $\dot{x}^B(\theta) > 0$, $\dot{s}^B(\theta) > 0$ hence second order incentive compatibility. Since $\varphi(\theta)u_{\theta x} \geq 0$ and $\varphi(\theta)u_{\theta s} \geq 0$, one can conclude that $x^B(\theta) \leq x^F(\theta)$ and $s^B(\theta) \leq s^F(\theta)$.

In the case of our specification:

$$x^B(\theta) = \frac{1+\alpha\beta}{2(1-\beta^2)}(\theta - \varphi(\theta)) \text{ and } s^B(\theta) = \frac{\alpha+\beta}{2(1-\beta^2)}(\theta - \varphi(\theta))$$

Now we can rewrite the tariff as:

$$T^B(\theta) = u(x^B(\theta), s^B(\theta), \theta) - U^B(\theta)$$

Moreover, implementing this tariff as three-part schedule, leads to define:

$$T^B(\theta) = \hat{T}^B(x,s) = Z^B(\theta) + p^B(\theta)x + r^B(\theta)s$$

where the fixed fee can be directly restated as:

$$Z^B(\theta) = T^B(\theta) - p^B(\theta)x^B(\theta) - r^B(\theta)s^B(\theta)$$

At the equilibrium the price of the commodity and service are respectively given by (ommitting arguments):

$$\begin{aligned} p^B &= u_x(x^B, s^B, \theta) = c'(x^B) + \varphi(\theta)u_{\theta x}(x^B, s^B, \theta) \\ r^B &= u_s(x^B, s^B, \theta) = c'(s^B) + \varphi(\theta)u_{\theta s}(x^B, s^B, \theta) \end{aligned}$$

Proposition 1 *In general, if the service is purely optional ($u_{\theta s} \equiv 0$), then the service price with bundling is always lower than with perfect discrimination that is for all $\theta \in \Theta$*

$$\begin{aligned} p^B &= u_x(x^B, s^B, \theta) = c'(x^B) + \varphi(\theta)u_{\theta x}(x^B, s^B, \theta) \lesseqgtr p^F \\ r^B &= u_s(x^B, s^B, \theta) = c'(s^B) \leq c'(s^F) = r^F \end{aligned}$$

The rate of the contingent service depend to the optional characteristic for the service. At the level of the service is purely optional the derivative of the utility related to the service is nil. For the bundling strategy the firm has an information extraction cost, the rate is lower than in a perfect information and consumers have more surplus.

Explicitely that is with the utility given by (H4),

$$\begin{aligned} p^B &= \frac{\theta(1+\alpha\beta) + \varphi(\theta)(1-\alpha\beta) - 2\varphi(\theta)\beta^2}{2(1-\beta^2)} \gtreqless p^F \text{ if } \beta \lesseqgtr \beta_x^B(\alpha) = \frac{1}{4}(\sqrt{8+\alpha^2} - \alpha) \\ r^B &= \frac{\theta(\alpha+\beta) + \varphi(\theta)(\alpha-\beta) - 2\varphi(\theta)\beta^2}{2(1-\beta^2)} \gtreqless r^F \text{ if } \beta \lesseqgtr \beta_s^B(\alpha) = \frac{1}{4\alpha}(\sqrt{8\alpha^2+1} - 1) \end{aligned}$$

where $\frac{\sqrt{2}}{2} \geq \beta_x^B(\alpha) > \beta_s^B(\alpha), \forall \alpha < 1$.

Proposition 2 *Under (H4) marginal prices of both energy and service are lower than in the first-best if* $1 \geq \beta > \beta_x^B(\alpha)$ *whenever* $\alpha < 1$ *(cf. figure 1)*

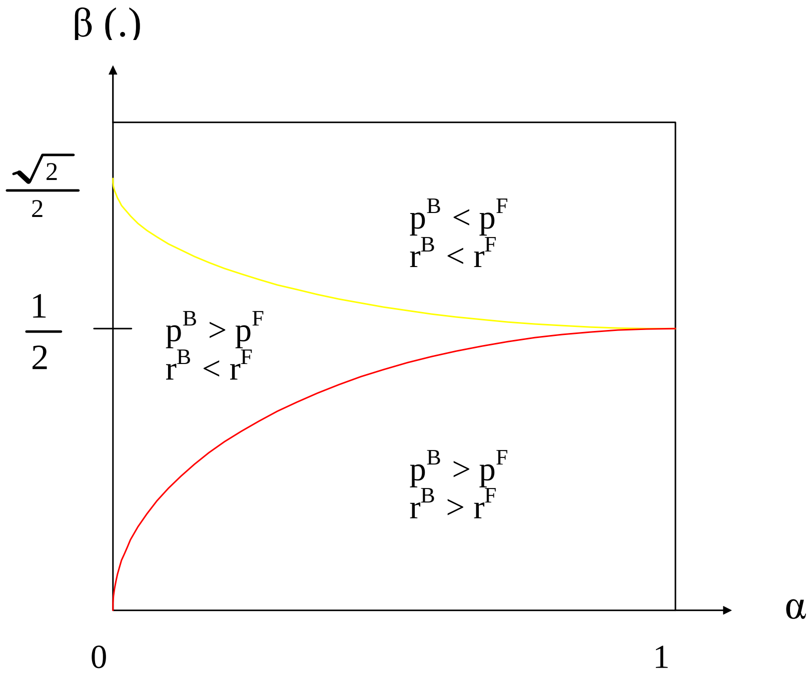

Figure 1: Rates comparaison between bundle strategy and first-best situation

From the Figure 1 we can make a comparison between the rates on the bundle strategy and the rates in the first-best situation. When the contingent service is purely optional ($u_{\theta s} \equiv 0$) and $0 \leq \beta \leq \frac{\sqrt{2}}{2}$ the rate of the related service is lower than in the first-best situation. For the high values of β ($\beta > \frac{\sqrt{2}}{2}$) and the service is not optional thus the rates of the energy and the related service are both lower than in the first-best situation.

Finally from (1), at the equilibrium the commodity supply is related to the service level by the "reaction" relation $x^b(s)$ such that:

$$x^{b\prime}(s) = -\frac{u_{xs}(x, s, \theta) - \varphi(\theta)u_{\theta xs}(x, s, \theta)}{u_{xx}(x, s, \theta) - \varphi(\theta)u_{\theta xx}(x, s, \theta) - c''(x)} \tag{2}$$

indeed $x^b(\theta) = x^b(s^B(\theta))$. Notice that if the service is purely optional ($u_{\theta s} = u_{\theta xs} \equiv 0$) then $x^{b\prime}(s) > 0$ since $u_{\theta xx}(x, s, \theta) > 0$ and costs are convex.

5 Separate sales and nonlinear tariff

Under the analysis of Martimort (1992), we consider the situation where two principals (the shop 1 is the gas retailer and the shop 2 is the service retailer) supply their contracts to a same type of agent under a nonlinear pricing. However, our analysis slightly differ from Martimort (1992) as $u(x, s, \theta)$ cannot be a symmetric function since energy and service don't fulfilled exactly the same intrinsic needs.

The consumers' utility can be represented by $u(x(\theta), s(\theta), \theta)$, however the type of consumer's report is signed by $(\hat{\theta})$. Thus the agent maximizes his utility in relation to the gas and service tariffs and in relation to the report type according his own type (θ). At equilibrium the agent report is truthfully, so the utility function for a consumer is given by:

$$U(\theta) = \max_{\hat{\theta}_x, \hat{\theta}_s} u(x(\hat{\theta}_x), s(\hat{\theta}_s), \theta) - t(\hat{\theta}_x) - \tau(\hat{\theta}_s) \text{ when } (\hat{\theta}_x, \hat{\theta}_s) = (\theta, \theta)$$

ex-post the reports for the gas level and the service level are truthfully: $(\hat{\theta}_x = \theta)$ and $(\hat{\theta}_s = \theta)$. Here t is the price to pay at the equilibrium for the gas level to the shop 1 and τ is the price to pay for the level of service to the shop 2. The first order of incentive compatibility constraints are given by:

$$(\hat{\theta} = \theta) \begin{cases} u_x(x(\theta), s(\theta), \theta)\dot{x}(\theta) - \dot{t}(\theta) = 0 \\ u_s(x(\theta), s(\theta), \theta)\dot{s}(\theta) - \dot{\tau}(\theta) = 0 \end{cases}$$

The necessary optimal condition can allow us to write (with the envelope theorem):

$$\dot{U}(\theta) = u(x(\theta), s(\theta), \theta)$$

This rent is increasing and must keep a positive value for all values of θ (under the IR constraint). Consequently we minimize the consumer rent with saturation constraint in $\underline{\theta} : U(\underline{\theta}) = 0$.

The principals, the gas retailer (shop 1) and the service retailer (shop 2), must choose a revealing mechanism which incite the consumer to tell the true and to reveal their preferences. Ex-post the agent would be well advised to report his true type than the consumer lies about their preferences $(\hat{\theta}_x, \hat{\theta}_s) = (\theta, \theta)$.

The second order incentive conditions are given by the sign of the hessian of U and have the form:

$$\dot{s}(\theta) \left[u_x(x(\theta), s(\theta), \theta)\dot{x}(\theta) + u_{\theta s}(x(\theta), s(\theta), \theta)\right] > 0$$
$$\dot{x}(\theta) \left[u_x(x(\theta), s(\theta), \theta)\dot{s}(\theta) + u_{\theta x}(x(\theta), s(\theta), \theta)\right] > 0$$
$$\dot{x}(\theta)\dot{s}(\theta)[u_{\theta x}(x(\theta), s(\theta), \theta)u_{\theta s}(x(\theta), s(\theta), \theta)$$
$$+u_x(x(\theta), s(\theta), \theta)(u_{\theta x}(x(\theta), s(\theta), \theta)\dot{s}(\theta) + u_{\theta s}(x(\theta), s(\theta), \theta)\dot{x}(\theta) > 0$$

These conditions are sufficient if and only if $\dot{x}(\theta), \dot{s}(\theta) > 0$.

5.1 Sales of good

In this case we consider only the principal program of the shop 1. Ex-post the binomial tariff for the gas supply will be:

$$t = A + px \Leftrightarrow A = t - px$$

where A is the fixed fee of the tariff and t is the overall price that consumers pay from purchasing gas. The cost, with an independent pricing, is proportionate to the quantities of good bought. Here, the cost according to the gas consumed is given by:

$$C(x, 0) = c(x)$$

The firm 1 maximizes its expected profits under first and second order incentive compatibility constraints with $t(\theta) = t(x(\theta))$. The firm's expected profit can be restated as:

$$\max_{U,x,\hat{\theta}_s(\theta)} E(\pi) = \int_{\underline{\theta}}^{\bar{\theta}} \left[u(x(\theta), s(\hat{\theta}_s(\theta)), \theta) - c(x(\theta)) - U(\theta) - \tau(\hat{\theta}_s(\theta))\right] f(\theta)d\theta$$

$$\dot{U}(\theta) = u_\theta(x(\theta), s(\hat{\theta}_s(\theta)), \theta) \qquad (\lambda)$$

$$U(\underline{\theta}) = 0$$

$$u_s(x(\theta), s(\hat{\theta}_s(\theta)), \theta)\ \dot{s}(\hat{\theta}_s(\theta)) - \dot{\tau}(\hat{\theta}_s(\theta)) = 0 \qquad (\mu) \qquad \text{(IC2)}$$

where $f(\theta)$ is the density function of consumers' preferences. At the equilibrium $\hat{\theta}_s(\theta) = \theta$.

To solve the program, we write the Hamiltonian under (λ) and (μ) constraints and under the analysis of Martimort (1992):

$$\begin{aligned} H(U, x, \hat{\theta}_s) &= f(\theta)[-c(x) - U - \tau(\hat{\theta}_s) + u(x, s(\hat{\theta}_s), \theta)] \\ &\quad +\lambda(\theta)u_\theta(x, s(\hat{\theta}_s), \theta) \\ &\quad +\mu(\theta)[u_{\theta s}(x, s(\hat{\theta}_s), \theta)\dot{s}(\hat{\theta}_s) - \tau(\hat{\theta}_s)] \end{aligned}$$

The dynamic system of Hamilton-Jacobi (SHJ) in relation to the state variable has a form:

$$\frac{\partial H}{\partial U} = \dot{\lambda}(\theta) \Leftrightarrow \dot{\lambda}(\theta) = f(\theta) \qquad (1)$$

Therefore, according to the edge condition $\dot{\lambda}(\theta) = f(\theta)$ and according to the transversal condition we can restate:

$$U(\underline{\theta}) = 0 \text{ and } \lambda(\bar{\theta}) = 0 \qquad (3)$$

After have rewritten the edge and transversal conditions we restate the SHJ with respect to the control variables:

$$\begin{aligned} \frac{\partial H}{\partial x} &= f(\theta)[-c'(x(\theta)) + u_x(x(\theta), s(\hat{\theta}_s(\theta)), \theta)] + \lambda(\theta)\left[u_{\theta x}(x(\theta), s(\hat{\theta}_s(\theta)), \theta)\right] \qquad (4) \\ &\quad +\mu(\theta)\left[u_{xs}(x(\theta), s(\hat{\theta}_s(\theta)), \theta)\ \dot{s}(\hat{\theta}_s(\theta))\right] = 0 \end{aligned}$$

If we suppose that the principals' contracts supply are truthfully ex-post we assume $\hat{\theta}_s(\theta) = \theta$, we can restate:

$$\begin{aligned}\frac{\partial H}{\partial \hat{\theta}_s}_{|\hat{\theta}_s=\theta} &= f(\theta)[(-\dot{\tau}(\theta) + u_s(x(\theta), s(\theta), \theta)\dot{s}(\theta)) \\ &+\lambda(\theta)(u_{\theta s}(x(\theta), s(\theta), \theta)\dot{s}(\theta)) \\ &+\mu(\theta)(u_{ss}(x(\theta), s(\theta), \theta)(\dot{s}(\theta))^2 + u_s(x(\theta), s(\theta), \theta)\ddot{s}(\theta) - \ddot{\tau}(\theta))] = 0\end{aligned} \tag{5}$$

As the principals offer truthtelling tariff for agents to reveal their true type, the preference for the service is restated $\hat{\theta}_s(\theta) = \theta$, the derivative second order condition (IC2) with respect to θ is given by:

$$\begin{aligned}&\ddot{s}(\theta)u_s(x(\theta), s(\theta), \theta) + u_{ss}(x(\theta), s(\theta))(\dot{s}(\theta))^2 - \ddot{\tau}(\theta) \\ &+u_{\theta s}(x(\theta), s(\theta), \theta)\dot{s}(\theta) + u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta)\dot{s}(\theta) = 0\end{aligned} \tag{6}$$

If the solution is separating then $\dot{x}(\theta) \neq 0, \dot{s}(\theta) \neq 0$, the second order incentive compatibility conditions are satisfied and the relation (1) is given by:

$$\lambda(\theta) = F(\theta) + k$$

where k is a constant. As $F(\overline{\theta}) = 1$, thus:

$$\begin{aligned}\lambda(\overline{\theta}) &= F(\overline{\theta}) + k = 0 \Rightarrow k^* = -1 \\ \lambda^*(\theta) &= F(\theta) - 1 = -(1 - F(\theta))\end{aligned} \tag{7}$$

From the equations (6) and (7) into (5), we can restate the SHJ constraints:

$$-(1 - F(\theta))u_{\theta s}(x(\theta), s(\theta), \theta)\dot{s}(\theta) + \mu(\theta)\left[-u_{\theta s}(x(\theta), s(\theta), \theta)\dot{s}(\theta) - u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta)\dot{s}(\theta)\right] = 0$$

$$\mu(\theta) = -(1 - F(\theta))\frac{u_{\theta s}(x(\theta), s(\theta), \theta)}{u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta) + u_{\theta s}(x(\theta), s(\theta), \theta)} \tag{8}$$

Under the analysis of Martimort (1992), by replacing the equation (8) into the equation (4), the SHJ can be restated as following:

$$\begin{aligned}&f(\theta)[(u_x(x(\theta), s(\theta), \theta) - c'(x(\theta))) + (-(1 - F(\theta))u_{\theta x}(x(\theta), s(\theta), \theta)) \\ &+(-(1 - F(\theta))\frac{u_{\theta s}(x(\theta), s(\theta), \theta)u_{xs}(x(\theta), s(\theta), \theta)\dot{s}(\theta)}{u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta) + u_{\theta s}(x(\theta), s(\theta), \theta)})] = 0\end{aligned} \tag{9}$$

It is possible to assume $\varphi(\theta) = \frac{1-F(\theta)}{f(\theta)}$ the equation (9) can be rewritten, with some simplifications, as:

$$\begin{aligned}&-c'(x(\theta)) + u_x(x(\theta), s(\theta), \theta) - \varphi(\theta)u_{\theta x}(x(\theta), s(\theta), \theta) \\ &-\varphi(\theta)\frac{u_{\theta s}(x(\theta), s(\theta), \theta)u_{xs}(x(\theta), s(\theta), \theta)\dot{s}(\theta)}{u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta) + u_{\theta s}(x(\theta), s(\theta), \theta)} = 0\end{aligned} \tag{10}$$

with $x(\overline{\theta}) = x^F(\overline{\theta})$.

With the specified utility, the SHJ can be rewritten as -omitting arguments-:

$$\theta - \varphi(\theta) - 2x + 2\beta s - \varphi(\theta)\frac{2\alpha\beta\ \dot{s}}{2\beta\ \dot{x} + \alpha} = 0 \tag{11}$$

5.2 Sales of service

In this case we consider only the shop 2 (principal) program. The same approach is used as in the previous section for the shop 1. The ex-post binomial tariff for the service supply is given by:

$$\tau = B + rs \Leftrightarrow B = \tau - rs$$

where B is the fixed fee of the tariff and τ is the overall price that consumers pay from service bought. The cost, with an independent pricing, is proportionate to the level of service chosen. Here, the cost according to the service signed is given by:

$$C(0, s) = c(s)$$

The shop 2 maximizes its expected profits with $\tau(\theta) = \tau(s(\theta))$. Here the tariff depends to the level of service signed thus the firm 2 maximizes the expectation profits under first and second order incentive compatibility constraints:

$$\max_{U,s,\hat{\theta}_x(\theta)} E(\pi) = \int_{\underline{\theta}}^{\overline{\theta}} \left[u(x(\hat{\theta}_x(\theta)), s(\theta), \theta) - c(s(\theta)) - U(\theta) - t(\hat{\theta}_x(\theta))\right] f(\theta)d\theta$$

$$\dot{U}(\theta) = u(x(\hat{\theta}_x(\theta)), s(\theta), \theta) \qquad (\lambda)$$

$$U(\underline{\theta}) = 0$$

$$u_x(x(\hat{\theta}_x(\theta)), s(\theta), \theta)\dot{x}(\hat{\theta}_x(\theta)) - \dot{t}(\hat{\theta}_x(\theta)) = 0 \qquad (\mu) \tag{IC2}$$

where $f(\theta)$ is the density function of consumers' preferences. At the equilibrium $\hat{\theta}_x(\theta) = \theta$.

To solve the program, we write the Hamiltonian under (λ) and (μ) constraints and under the analysis of Martimort (1992):

$$\begin{aligned} H(U, s, \hat{\theta}_x) &= f(\theta)[-c(s) - U - t(\hat{\theta}_x) + u(x(\hat{\theta}_x), s, \theta)] \\ &\quad + \lambda(\theta) u_\theta(x(\hat{\theta}_x), s, \theta) \\ &\quad + \mu(\theta)[u_x(x(\hat{\theta}_x), s, \theta)\dot{x}(\hat{\theta}_x) - t(\hat{\theta}_x)] \end{aligned}$$

Here relations (1), (3) still holds and the optimal path of service is such that:

$$\begin{aligned} \frac{\partial H}{\partial s} &= f(\theta)[-c'(s(\theta)) + u_s(x(\hat{\theta}_x(\theta)), s(\theta), \theta)] + \lambda(\theta)\left[u_{\theta s}(x(\hat{\theta}_x(\theta)), s(\theta), \theta)\right] \\ &\quad + \mu(\theta)\left[u_{xs}(x(\hat{\theta}_x(\theta)), s(\theta), \theta)\dot{x}(\hat{\theta}_x(\theta))\right] = 0 \end{aligned} \tag{12}$$

If we suppose that the principals' contracts supply are truthfully ex-post we assume $\hat{\theta}_x(\theta) = \theta$, we can restate:

$$\frac{\partial H}{\partial \hat{\theta}_x}_{|\hat{\theta}_x=\theta} = f(\theta)[(-\dot{t}(\theta) + u_x(x(\theta), s(\theta), \theta)\dot{x}(\theta)) \tag{13}$$
$$+\lambda(\theta)(u_{\theta x}(x(\theta), s(\theta), \theta)\dot{x}(\theta))$$
$$+\mu(\theta)(u_{xx}(x(\theta), s(\theta), \theta)(\dot{x}(\theta))^2 + u_x(x(\theta), s(\theta), \theta)\ddot{x}(\theta) - \ddot{t}(\theta))] = 0$$

As the principals offer truthtelling tariff for agents to reveal their true type, the preference for the energy is restated $\hat{\theta}_x(\theta) = \theta$, the derivative second order condition (IC2) with respect to θ is given by:

$$\ddot{x}(\theta)u_x(x(\theta), s(\theta), \theta) + u_{xx}(x(\theta), s(\theta), \theta)(\dot{x}(\theta))^2 - \ddot{t}(\theta) \tag{14}$$
$$+u_{\theta x}(x(\theta), s(\theta), \theta)\dot{x}(\theta) + u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta)\dot{s}(\theta) = 0$$

If the solution is separating then $\dot{s}(\theta) \neq 0, \dot{x}(\theta) \neq 0$, the second order incentive compatibility conditions are satisfied and (7) holds again. From equations (7) and (14) into (13), we can restate the SHJ constraints:

$$-(1 - F(\theta))u_{\theta x}(x(\theta), s(\theta), \theta)\dot{x}(\theta) + \mu(\theta)\left[-u_{\theta x}(x(\theta), s(\theta), \theta)\dot{x}(\theta) - u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta)\dot{s}(\theta)\right] = 0$$
$$\mu(\theta) = -(1 - F(\theta))\frac{u_{\theta x}(x(\theta), s(\theta), \theta)}{u_{xs}(x(\theta), s(\theta), \theta)\dot{s}(\theta) + u_{\theta x}(x(\theta), s(\theta), \theta)} \tag{15}$$

By replacing equation (15) into (12), the SHJ can be restated as following:

$$f(\theta)[(u_s(x(\theta), s(\theta), \theta) - c'(s(\theta))) + (-(1 - F(\theta))u_{\theta s}(x(\theta), s(\theta), \theta)) \tag{16}$$
$$+(-(1 - F(\theta))\frac{u_{\theta x}(x(\theta), s(\theta), \theta)(u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta)}{u_{xs}(x(\theta), s(\theta), \theta)\dot{s}(\theta) + u_{\theta x}(x(\theta), s(\theta), \theta)})] = 0$$

and equation (16) rewrites:

$$-c'(s(\theta)) + u_s(x(\theta), s(\theta), \theta) - \varphi(\theta)u_{\theta s}(x(\theta), s(\theta), \theta) \tag{17}$$
$$-\varphi(\theta)\frac{u_{\theta x}(x(\theta), s(\theta), \theta)u_{xs}(x(\theta), s(\theta), \theta)\dot{x}(\theta)}{u_{xs}(x(\theta), s(\theta), \theta)\dot{s}(\theta) + u_{\theta x}(x(\theta), s(\theta), \theta))} = 0$$

with $s(\overline{\theta}) = s^F(\overline{\theta})$.

Explicitely (17) writes:

$$\alpha(\theta - \varphi(\theta)) - 2s + 2\beta x - \varphi(\theta)\frac{2\beta\ \dot{x}}{2\beta\ \dot{s} + 1} = 0 \tag{18}$$

5.3 Independent pricing schedule

The contract is optimal if there is a couple $\{x^*(\theta), s^*(\theta)\}$ which satisfy the equation system (10) and (17) omitting arguments:

$$\begin{cases} -c'(x) + u_x(x,s,\theta) - \varphi(\theta)u_{\theta x}(x,s,\theta) - \varphi(\theta)\dfrac{u_{\theta s}(x,s,\theta)u_{xs}(x,s,\theta)\ \dot{s}}{u_{xs}(x,s,\theta)\ \dot{x} + u_{\theta s}(x,s,\theta)} = 0 \\ -c'(s) + u_s(x,s,\theta) - \varphi(\theta)u_{\theta s}(x,s,\theta) - \varphi(\theta)\dfrac{u_{\theta x}(x,s,\theta)\ u_{xs}(x,s,\theta)\ \dot{x}}{u_{xs}(x,s,\theta)\ \dot{s} + u_{\theta x}(x,s,\theta)} = 0 \end{cases} \tag{19}$$

with $x(\bar{\theta}) = x^F(\bar{\theta})$ and $s(\bar{\theta}) = s^F(\bar{\theta})$.

Rewritting (19) leads to the system of differential equations. In our model these equations are not symmetric:

$$\begin{cases} \dot{x} = \frac{u_{\theta s}(x,s,\theta)}{u_{xs}(x,s,\theta)} \dfrac{[u_s(x,s,\theta) - \varphi(\theta)u_{\theta s}(x,s,\theta) - c'(s)]\,[u_x(x,s,\theta) - c'(x)]}{\Gamma(x,s,\theta)} \\ \dot{s} = \frac{u_{\theta x}(x,s,\theta)}{u_{xs}(x,s,\theta)} \dfrac{[u_x(x,s,\theta) - \varphi(\theta)u_{\theta x}(x,s,\theta) - c'(x)]\,[u_s(x,s,\theta) - c'(s)]}{\Gamma(x,s,\theta)} \end{cases} \tag{20}$$

where

$$\Gamma(x,s,\theta) = [u_s(x,s,\theta) - c'(s)]\,[u_x(x,s,\theta) - c'(x) - \varphi(\theta)u_{\theta x}(x,s,\theta)] \\ - [u_x(x,s,\theta) - c'(x)]\,\varphi(\theta)u_{\theta s}(x,s,\theta)$$

with $\Gamma(x^F(\bar{\theta}), s^F(\bar{\theta}), \bar{\theta}) = 0$.

The general analysis of (20) is done in Martimort (1992, 1996) in the case where $u(\cdot)$ has strong symmetric properties. If it was the case here then that any optimal independent nonlinear pricing scheme leads a continuum of allocations $(x^I(\theta), s^I(\theta))$ such that

$$s^\infty(\theta) = x^\infty(\theta) \leq x^I(\theta) = s^I(\theta) \leq x^B(\theta) = s^B(\theta) \tag{21}$$

where $s^\infty(\theta) = x^\infty(\theta)$ should be solution of

$$-c'(x) + u_x(x,x,\theta) - 2\varphi(\theta)u_{\theta x}(x,x,\theta) = 0$$

In this symmetric setting (and with complementarity $u_{xs}(x,s,\theta) \geq 0$), Martimort (1992) shows that separating sales introduces ineffiencies due to the implicit competition between shop managers (principals) and of course $E(\pi^B) \geq E(\pi^I)$ since by definition bundling maximizes the total expected profit.

In our model however, one cannot directly conclude that (21) holds because of asymmetric properties (H1)-(H3) we consider.

We do not attempt to investigate the global analysis of (20), but we first try to define the solution when the service is purely optional that is if ($u_{\theta s} \equiv 0$). In this situation, (20) becomes:

$$\begin{cases} -c'(x) + u_x(x,s,\theta) - \varphi(\theta) u_{\theta x}(x,s,\theta) = 0 \\ -c'(s) + u_s(x,s,\theta) - \varphi(\theta) \dfrac{u_{\theta x}(x,s,\theta)\ u_{xs}(x,s,\theta)\ \dot{x}}{u_{xs}(x,s,\theta)\ \dot{s} + u_{\theta x}(x,s,\theta)} = 0 \end{cases} \tag{22}$$

we see from the first equation in (22) that $x = x^B(s)$ so from (2) we know the "reaction" function $x^B(s)$ is increasing that is $x^{B\prime}(s) > 0$ so (22) writes knows

$$\begin{cases} x = x^B(s) \\ -c'(s) + u_s(x,s,\theta) - \varphi(\theta) \dfrac{u_{\theta x}(x,s,\theta)\ u_{xs}(x,s,\theta)\ x^{b\prime}(s)\dot{s}}{u_{xs}(x,s,\theta)\ \dot{s} + u_{\theta x}(x,s,\theta)} = 0 \end{cases}$$

If second order incentive compatibility conditions are satisfied, such that $\dot{x}(\theta), \dot{s}(\theta) > 0$, it must be true that $u_s(x,s,\theta) = c'(s) + \varphi(\theta) \frac{u_{\theta x}(x,s,\theta)\ u_{xs}(x,s,\theta)\ x^{b\prime}(s)\dot{s}}{u_{xs}(x,s,\theta)\ \dot{s} + u_{\theta x}(x,s,\theta)} > c'(s)$ hence[6] $s^I(\theta) \leq s^B(\theta)$ and $x^I(\theta) = x^b(s^I(\theta)) \leq s^B(\theta) = x^b(s^B(\theta))$ since $x^{b\prime}(s) > 0$ from (2).

Proposition 3 *When the service is purely optional ($u_{\theta s} \equiv 0$) the energy price with independent pricing is always higher than with bundling that is for all $\theta \in \Theta$ but this not necessarily the case for the service rate.*

$$\begin{aligned} p^I &= u_x(x^I, s^I, \theta) = c'(x^I) + \varphi(\theta) u_{\theta x}(x^I, s^I, \theta) > p^B \\ r^I &> c'(s^I) \lesseqgtr r^B = c'(s^B) \end{aligned}$$

In the independent pricing strategy, it is costly for consumers to sign two contracts at different shops. Each shop has a cost of extracting information, the rates of the energy is higher than in the bundle situation.

Using (H4), one could improve this result.

6 Conclusion

Bundling energy and a contingent service is a profitable strategy for a energetician monopoly practising optimal nonlinear tariff. The consumers have a willingness to pay for the energy more important than their willingness to pay for the contingent service to satisfy heating necessary. The rates of the energy and the contingent service depend to the optional character of the contingent service and depend to the values of β.

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