Working Paper Series n° 532

March, 2010

"Health Care Providers Payments Regulation when Horizontal and Vertical Differentiation Matter"

David BARDEY, Chiara CANTA and Jean-Marie LOZACHMEUR

Institut d'Economie Industrielle (IDEI) – Manufacture des Tabacs
Aile Jean-Jacques Laffont – 21, allée de Brienne – 31000 TOULOUSE – FRANCE
Tél. + 33(0)5 61 12 85 89 – Fax + 33(0)5 61 12 86 37 – **www.idei.fr** – contact@cict.fr

Health care providers payments regulation when horizontal and vertical differentiation matter[1]

David Bardey[2], Chiara Canta[3] and Jean-Marie Lozachmeur[4]

March 15, 2010

[1]We gratefully acknowledge the financial support of the Fondation du Risque (Chaire Santé, Risque et assurance, Allianz).

[2]Ecole Polytechnique de Paris, Toulouse School of Economics (GREMAQ) and University of Rosario (Bogota).

[3]Toulouse School of Economics (GREMAQ).

[4]Toulouse School of Economics (IDEI and GREMAQ-CNRS).Corresponding Author: Jean-Marie Lozachmeur, Manufacture des Tabacs, 21 Allée de Brienne, F-31000 Toulouse. jean-marie.lozachmeur@univ-tlse1.fr. Tel: +33(0)561128564.

Abstract

This paper analyzes the regulation of payment schemes for health care providers competing in both quality and product differentiation of their services. The regulator uses two instruments: a prospective payment per patient and a cost reimbursement rate. When the regulator can only use a prospective payment, the optimal price involves a trade-off between the level of quality provision and the level of horizontal differentiation. If this pure prospective payment leads to underprovision of quality and overdifferentiation, a mixed reimbursement scheme allows the regulator to improve the allocation efficiency. This is true for a relatively low level of patients'transportation costs. We also show that if the regulator cannot commit to the level of the cost reimbursement rate, the resulting allocation can dominate the one with full commitment. In particular, some cost reimbursement might be optimal even for higher levels of transportation costs.

JEL Code: I18, L51.

1 Introduction

The literature dealing with the optimal regulation of health care providers' payments has been prolific. It has mainly focused on the desirability of mixed reimbursement schemes in the presence of providers' moral hazard, variable quality of care and cream skimming. As summarized in Newhouse (1996), more prospective payment schemes induce more effort on cost containment while inducing risk selection and lower quality. Conversely, retrospective payments may be useful to elicit a sufficient quality level or to avoid cream skimming strategies but to jeopardize cost containment. This literature usually adopts a principle-agent framework in which imperfect competition between health care providers is not an issue. The goal of this paper is precisely to revisit the question of the desirability of mixed payment schemes in a setting with non contractible horizontal and vertical differentiation on the providers' side. While non contractible vertical differentiation (understood here as the quality provision) has been the object of many studies, non contractible horizontal differentiation - like the physical location or product differentiation of health care providers - has not very much attracted the attention so far.

Indeed, empirical and anecdotal evidence shows that both providers' location and health services' differentiation are important features of health care markets, possibly affecting the nature of competition between providers and the quality of health care delivered to patients. In both cases, this choice constitutes for physicians a manner to attenuate competition intensities. Empirical evidence suggests that distance from providers is an important determinant of patients' choice. For instance, Tay (2003) estimates the importance of distance and quality in the choice of an hospital by acute myocardial infarction patients. She shows that spatial differentiation is important in explaining hospital choices, even though patients seem to trade-off quality and distance. However, at least in local markets, it is generally impossible to contract directly the degree of spatial differentiation.[1] Health care providers can also differentiate their products in many ways. While reimbursement schemes are usually different across medical specialties, providers belonging to a given specialty group are often not providing exactly the same kind of services. For instance, doctors can differ in their medical practices.[2] Hospital medical practices might not be homogeneous due to different treatment styles of affiliated doctors. A long as these differences are perceived by patients, this creates horizontal differentiation across services provided in the same areas. As pointed out by Epstein and Nicholson (2003) in the case of

[1] According to the level of decentralization in the health care system, some regulatory differences can appear between hospitals which belong to different regions. As we study competition in local markets, this situation is out of the scope of this paper.

[2] Physicians preferences towards different medical medical practices are often referred as school effects (Phelps and Mooney, 1993).

cesarean sections, the small area variation in hospital medical practices can be huge within markets. Doctors can also attempt to differentiate by other means. A look at the advertisements posted by general practitioners on the Yellow pages, though anecdotal, is fairly instructive. On the Paris Yellow Pages, one post says: "University Lecturer in Homeopathy. Fluent English" On the London Yellow Pages, one can find a general practice describing itself with these words: "All women doctors. Physiotherapist, Counselors, Acupuncture, Dermatology..."At least in terms of marketing, the attempt to differentiate is quite clear. Another example of differentiation is the specialization in alternative medical practices. In the Paris Yellow Pages, one can easily verify that 20% of general practitioners are specialized in some kind of alternative medicine such as homeopathy and acupuncture.[3]

Using a standard Hotelling model of spatial competition, we analyze health providers' strategies in terms of location and quality. Patients choose a provider and incur a transportation cost according to the distance between their location and the provider's one. Following Ma (1994), we assume that patients are also sensitive to the level of quality provided. We consider that quality not only affects the fixed cost of the health care but also the variable cost incurred by providers. Indeed, in most cases, the purchase of equipment by providers constitutes some fixed costs while their utilization generate variable costs.[4] On top of that, the regulator uses two instruments: a fixed payment per patient and a cost reimbursement rate. For instance, in some countries, general practitioners and specialists are reimbursed by a mix of capitation and fee-for-service. Also in most European health systems, hospitals are nowadays remunerated on a D.R.G. basis but some cost-based adjustments are still rather common (e.g. through *per diem* reimbursement for long inpatient treatments, or through adjustments based on the patients' mix).

Our results show that when the degree of horizontal differentiation is contractible, the standard result holds: a pure prospective scheme achieves the first best allocation. On the contrary, there is room for some cost reimbursement when it is not contractible. Similarly to a multitasking setting *à la* Holmstrom and Milgrom (1992), horizontal and vertical differentiation are substitutes in our model: an increase in horizontal differentiation leads

[3]In France, visits to general practitioners are equally remunerated, whatever is the G.P. specialization. In practice, the regulation and the level of reimbursements are usually different across specialities but the same regulatory scheme is likely to apply to all doctors in the same speciality. In the case of general practitioners, acupuncture treatments are not reimbursed at the same rate, and a big share of the price is paid out of pocket by the patient. If the acupuncture treatment is performed by the family general practitioner, however, the visit is totally reimbursed to the patient (as a practitioner visit).

[4]Our application to hospitals markets is restricted to health care systems where hospitals are characterized by a price regulation such as in many European health care systems or the US Medicare and Medicaid programmes (see Brekke *et al.* [2008] for a similar caveat).

to a decrease in quality, since locating further apart allows providers to relax quality competition. If the only instrument available to the regulator is a capitation payment, a trade-off between quality and differentiation occurs. This trade-off can be partially relaxed by some level of cost reimbursement.

When the regulator can commit on both instruments, our results reveal that a mixed reimbursement scheme is welfare improving if the allocation induced by an optimal prospective payment alone is characterized by underprovision of quality and overspecialization. The intuition for this result is that, if the transportation cost is low, providers have strong incentives to locate far apart, in order to dampen quality competition. Since the level of differentiation increases with the regulated price, the latter must be so low to elicit the optimal locations, that the resulting level of quality is too low. The regulator optimally introduces some cost reimbursement to make quality less costly.

When the regulator cannot commit to any instrument or can only commit to a cost reimbursement rate, the quality level is equal to its first best value while maximum differentiation occurs. Alternatively, when the regulator can only commit to a prospective payment, the optimal payment mechanism is sometimes able to improve the level of welfare obtained under full commitment. This occurs when the transportation cost is low or high enough, *i.e.* when the full commitment solution either implies full or zero cost reimbursement.

This paper relates to and borrows from two strands of the literature. In a framework where the demand for health care is sensitive to quality and costs are observable *ex post*, Ma (1994) shows that a pure prospective reimbursement leads to an optimal allocation. However, as Allen and Gertler (1991) and Ma (1994) himself point out, a mixed remuneration scheme may be optimal in the presence of cream skimming or dumping. This reimbursement system is motivated by the necessity to obtain uniform levels of quality and access to care, even if it reduces the effort in cost containment.[5] Economides (1989) analyzes the price competition market outcome in a Hotelling model with horizontal and vertical differentiation. Calem and Rizzo (1995) consider the strategic behavior of hospitals that compete in quality and that choose their location in a setting in which hospitals internalize part of the patients' transportation costs. The ingredients of their model are similar to ours but they focus on the equilibrium outcome and do not study the optimal regulation. Ma and Burgess (1993) and Wolinsky (1997) look at price competition and price regulation in a spatial duopoly model including the quality dimension. However, they do not consider the interaction between quality and location. To our knowledge, the only paper that tackles the problem of regulation when locations are endogenous is the one by Brekke

[5] Similarly, Chalkley and Malconsom (1998) show that a mixed reimbursement scheme improves on a prospective one when it is not efficient to treat all the patients.

et al. (2006). Their model is very close to ours but it does not include a variable cost that depends on the provider's quality levels, thus ruling out any possible role for cost reimbursement.

The paper is structured as follows: section 2 is devoted to the presentation of the model. Section 3 characterizes the optimal regulation in presence of full commitment, while section 4 considers the case of partial commitment. The last section concludes.

2 The model

We consider a standard Hotelling model, with two providers indexed by $i = 1, 2$, both located on a line of length one. Without loss of generality, we call provider 1 the provider whose location x_1 is on the left, and provider 2 the one whose location x_2 is on the right. There is a mass one of patients all purchasing one unit of medical care. Both providers offer the medical good with quality q_i, $i = 1, 2$. The unit price perceived by the patients is equal to zero since a third payer remunerates the providers.

For each unit of medical good supplied, each provider receives a prospective payment P and a cost reimbursement rate $\alpha \in [0, 1]$ based on variable costs reported. Since the demand of health care is fixed to one, each provider gets a payment $P + \alpha c q_i$ per patient where $c < 1$ is a variable cost per unit of quality q supplied. Quality is assumed to be not observable, but verifiable *ex post* by the regulator (see Laffont and Tirole, 1993). Importantly, the payment scheme is not conditioned on the degree of product differentiation or on the location of a provider. As pointed out in the introduction, in spite of the fact that health providers may differentiate themselves in order to reduce the competition intensity, they receive the same payment. Concerning hospitals competition, the payment to hospitals for the same treatments are generally the same and are independent of their location or kind of medical practice.

In the benchmark model, the timing is as follows: first, the regulator chooses the payment scheme that optimizes an utilitarian social welfare function. Then, providers decide where to locate over the line. In a next step, they set the level of quality provided.[6] Finally, patients choose which provider they visit. In section 4, we consider another timing in order to cope with lack of commitment issues.

The following sections consider the behavior of the different actors. First, we focus on patients' choice in terms of providers. Next, we analyze the

[6] In our model the level of quality is considered to be a short term decision variable. Here, quality is the result of short term investments in machines, diagnostic tests, amenities that may improve the outcome of the treatment or patients' comfort. It should not be interpreted as the quality of the provider (for instance the academic reputation of the medical school one provider attended), which is assumed to be exogenous and homogenous in the model.

providers' incentives with respect to health care quality and location decisions assuming that the regulator can commit on both instruments.

2.1 Patients' behavior

Patients are uniformly located along the line and they incur quadratic transportation costs. They perfectly observe the level of quality and the location of each provider. The patient with address $x \in [0,1]$ and choosing provider i with address x_i has an utility of the form:

$$U_i(x) = \bar{s} + q_i - t(x - x_i)^2,\ i = 1, 2,$$

where $\bar{s}$ is the common utility that each patient gets from a visit to a provider. In other words, we implicitly assume out any heterogeneity in the severity of the illness. Moreover, the patients' utility is increasing in the quality q_i supplied by the provider i and is decreasing in the transportation cost t. Patients benefit from full coverage so that their utility does not depend on the level of prices. We assume that $\bar{s}$ is large enough so as to ensure that the market is fully covered for any value of $q_i,\ i = 1,\ 2$.[7] The demand faced by provider 1 is thus equal to:

$$\bar{x} = \frac{1}{2}(x_1 + x_2) + \frac{q_1 - q_2}{2t\Delta}, \tag{1}$$

where $\Delta = (x_2 - x_1)$ represents the degree of horizontal differentiation between providers. As the market is fully covered, the demand faced by provider 2 is thus equal to $(1 - \bar{x})$.[8]

2.2 Providers' behavior

Providers are profit maximizers. Substituting the demand function described by equation (1), providers 1 and 2 profit functions are respectively:

$$\begin{aligned} \pi_1 &= (P - c'q_1)\left(\frac{1}{2}(x_1 + x_2) + \frac{q_1 - q_2}{2t\Delta}\right) - \frac{\gamma}{2}q_1^2, \qquad (2) \\ \pi_2 &= (P - c'q_2)\left(1 - \frac{1}{2}(x_1 + x_2) + \frac{q_2 - q_1}{2t\Delta}\right) - \frac{\gamma}{2}q_2^2, \end{aligned}$$

where $c'q = (1-\alpha)cq$ constitutes the net variable cost faced by providers, according to the reimbursement level α. $\gamma > 0$ measures the relative importance of the fixed cost incurred for a quality level q_i. It is worth noticing

[7] In a symmetric equilibrium, the market is covered for every $q_i \geq 0$ if and only if $\bar{s} \geq Max\left[t(\tilde{x})^2,\ t\,(1 - 2\,\tilde{x})\,/2)\right]$, where $\tilde{x}$ is the distance between the provider's location and the middle of the line.

[8] The transportation costs are fully borne by patients. In the physical location interpretation of the model, this rules out the possibility of home visits by the provider. This assumption is reasonable as long as the patients have to pay out-of-pocket to get home visits from general practitioners, unless their health status makes it necessary.

that in our setting, regulating the cost reimbursement or the marginal cost is equivalent. Indeed, in our framework, the level of quality has an effect on both variable and fixed costs.[9] As in Ma (1994), the cost reimbursement only depend on variable costs. The provision of quality may require to invest in equipment and machines needed to perform some tests or treatments. We allow health care providers to report the functioning cost of these machines but we assume out the possibility to claim the reimbursement of the fixed cost. This seems realistic as the imputation of the fixed cost to each single act may be difficult or even prohibited by law. Usually the fixed costs related to the equipment of a practice are completely in charge of the provider.

As in a standard backward analysis, we first analyze the providers' quality choice. Then, we focus on the location sub-game equilibrium.

2.2.1 Quality choice

Providers choose the level of quality that maximizes their profit given their respective location x_1 and x_2. Each provider's strategy set in this subgame is thus $\Re^+$. Assuming an interior solution and maximizing the profit of provider i with respect to q_i, $i = 1, 2$ yield respectively the following first order conditions:[10]

$$\frac{(P - c'q_1)}{2t\Delta} - c'\left(\frac{1}{2}(x_1 + x_2) + \frac{q_1 - q_2}{2t\Delta}\right) = \gamma q_1, \tag{3}$$

$$\frac{(P - c'q_2)}{2t\Delta} - c'\left(1 - \frac{1}{2}(x_1 + x_2) + \frac{q_2 - q_1}{2t\Delta}\right) = \gamma q_2. \tag{4}$$

Using (3) and (4) for a symmetric equilibrium in which $x_1 = 1 - x_2$ gives:

$$q^*(\Delta, .) = \frac{P - c't\Delta}{c' + 2t\gamma\Delta}. \tag{5}$$

Differentiating (5) with respect to P, c' and Δ yields the following comparative statics:

$$\begin{aligned}
\frac{\partial q^*(\Delta,.)}{\partial P} &= \frac{1}{c' + 2t\gamma\Delta} > 0, \\
\frac{\partial q^*(\Delta,.)}{\partial c'} &= -\frac{2\gamma t^2\Delta^2 + P}{(c' + 2t\gamma\Delta)^2} < 0, \\
\frac{\partial q^*(\Delta,.)}{\partial t} &= -\frac{\left(c'^2 + 2P\gamma\right)\Delta}{(c' + 2t\gamma\Delta)^2} < 0, \\
\frac{\partial q^*(\Delta,.)}{\partial \Delta} &= -\frac{t\left(c'^2 + 2\gamma P\right)}{(c' + 2t\gamma\Delta)^2} < 0.
\end{aligned} \tag{6}$$

[9] For instance, a provider may decide to buy the equipment to make radiographies inside his practice. The purchase of the machine constitutes a fixed cost while it affects the variable cost of the provider's diagnostic according to the number of radiographies provided.

[10] The second order conditions are fulfilled since $\partial^2\pi_i/\ \partial q_i^2 = -(2c'/2t\Delta) - \gamma < 0$.

Remark 1 *The level of quality increases in the prospective payment and decreases in the variable cost, the transportation cost and the differentiation intensity.*

As the marginal return of quality is increasing in P, q^* is increasing in the prospective payment P. Quality obviously decreases with the net variable cost parameter c' and the fixed cost parameter γ. t captures the horizontal differentiation sensitivity of the demand. Thus the higher is t the lower is the quality competition intensity. Clearly, the higher is the degree of horizontal differentiation Δ, the lower are the incentives to provide high quality, since the demand is more captive due to the large distance among providers. This implies that horizontal and vertical differentiation are substitutes: the higher (lower) is the degree of horizontal differentiation, the lower (higher) is the level of quality. In other words, horizontal differentiation dampens quality competition.[11]

2.2.2 Location choice

For given levels of regulatory parameters, each provider sets his location on the Hotelling line.[12] More precisely, provider 1 maximizes his profit function (2) with respect to x_1. Using the envelope theorem, the first order condition is:

$$(P - c'q_1)\left(\frac{1}{2} + \frac{q_1 - q_2}{2t\Delta^2} - \frac{\partial q_1}{\partial x_1}\frac{1}{2t\Delta}\right) = 0. \tag{7}$$

In a symmetric equilibrium, substituting equation (5) in (7) and assuming an interior solution gives:

$$(P - c'q^*)\left(1 - \frac{\partial q^*(\Delta,.)}{\partial x_1}\frac{1}{t\Delta}\right) = 0.$$

Note that since $(P - c'q^*) = 0$ implies negative profits, this equation holds as long as $(1 - (\partial q^*(\Delta,.)/\partial x_1)(1/t\Delta)) = 0$. Substituting the expression for $(\partial q^*(\Delta,.)/\partial x_1)$, this condition is satisfied if and only if:

$$\frac{\left(2\gamma P + c'^2\right)}{(c' + 2t\gamma\Delta^*)^2} = \Delta^*, \tag{8}$$

[11] To ensure the existence of a symmetric equilibrium in the two stage game, we need to check that, for every pair of locations such that $x_1 = 1 - x_2$, the providers earn non negative profits by setting their quality according to the rule $q = q^*(\Delta,.)$. The condition that has to hold to ensure non negative profits is

$$(c' + 2t\gamma\Delta)(2t\gamma\Delta P + c'^2 t\Delta) \geq \gamma(P - c'^2).$$

[12] We restrict the location strategy set of provider 1 to be $[0, 1/2[$, and the strategy set of provider 2 to $]1/2, 1]$. By excluding the possibility that the providers both locate in the point $1/2$, we ensure that the problem is well defined for each value of the regulatory parameters. In fact, equation (5) shows that if $\Delta = 0$ and $c' = 0$, there would exist no Nash equilibrium in the quality subgame.

which defines implicitly $\Delta^*(.)$ as a solution of a third degree polynomial. Note that at any solution of (8), $\Delta^*(.)$ is strictly positive.[13] The equilibrium level of quality is thus given by $q^*(.) = q^*(\Delta^*, .)$. Proposition 1 establishes some useful comparative statics results:

Proposition 1 *Comparative statics on condition (8) show that the equilibrium values of* $\Delta^*(.)$ *and* $q^*(.)$ *are both increasing in* P *and decreasing in* c' *and* t.

Proof. See appendix B. ■

As usual in horizontal differentiation models, there are two opposite effects at work: a demand and a strategic effect (Tirole, 1988). On the one hand, for a given location of the competitor, reducing the level of differentiation leads to higher market shares (demand effect). On the other hand, less differentiation leads to tougher competition on quality which drives the providers to increase the level of differentiation in order to dampen quality competition (strategic effect). In our model, the demand effect for provider 1 in a symmetric equilibrium is:

$$\frac{\partial D_1}{\partial x_1} = \frac{1}{2},$$

while the strategic effect is captured by:

$$\frac{\partial D_1}{\partial q_2}\frac{\partial q_2}{\partial x_1} = \frac{1}{2\Delta}\frac{\left(c'^2 + 2\gamma P\right)}{\left(c' + 2t\gamma\Delta\right)^2}.$$

When P increases or c' decreases, the price-cost margin increases. This implies a higher strategic effect, while the demand effect is not affected so that providers choose a higher level of differentiation. However, when t increases, quality competition in the second stage becomes less intensive so that the strategic effect is weaker thus leading to a lower level of horizontal differentiation.

As shown in section 2.2.1, the quality level in the last stage is increasing in the price-cost margin level. However, since the level of differentiation increases as well, the equilibrium quality level may also decrease because of the reduction in quality competition. Proposition 1 states that the direct effect dominates so that the equilibrium level of quality increases. Direct effects also dominate for a change in the transportation cost, so that the equilibrium level of quality decreases in t.

3 Optimal regulation with full commitment

In this section, we analyze the optimal regulation scheme. As usual, we start with a first best analysis. We show how the first best can be implemented

[13]We show in appendix A that Δ^* is a global maximum and unique in $\Re^{++}$.

through a prospective payment when locations are exogenous (Ma, 1994). Next, we characterize the optimal regulation scheme when providers can strategically set their locations.

3.1 First best allocation

The social planner maximizes an utilitarian social welfare function. For purpose of simplicity, we assume that the social planner puts the same weight on the consumers' surplus and the providers' profit. The optimal allocation maximizes the social welfare function, which, under a symmetric equilibrium, has the form:[14]

$$\begin{aligned} W &= \int_0^{\frac{1}{2}} U_1(x)dx + \int_{\frac{1}{2}}^1 U_2(x)dx + \pi_1 + \pi_2 \\ &= q(1-c) - \gamma q^2 + \frac{t(6x_1\Delta - 1)}{12}. \end{aligned} \tag{9}$$

The social planner takes into account benefits and costs of quality and minimizes the level of transportation costs. The optimal levels of quality and differentiation are then:

$$q^{FB} = \frac{1-c}{2\gamma}, \tag{10}$$

$$\Delta^{FB} = \frac{1}{2}. \tag{11}$$

The assumption $c < 1$ ensures that a positive level of quality is always optimal. The optimal level of quality is obviously decreasing with the marginal cost c and with the parameter γ that weights the fixed cost. The optimal level of differentiation is equal to $1/2$, a standard result in the Hotelling model with a line of length one.

Note that this optimal allocation can easily be achieved when locations are exogenously set to their optimal value. This corresponds to the case where the regulator can control directly the level of horizontal differentiation

[14]Total transportation costs T are computed as follows:

$$T = -\int_0^{x_1} t(x_1 - x)^2 dx + -\int_{x_1}^{\frac{1}{2}} t(x - x_1)^2 dx - \int_{\frac{1}{2}}^{x_2} t(x_2 - x)^2 dx + \int_{x_2}^1 t(x - x_2)^2 dx.$$

Since in a symmetric equilibrium $x_2 = 1 - x_1$,

$$\begin{aligned} T &= \frac{2}{3}t\left[x_1^3 + (\frac{1}{2} - x_1)^3\right] \\ &= \frac{2}{3}t\left[\frac{1 + 6x_1(2x_1 - 1)}{8}\right]. \end{aligned}$$

Since $\Delta = 1 - 2x_1$, this yields $T = 1/12t\,[1 - 6x_1\Delta]$.

(for instance by issuing licences conditioned on location). Indeed, if the differentiation level is equal to 1/2, the social planner is able to elicit the optimal level of quality by a prospective payment P such that the right hand side of (5) and (10) are equalized. This result, first pointed out in Ma (1994) is resumed in the following remark:

Remark 2 *If locations are contractible, a pure prospective payment*

$$P = \left(c + \gamma t - c^2\right)/2\gamma$$

allows to implement the first best allocation.

Ma's result holds as long as the demand is sensitive to the quality level offered by the providers. Note that, with exogenous locations, the optimal regulated price is increasing in the transportation cost parameter t. High transportation costs reduce the providers' incentives to offer a high level of quality since the demand they face becomes less elastic with respect to quality. Thus in order to enhance competition among providers, the regulator has to increase the prospective payment.

3.2 Endogenous locations

Consider now the case in which locations are not contractible. The optimal regulatory parameters P and c' are the solutions of the following problem:

$$\begin{aligned}&\max_{P,c'} (1-c)q(.) - \gamma q^2(.) + \frac{t\left[3\left(\Delta(.) - \Delta^2(.)\right) - 1\right]}{12},\\ &\text{s.t. } (\nu)\ c' \leq c,\ (\mu)\ c' \geq 0,\end{aligned}$$

where ν and $\mu \geq 0$ are the Lagrange multipliers associated to the feasible domain of c'. If $\nu > 0$ ($\mu = 0$), then $c' = c$ which corresponds to the case where there is no cost reimbursement *i.e.* $\alpha = 0$, while $\mu > 0$ ($\nu = 0$) implies full cost reimbursement *i.e.* $\alpha = 1$. The first order conditions with respect to P and c' are respectively:[15]

$$\frac{dq^*(.)}{dP}(1 - c - 2\gamma q) + \frac{t}{4}\frac{d\Delta^*(.)}{dP}(1 - 2\Delta) = 0, \quad (12)$$

$$\frac{dq^*(.)}{dc'}(1 - c - 2\gamma q) + \frac{t}{4}\frac{d\Delta^*(.)}{dc'}(1 - 2\Delta) - \nu + \mu = 0. \quad (13)$$

In the following sections, we characterize the optimal regulation in two cases. First, we consider a regulator constrained to use a pure prospective payment. We show that, in general, this single instrument does not allow to implement the first best allocation. We thus turn to the case where the regulator has one more instrument, namely the cost reimbursement rate α.

[15] We assume that the second order conditions of the problem always hold.

3.2.1 Optimal pure prospective price

To make a parallel between our analysis and the one of Brekke *et al.* (2006), let us first assume that the regulator is constrained to use a prospective payment alone. We obtain the following result:

Proposition 2 *If the regulator is constrained to use a pure prospective payment, the first best allocation described by equations (10) and (11) can be reached if and only if* $t = \bar{t} = (2 - c)/\gamma$. *Otherwise, if* t *is greater(lower) than* $\bar{t}$, *the second best allocation is characterized by over(under)provision of quality and under(over)differentiation.*

Proof. See appendix C. ■

This result is in line with the findings of Brekke *et al.* (2006). The intuition for this result is related to the size of the above mentioned demand and strategic effects. If t is low enough, the strategic effect is strong, since the change in the level of differentiation necessary to dampen competition is high. In this case, the price inducing the first best level of differentiation is so low that underprovision of quality occurs. The optimal price realizes the trade-off between these two effects so that one ends up with underprovision of quality and overdifferentiation. The reverse reasoning can be applied to the case in which t is high.

3.2.2 Optimal policy mix

In this subsection, we characterize the optimal reimbursement scheme that can be achieved when the regulator has two instruments: a prospective price and a cost reimbursement rate. There are three regimes to consider depending upon the values of c': regime A where c' is constrained to be equal to 0, regime B where $c' \in (0, c)$ and regime C where c' is constrained to be equal to c. Denote each regime's equilibrium values of quality and differentiation at the optimum by $\left(q^k, \Delta^k\right)$ where $k = A, B$ or C. Consider now the price P that decentralizes the first best level of horizontal differentiation. Equalizing the RHS of (8) and (11) and allowing some cost reimbursement yield:

$$P = \left[(t\gamma + c')^2 - 2c'^2\right]/4\gamma.$$

This gives the following equilibrium level of quality:

$$q\left(P, c'\right) = \left(t\gamma - c'\right)/4\gamma. \tag{14}$$

This level of quality is monotonically decreasing in c'. Thus setting an appropriate level of c' allows to decentralize the first best level of quality. Of course, the level of c' can only belong to a certain range of parameters. When the regulator uses a cost reimbursement rate in addition to a pure prospective payment, the following result applies:

Proposition 3 *For any triplet* (c, t, γ) *and* $\underline{t} = 2(1-c)/\gamma$ *the following statements hold:*

(i) If $t < \underline{t}$*, regime A is optimal. The second best allocation is then characterized by* $q^A < q^{FB}$ *and* $\Delta^A > \Delta^{FB}$ *so that there is underprovision of quality and overdifferentiation.*

(ii) If $t \in [\underline{t}, \overline{t}]$*, regime B is optimal. The first best allocation* $(q^B, \Delta^B) = (q^{FB}, \Delta^{FB})$ *can be implemented with a mixed reimbursement scheme* (P^B, c'^B) *such that:*

$$P^B = \frac{\gamma t^2}{2} - \frac{(c-1)^2}{\gamma}, \tag{15}$$

$$c'^B = 2(c-1) + \gamma t. \tag{16}$$

(iii) If $t > \overline{t}$*, regime C is optimal. The second best allocation is then characterized by* $q^C > q^{FB}$ *and* $\Delta^C < \Delta^{FB}$ *so that there is overprovision of quality and underdifferentiation.*

Proof. See appendix D. ■

The regulator faces a trade-off since both quality and differentiation increase with the reimbursement parameter. For given levels of the cost parameters, the providers have strong incentives to locate apart if the transportation cost is low. Decreasing the regulated price in order to reduce the level of horizontal differentiation has a negative effect on quality as well. However, if an additional instrument, such as a cost reimbursement rate, is available to the regulator, the latter can use it to balance these incentives. This allows to enhance welfare and, for a certain range of parameters, to reach the first best allocation.

Remember that when $t < \overline{t}$, the pure prospective payment inducing the first best level of differentiation is so low that there is underprovision of quality. Since this level of quality is decreasing in the level of c', increasing the cost reimbursement (or decreasing c') allows to increase the level of quality without changing the level of horizontal differentiation. The trade-off occurring when the regulator can only use the pure prospective payment thus disappears. However, the maximal reimbursement rate is constrained to be lower than one. Thus, for lower values of t ($< \underline{t}$), the regulator can only partially increase the level of equilibrium quality by reimbursing all the variable costs. In this case, the trade-off mentioned in the previous section still occurs and the second best optimum still leads to underprovision of quality with overdifferentiation. Finally, when t is larger than $\overline{t}$, using cost reimbursement is no longer optimal. Indeed, since the quality level q in (14) is decreasing in c' and the social planner would like to decrease the level of quality, there is no room for using a cost reimbursement mechanism (one would like to tax variable costs associated to the level of quality instead of subsidizing them).

In other words, if transportation costs are low enough, providers have incentives to impose high costs on the patients located close to the center (competitive area) in order to reduce their sensitivity to quality and relax competition. In this model there is no cream skimming since demand is inelastic and the level of quality is the same for all patients. However, location is a way to discriminate among patients, since not all of them incur the same transportation costs. In this context, cost reimbursement is a useful tool to prevent providers to overdifferentiate and offer a suboptimal level of quality.

4 Optimal regulation with partial commitment

So far, we have assumed that the government is able to commit to a prospective and a retrospective payment. However, a regulation policy set before the providers' differentiation choice is done might be non credible. In particular, once the level of differentiation is chosen, the regulator has always an incentive to renegotiate the remuneration scheme in order to obtain a first best quality level.

When the regulator is not able to commit to both instruments (*i.e.* its policy is set after the providers location's choice), the final allocation has the same form as in the non commitment case depicted in Brekke *et al.* (2006). The regulator chooses *ex post* the first best level of quality. But for a given level of quality, maximum differentiation occurs so that the two providers locate at the two extremes of the Hotelling line.

In our setting however, it is interesting to consider the case in which the regulator cannot fully commit to the level of only one policy instrument. For instance, the prospective and retrospective components of the payment schedule may not be negotiated at the same time. In many countries, the amount of the prospective reimbursement is fixed by law for each diagnostic group (DRG), while some cost reimbursement such that a *per diem* can be the object of further negotiations. This situation occurs in health care systems where the budget for some specialities are voted by law. In this context, the regulator announces a reimbursement rate that can be the object of several revisions during the current year in order to satisfy the budget constraint.[16] In health care systems which are characterized by a public administration that intervenes at different levels, some commitment problems may arise as well. In Italy for instance, the reimbursements rates are activity based. For hospitalizations they rely on DRGs' nomenclature. In spite of the fact that DRGs are determined at the national level, the regions are allowed to modify the nomenclature or the amounts corresponding to the DRGs. In such a case, the different levels of government involved reduce the commitment of the regulator.

[16]In France, this system is called "floating point".

In a first part, we study the case where the regulator cannot commit to a prospective price. The timing is then as follows: first, the regulator chooses the cost reimbursement rate that maximizes the social welfare function. Then, providers decide where to locate over the line. In a next step, the regulator sets the level of prospective payment. Finally, the providers choose the level of quality provided and patients choose which provider they visit. We then turn to the reverse case where the regulator can only commit to a pure prospective payment while the cost reimbursement rate is chosen after the providers' location choice.

4.1 Commitment to a retrospective payment

When the regulator can only commit to a retrospective payment, the optimal P is set after the location choices are made. In this case, the regulator chooses the level of P inducing the first best level of quality. Equalizing (5) to (10), this yields:

$$P = \frac{(1-c)\left(c' + 2t\gamma\Delta\right)}{2\gamma} + c' t\Delta \geq 0.$$

The location choice is the result of the following program:

$$\max_{x_1} \pi_1 = (P - c' q_1)\left(\frac{1}{2}(x_1 + x_2) + \frac{q_1 - q_2}{2t\Delta}\right) - \frac{\gamma}{2} q_1^2,$$

where $P = (1-c) : (c' + 2t\gamma\Delta)/2\gamma + c' t\Delta$ and $q_1 = q_2 = (1-c)/2\gamma$. This leads to the following proposition.

Proposition 4 *If the regulator can only commit to a retrospective payment level, the first best level of quality described by (10) is achieved and there is maximum differentiation.*

To understand this result, observe that the price cost margin can be decomposed as the product of two functions: one depending solely on c' and the other on Δ. Indeed one has:

$$P - c' q_1 = 2t\Delta(1 - c + c'),$$

so that the program of provider 1 can be rewritten as:

$$\max_{x_1} \pi_1 = 2t\Delta(1 - c + c')\left(\frac{1}{2}(x_1 + x_2)\right).$$

The marginal effect of differentiation on profits thus only depends linearly on c' so that the differentiation's choice is independent of the cost reimbursement parameter. It is then easy to show that the resulting level of differentiation is such that $\Delta = 1$.

4.2 Commitment on the prospective payment

When the regulator can only commit to a prospective price, the level of quality continues to be given by (5). Taking P and Δ as given, the regulator chooses c' such that it maximizes W as given by (9). As in the preceding section, there are three regimes to consider depending upon the values of c' adopted in stage 3 **:** regime A where $c'^{A} = 0$, regime B where $c'^{B} \in (0, c)$ and regime C where $c'^{C} = c$.

Before going further, we prove the following lemma in appendix E:

Lemma 1 *Regimes A and C are respectively credible if and only if $t \leq \underline{t}$ and $t \geq \overline{t}$. If implemented, the equilibrium allocations $\left(q^{k}, \Delta^{k}\right)$ are the ones described in proposition 3 for $k = A, C$.*

This result is not surprising in the light of proposition 3. The question behind is in which case a regulator can commit to a price that induces her to choose a corner solution for cost reimbursement at the third stage. As stated in proposition 3, the regulator always chooses an interior solution for the cost reimbursement when $t \in \left[\underline{t}, \overline{t}\right]$ since it allows to completely eliminate the trade-off between the levels of horizontal and vertical differentiation. However, say when $t < \underline{t}$, the regulator is constrained to reimburse all the costs and sets a price that trade-offs between overspecialization and underprovision of quality. It thus turns out that the regulator can choose a price leading to full cost reimbursement only if it is optimal to do so with full commitment. The same reasoning applies when $t > \overline{t}$.

The last lemma does not mean however that regime A and C are respectively optimal whenever $t \leq \underline{t}$ and $t \geq \overline{t}$. To see this, let us analyze the optimal price and cost reimbursement when the latter turns out to be interior, that is to say when regime B occurs. In this case, the optimal level of quality is implemented with c'^{B} such that $q^{*}(\Delta, .) = q^{FB} = 1 - c/2\gamma$ where $q^{*}(\Delta, .)$ is given by (5). Solving this equation yields:

$$c'^{B}(\Delta, P) = 2\gamma \left(P - (1-c)\, t\Delta\right) / \left(1 - c + 2t\gamma\Delta\right). \tag{17}$$

Provider 1 thus chooses x_1 such that it solves:

$$\max_{x_1} \pi_1 = (P - c'^{B}\left((\Delta, P)\right) q^{FB})\frac{1}{2}(x_1 + x_2).$$

It is important to note that the price cost margin $\left(P - c'(\Delta, P)\right) q^{FB}$ can be rewritten as the product of two functions: one depending solely on P and the other depending solely on the differentiation level Δ. To see this, a straightforward manipulation leads to:

$$(P - c'^{B} q^{FB}) = (2\gamma P + (1-c))\frac{t\Delta(1-c)}{1 - c + 2t\gamma\Delta}.$$

As a consequence, the marginal effects of differentiation is proportional to P so that the differentiation's choice is not affected by the level of the prospective price. Indeed, it is easy to show that the equilibrium values of x_1 and x_2 are such that $\Delta^B \equiv \Delta^B(c,t,\gamma)$ which is implicitly given by the solution of the following second degree polynomial:[17]

$$2t\gamma\left(\Delta^B\right)^2 + (1-c)\,\Delta^B - (1-c) = 0 \tag{18}$$

In other words, for any price P^B such that $c'^B\left(\Delta^B, P^B\right) \in [0,c]$, regime B leads to Δ^B. According to equation (17), the range of admissible prospective prices ensuring $c'^B \in [0,c]$ is defined by $P^B \in \left[(1-c)\,t\Delta^B, t\Delta^B + c(1-c)/2\gamma\right]$. We can now state the following lemma:

Lemma 2 *Regime B is credible for any values of t. If implemented, the equilibrium allocation $\left(q^B, \Delta^B\right)$ is such that $q^B = q^{FB}$ and Δ^B is the solution to* (18)*. The corresponding optimal cost reimbursement is such that*

$$c'^B = 2\gamma\left(P^B - (1-c)\,t\Delta^B\right) / \left(1 - c + 2t\gamma\Delta^B\right),$$

and there is a continuum of optimal prices defined by:

$$P^B \in \left[(1-c)\,t\Delta^B, t\Delta^B + c(1-c)/2\gamma\right].$$

A direct consequence of this lemma is that regime B yields the first best allocation for $t = \underline{\underline{t}} = (1-c)/2\gamma < \underline{t}$. Indeed, it is easy to show that the differentiation level implicitly described by equation (18) leads to $\Delta^B = \Delta^{FB} = 1/2$ if $t = \underline{\underline{t}}$ (and $\Delta^{*B} \lesseqgtr 1/2$ if $t \gtreqless \underline{\underline{t}}$). The following proposition describes more generally the sets of t for which regime B is optimal.

Proposition 5 *(i) There always exists $\underset{\cdot}{t}$ with $\underline{\underline{t}} < \underset{\cdot}{t} < \underline{t}$ such that regime B is optimal for any $t < \underset{\cdot}{t}$.*

(ii) There can exist $\dot{t}$ with $\dot{t} > \bar{t}$ such that regime B is optimal for any $t > \dot{t}$.

Proof. See appendix F. ■

Summarizing, only regime B is credible if $\underline{t} < t < \bar{t}$. Regime A is credible and optimal if $\underset{\cdot}{t} < t < \underline{t}$. Regime B is always optimal if $t < \underset{\cdot}{t}$. As regime B is characterized by a continuum of equilibria with $c'^B \in [0,c]$, a partial cost reimbursement is compatible with a welfare improvement with respect to the full commitment solution. When the transportation cost is higher than

[17] This second degree polynomial has 2 roots, one negative and strictly smaller than $-(1-c)/4t\gamma$, and one positive belonging to the interval $]0,\ 1[$. The second order condition with respect to x_1, $4t\gamma\Delta + 1 - c \geq 0$ holds if and only if $\Delta \geq -(1-c)/4t\gamma$. Thus the maximum of the profit function is attained when Δ equals the positive root of the polynomial.

$\bar{t}$, either regime C is always optimal or the regime C dominates if $t < \dot{t}$ and regime B dominates if $t > \dot{t}$. This implies that some cost reimbursement may be optimal under partial commitment even for high transportation costs. With respect to full commitment, the resulting level of welfare is enhanced. Figure 1 illustrates the optimal regimes depending upon the level of t under full commitment and partial commitment on P.

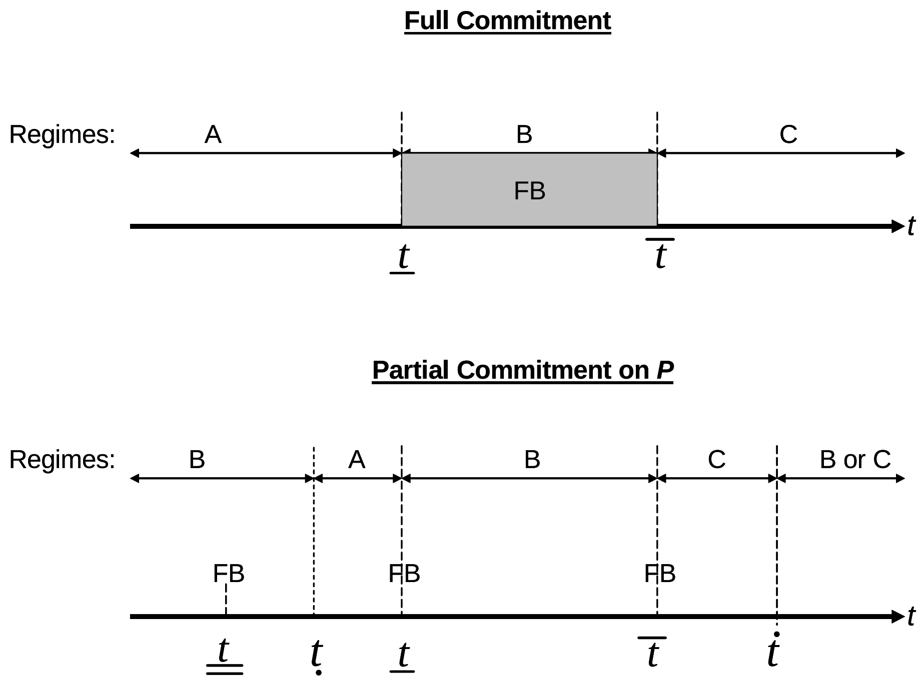

FIGURE 1: Regimes under full commitment and partial commitment on P

4.3 Illustration

In the previous section we showed that regime C is credible if and only if $t \geq (2-c)/\gamma$, while regime B is credible in any parameters' range. If $t = (2-c)/\gamma$, the first best is implemented by regime C; regime B is thus dominated. When $t > (2-c)/\gamma$, regime C yields the first best quality level. However the resulting allocation is characterized by underspecialization. Conversely, regime B is characterized by overprovision of quality and underdifferentiation. Without a close form solution for Δ^B, the level of differentiation in regime B, it is not possible to compare analytically the level of welfare obtained in the two regimes. In this section we use numerical simulations in order to check which regime dominates in terms of social welfare.

In particular, we set $c = 0.3$, and we consider different levels of the parameter γ. For small values of this parameter, regime C always dominates the other. In figure 2 we plot the welfare level obtained in regime B (W^B)

and in regime C (W^C) when $\gamma = .1$ and $t \geq (1-c)/\gamma$. At $t = (2-c)/\gamma = 17$, regime C dominates, as it was shown analytically, and this is true for all values of t. This result is not particularly surprising, since for a low value of the fixed cost parameter, the overprovision of quality of regime C becomes less important, compared to the possible gains due to a less distorted level of differentiation.

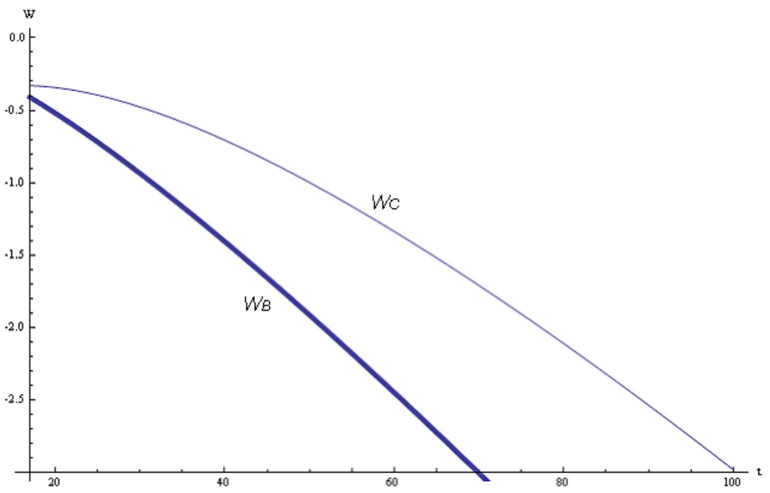

FIGURE 2: Regime C dominates ($\gamma = 0.1,\ c = 0.3$)

For greater values of γ, however, regime B might dominate regime C if t is high enough. Consider the example reported in figure 3, where $\gamma = 1.5$. We plot the welfare level obtained in regime B (W^B) and in regime C (W^C). At $t = (2-c)/\gamma \simeq 1.3$, regime C dominates. This is not true anymore starting from a certain level of t. This is justified by the fact that the overprovision of quality in regime C has a greater negative impact on welfare when fixed costs become more important in the cost function. In this regime, if t increases, the regulator needs to further distort up the provision of quality in order not to reduce too much the level of differentiation. In regime B, on the other hand, the level of quality is always set at its first best level. For high values of γ, regime B dominates, even though increasing t makes underdifferentiation worse. In such cases, for values of the transportation cost parameter greater than a certain threshold, partial commitment improves on the second best result with full commitment.

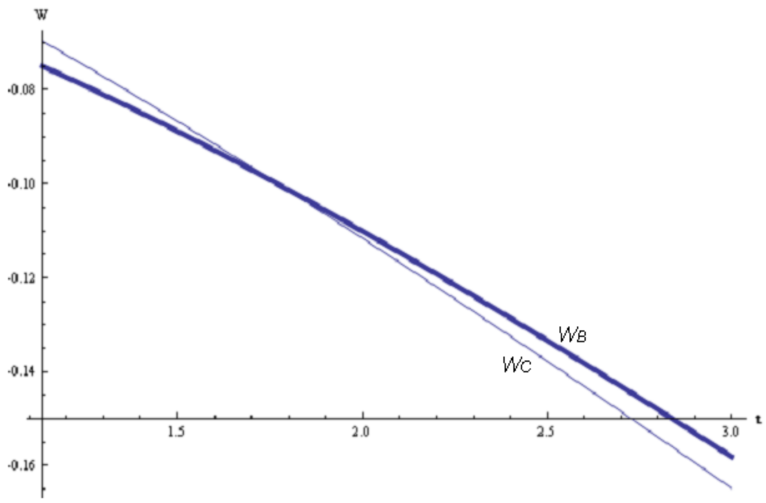

FIGURE 3: Regime B dominates if t high enough ($\gamma = 1.5,\ c = 0.3$)

5 Conclusion

In this paper, we analyze the optimality of a mixed cost reimbursement when providers set strategically their levels of horizontal differentiation and of quality provided. The question is relevant since a pure prospective reimbursement scheme may fail to decentralize the optimal allocation when there is more than one dimension of choice on the providers' side. Moreover, cost reimbursement has been many times advocated in the literature dealing with the regulation of payments to health care providers. The main reason is the possibility of dumping or cream-skimming behaviors on the supply side of the health care sector. We consider the model of Ma (1994), applied to a context in which two providers compete over quality on an Hotelling line. Extending the framework adopted in Brekke *et al.* (2006), we allow the health care providers to incur some variable costs for each unit of quality supplied. This gives the regulator the opportunity to use a mixed reimbursement scheme involving a pure prospective payment and a cost reimbursement rate applied to variable costs as in Ma (1994).

We show that a pure prospective payment implies a trade-off between the desirable provision of quality and horizontal differentiation. Then we show that this trade-off can be mitigated or even eliminated when allowing the regulator to reimburse partially or totally the variable costs due to higher quality levels. This happens when a pure prospective payment leads to underprovision of quality and overdifferentiation. In this case, cost reimbursement allows to increase the provision of quality while keeping the price level low enough to limit horizontal differentiation. The main conclusion of this paper is that a pure prospective reimbursement scheme itself may be not suitable in cases in which the level of specialization is not contractible. This gives a new rationale for retrospective payments to health care providers.

If the regulator is not able to commit *ex ante* to the reimbursement scheme, or can only commit to the cost reimbursement rate, this results in maximal differentiation and optimal provision of quality. Conversely, if the government can only commit on the prospective payment, the resulting allocation depends on the parameters' value. In particular, this form of partial commitment is an improvement over the full commitment scenario if the transportation costs are very low. In some cases, partial commitment is superior in terms of welfare results even when transportation costs are very high. Interestingly, some cost reimbursement may be optimal with partial commitment, while it is not under full commitment.

This paper could be extended in several directions. First, similarly to Brekke *et al.* (2008), a dynamic approach in which quality investment are long run decisions could be useful to understand the design of an optimal dynamic regulation. Second, it would provide useful insights to consider a mixed oligopoly framework in which hospitals are characterized by different objectives (private, public, collective, *etc...*) as in Cremer and Thisse (1991) or more recently in Herr (2009).

References

[1] Arrow K. J., 1963, Uncertainty and the Welfare Economics of Medical Care, *The American Economic Review*, 53, 5, 941-973.

[2] Allen R. and P. Gertler, 1991,Regulation and the Provision of Quality to Heterogeneous Consumers: The Case of Prospective Pricing of Medical Services, *Journal of Regulatory Economics*, 3, 4, 361-375.

[3] Brekke K. R., R. Nuscheler and O. Straume, 2006, Quality and Location Choices Under Price Regulation, *Journal of Economics & Management Strategy*, 15, 1, 207-227.

[4] Brekke K.R, R. Celini , L. Siciliani L and O. Straume, 2008, Competition and quality in regulated markets: a differential-game approach, CEPR Discussion Paper.

[5] Calem P. S. and J.A. Rizzo, 1995, Competition and Specialization in the Hospital Industry: an Application of Hotelling's location model, *Southern Economic Journal*, 61, 1183-1198.

[6] Chalkley M. and J. Malcomson, 1998, Contracting for Health Services with Unmonitored Quality, *The Economic Journal*, 108, 1093-1110.

[7] Choné P. and C.A. Ma, 2009, Optimal Health Care Contracts under Physician Agency, Boston University Working Papers Series WP2007-004.

[8] Cremer H., M. Marchand and J.-F. Thisse, 1991, Mixed oligopoly with differentiated products, *International Journal of Industrial Organization* 9(1), 45-53.

[9] Economides N., 1989, Quality Variations and Maximal Variety Differentiation, *Regional Science and Urban Economics*, 19, 21-29.

[10] Ellis R.P. and T.G. McGuire, 1986, Provider behavior under prospective reimbursement: Cost sharing and supply, *Journal of Health Economics*, 5, 2, 129-151.

[11] Ellis R.P. and T.G. McGuire, 1990, Optimal payment system for health services, *Journal of Health Economics*, 9, 2, 375-396.

[12] Epstein A. and S. Nicholson, 2009, The formation and Evolution of Physicians' Treatment Styles: An Application to Cesaeran Sections, *Journal of Health Economics*, 28, 6, 1126-1140.

[13] Herr A., 2009, Product differentiation and welfare in a mixed duopoly with regulated prices: The case of a public and private hospital, IWQW Discussion Paper.

[14] Holmstrom B. and P. R. Milgrom, 1991, Multitask Principle-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design, *Journal of Law, Economics and Organization*, 7, 24-52.

[15] Hotelling H., 1929, Stability in Competition, *The Economic Journal*, 39, 41-57.

[16] Jack W., 2006, Optimal risk adjustment in a model with adverse selection and spatial competition, *Journal of Health Economics*, 25, 5, 908-926.

[17] Laffont J-J. and J. Tirole, 1993, A Theory of Incentives in Procurement and Regulation, MIT Press.

[18] Ma C. A., 1994, Health Care Payment Systems: Cost and Quality Incentives, *Journal of Economics & Management Strategy*, 3, 93-112.

[19] Ma C.A. and J. F. Burgess, 1993,Quality competition , welfare and regulation, *Journal of Economics*, 58, 2, 153-173.

[20] Newhouse J.P, 1996, Reimbursing Health Plans and Health Providers: Efficiency in Production Versus Selection, *Journal of Economic Literature* , 34, 1236-1263.

[21] Phelps CE and C. Mooney, 1993. Variation in the use of medical practice use: causes and consequences. In Competitive Approaches to Health Care Reform, Arnould RJ, Rich RF, White WD (eds). Urban Institute Press: Washington, D.C.

[22] Tay A., 2003, Assessing Competition in Hospital Care Markets: the Importance of Accounting for Quality Differentiation, *The Rand Journal of Economics*, 34, 4, 786-814.

[23] Tirole J., 1988, The Theory of Industrial Organization, MIT Press.

[24] Wolinsky A., 1997, Regulation of duopoly: managed competition vs regulated monopolies, *Journal of Economics & Management Strategy*, 6, 821-847.

Appendix

A Unicity of Δ^* and maximum globality of the locational solution

To prove that Δ^* as defined by (8) is unique in $\Re^{++}$ and such that x_i^* is a global maximum, we proceed in two steps. The first step consists in showing that Δ^* is unique. The second step consists in showing that Δ^* is a global maximum. To do so, we first show that the profit is monotonically increasing in x_1 up to the point x_1^* and then monotonically decreasing in x_1.

- The set of candidates for the optimal value of Δ are the roots of the following third degree polynomial:

$$a\Delta^3 + b\Delta^2 + e\Delta + f = 0,$$

where $a = 4t^2\gamma^2$, $b = 4c't\gamma$, $e = c'^2$and f. Let define $z = \Delta + b/3a$. The polynomial can thus be rewritten as the following reduced form:

$$z^3 + nz + m = 0,$$

where

$$\begin{aligned} n &= -\frac{b^2}{3a^2} + \frac{e}{a} = -\frac{1}{12}\frac{c'^2}{t^2\gamma^2}, \\ m &= \frac{b}{27a}\left(\frac{2b^2}{a^2} - \frac{9e}{a}\right) + \frac{f}{a} = -\left(\frac{c'^3}{108\,t^3\gamma^3} + \frac{2\gamma P + c'^2}{4t^2\gamma^2}\right). \end{aligned}$$

The discriminant of this polynomial is:

$$\begin{aligned} \nabla &= m^2 + \frac{4}{27}n^3 = m^2 - \frac{c'^6}{11664\,t^6\gamma^6} \\ &= \frac{2\gamma P + c'^2}{4t^2\gamma^2} + \frac{2c'^3\left(2\gamma P + c'^2\right)}{432t^5\gamma^5}. \end{aligned}$$

Since $\nabla > 0$, the polynomial admits only one real solution and two complex ones where the real solution is of the form:

$$z^* = \sqrt[3]{\frac{-m - \sqrt{\nabla}}{2}} + \sqrt[3]{\frac{-m + \sqrt{\nabla}}{2}}.$$

Since $\nabla \leq m^2$and $m \leq 0$, this solution is positive for any value of the parameters. Then the optimal distance among firms is unique in the set $\Re^{++}$ and has the form $\Delta^* = z^* - \frac{b}{3a}$.

- To show that Δ^* is such that x_1^* is a global maximum in the set $\Re^{++}$consider the first and the second derivatives of the profit function with respect to x_1:

$$
\begin{aligned}
\frac{\partial \pi_1}{\partial x_1} &= (P - c' q^*)\left(1 - \frac{\partial q^*}{\partial x_1}\frac{1}{t\Delta}\right), \\
\frac{\partial^2 \pi_1}{\partial x_1^2} &= (P - c' q^*)\left(-\frac{\partial q^*}{\partial x_1}\frac{1}{t\Delta^2} - \frac{\partial^2 q^*}{\partial x_1^2}\frac{1}{t\Delta}\right) - c'\frac{\partial q^*}{\partial x_1}\left(1 - \frac{\partial q^*}{\partial x_1}\frac{1}{t\Delta}\right).
\end{aligned}
$$

We focus on the interval $x_1 \in (-\infty, 1/2[$, since we have shown that Δ^* is strictly positive for any value of the parameters and provider 1 is constrained to choose x_1 in the interval $x_1 \in [0, 1/2[$. As shown in (6), q^* is increasing in x_1 since it is decreasing in Δ. Thus $(P - c'q^*)$ is decreasing in x_1 and since $(P - cq^*) = 0$ when $x_1 = 1/2$, $(P - c'q^*)$ is positive for any $x_1 \in (-\infty, 1/2[$. Moreover straightforward derivation of (6) shows that q^* is convex in x_1. Thus $1 - \partial q^*/\partial x_1\,(1/t\Delta)$ is decreasing in x_1 for any $x_1 \in (-\infty, 1/2[$. Since $(1 - \partial q^*/\partial x_1\,(1/t\Delta)) = 0$ at x_1^*, it thus follows that $(1 - \partial q^*/\partial x_1\,(1/t\Delta)) > 0$ for any $x_1 \in (-\infty, x^*[$ and $1 - \partial q^*/\partial x_1\,(1/t\Delta) < 0$ for any $x_1 \in [x^*, 1/2[$. As a result, $\partial \pi_1/\partial x_1 > 0$ for any $x_1 \in (-\infty, x^*[$ and $\partial \pi_1/\partial x_1 < 0$ for any $x_1 \in [x^*, 1/2[$. This proves that x_1^* is a global maximum.

B Proof of proposition 1

Differentiation of (8) with respect to P, c' and t respectively leads to:

$$
\begin{aligned}
\frac{d\Delta^*(.)}{dP} &= \frac{2\gamma\,(c' + 2t\gamma\Delta)}{(c'^2 + 2\gamma P)\,4t\gamma + (c' + 2t\gamma\Delta)^3} > 0, \\
\frac{d\Delta^*(.)}{dc'} &= -\frac{4\gamma\,(P - c' t\Delta)}{(c'^2 + 2\gamma P)\,4t\gamma + (c' + 2t\gamma\Delta)^3} < 0, \\
\frac{d\Delta^*(.)}{dt} &= -\frac{4\gamma\Delta\left(2\gamma P + c'^2\right)}{(c'^2 + 2\gamma P)\,4t\gamma + (c' + 2t\gamma\Delta)^3} < 0.
\end{aligned}
$$

Using the above expressions and differentiation of (5) with respect to P, c' and t respectively leads to:

$$\begin{aligned}
\frac{dq^*(.)}{dP} &= \left(\frac{\partial q\left(\Delta^*,.\right)}{\partial \Delta}\frac{\partial \Delta^*\left(.\right)}{\partial P} + \frac{\partial q\left(\Delta^*,.\right)}{\partial P}\right) \\
&= \frac{2t\gamma\left(c'^2+2\gamma P\right)+\left(c'+2t\gamma\Delta\right)^3}{\left(c'+2t\gamma\Delta\right)\left[\left(c'^2+2\gamma P\right)4t\gamma+\left(c'+2t\gamma\Delta\right)^3\right]} > 0, \\
\frac{dq^*(.)}{dc'} &= \left(\frac{\partial q\left(\Delta^*,.\right)}{\partial \Delta}\frac{\partial \Delta^*\left(.\right)}{\partial c'} + \frac{\partial q\left(\Delta^*,.\right)}{\partial c'}\right) \\
&= -\frac{4t\gamma\left(c'^2+2\gamma P\right)\left(c'^2\Delta^2\right)+\left(c'+2t\gamma\Delta\right)^3\left(2\gamma t^2\Delta^2+P\right)}{\left(c'+2t\gamma\Delta\right)\left[\left(c'^2+2\gamma P\right)4t\gamma+\left(c'+2t\gamma\Delta\right)^3\right]} < 0, \\
\frac{dq^*(.)}{dt} &= \left(\frac{\partial q\left(\Delta^*,.\right)}{\partial t}\frac{\partial \Delta^*\left(.\right)}{\partial t} + \frac{\partial q\left(\Delta^*,.\right)}{\partial t}\right) \\
&= -\frac{c'\Delta^2+2t\gamma\Delta^3}{6t\gamma\Delta+c'} < 0.
\end{aligned}$$

C Proof of proposition 2

If the regulator is constrained to a pure prospective payment, her problem is:

$$\max_P \,(1-c)q(P)-\gamma(q(P))^2+\frac{t\left[3\left(\Delta(P)-(\Delta(P))^2\right)-1\right]}{12}.$$

The first order condition with respect to P can be written as:

$$\Phi\left(P\right)=(1-c-2\gamma q(P))\frac{\partial q^*\left(.\right)}{\partial P}+\frac{t}{4}(1-2\Delta\left(P\right))\frac{\partial \Delta^*\left(.\right)}{\partial P}=0. \qquad (19)$$

Consider now the price P^L that decentralizes the first best location choices *i.e.* $P^L=(t\gamma+c)^2-2c^2/4\gamma$ which is increasing in t. The left hand side of (19) thus becomes:

$$\Phi\left(P^L\right)=(1-c-2\gamma q\left(P^L\right))\frac{\partial q\left(P^L\right)}{\partial P}.$$

(i) P^L decentralizes the first best level of quality if and only if $\Phi\left(P^L\right)=0$ and $q^L\left(P^L\right)=q^{FB}$. Using (5), $q\left(P^L\right)=P^L-ct/2\left(c+t\gamma\right)=t\gamma-c/4\gamma$. Thus comparing this last expression to (10), $q\left(P^L\right)=q^{FB}=1-c/2\gamma$ if and only if $t=\left(2-c\right)/\gamma=\bar{t}$.

(ii) If $t>\bar{t}$, $q\left(P^L\right)>q^{FB}$ since q^L is increasing in t. As a consequence $(1-c-2\gamma q\left(P^L\right))<0$. Moreover, we showed in appendix B that $\left(\partial q\left(P\right)/\partial\Delta\right)\left(\partial\Delta\left(P\right)/\partial P\right)+\left(\partial q\left(P\right)/\partial P\right)>0$ so that $\Phi\left(P^L\right)<0$. Then P^L cannot be the optimal price. By concavity of the problem, the second best price P^{SB} is such that $P^{SB}<P^L$. Since $\Delta\left(P\right)$ is increasing in P in

equilibrium, $\Delta\left(P^{SB}\right) < 1/2$. The second best is thus characterized by underdifferentiation. Furthermore, $(t/4)\left(1-2\Delta\left(P^{SB}\right)\right)\left(\partial\Delta\left(P^{SB}\right)/\partial P\right) > 0$. Thus, in order to satisfy the first order condition (19), the optimal price must be such that $\left(1-c-2\gamma q\left(P^{SB}\right)\right)\left(\left(\partial q\left(P^{SB}\right)/\partial\Delta\right)\left(\partial\Delta\left(P^{SB}\right)/\partial P\right)+\left(\partial q\left(P^{SB}\right)/\partial P\right)\right) < 0$, which is true if and only if $q^{SB} > q^{FB}$. The second best is thus characterized by overprovision of quality.

(iii) The reverse reasoning can be applied to the case in which $t < \bar{t}$.

D Proof of proposition 3

(i) To obtain the first best allocation, setting (10) and (11) equal to (5) and (8) respectively yields:

$$\frac{2P - c't}{c' + \gamma t} = \frac{1-c}{\gamma},$$
$$\frac{\left(2\gamma P + c'^2\right)}{c'^2} - \frac{1}{2} = 0.$$

From these conditions, we obtain the regulatory parameters as described in (15) and (16).

(i) Note that $c' = 2\,(c-1) + \gamma t \in [0, c]$ if and only if $t \in [2(1-c)/\gamma, (2-c)/\gamma]$. As shown in proposition 2, the first best allocation can be decentralized using a simple prospective reimbursement if $t = \bar{t} = (2-c)/\gamma$. If $t = \underline{t} = 2\,(1-c)/\gamma$, costs are fully reimbursed. It remains to be checked that the first best regulatory parameters ensure positive profits in a symmetric equilibrium. Substituting the first best values of quality, location and regulatory parameters in the profit function we obtain:

$$\pi^* = \left[\frac{\gamma t^2}{2} - \frac{(1-c)^2}{\gamma} - \left(2 - \frac{2-\gamma t}{c}\right) c\frac{(1-c)}{2\gamma}\right]\frac{1}{2} - \frac{(1-c)^2}{8\gamma}.$$

The non-negative profit condition thus reduces to:

$$2\gamma t(\gamma t - (1-c)) - (1-c)^2 \geq 0,$$

which is always true if $t \in \left[\underline{t}, \bar{t}\right]$.

(ii) When $t > \bar{t}$, equation (16) says that the constraint $c' \leq c$ is binding so that $\nu > 0$ and $c' = c$. This case corresponds to the one where the regulator only uses the prospective payment P so that by proposition 2 there is overprovision of quality and under-differentiation.

(iii) When $t < \underline{t}$, equation (16) says that the constraint $c' \geq 0$ is binding so that $\mu > 0$ and $c' = 0$. One can then repeat the proof of proposition 2 where $c' = 0$ and $t < \underline{t} < \bar{t}$ to show that the optimum is such that there is underprovision of quality and overdifferentiation.

E Proof of lemma 1

For a given pair (P, Δ), the regulator chooses c' such that it solves:

$$\max_{c'} \; (1-c)q(\Delta, c') - \gamma q^2(\Delta, c'),$$
$$\text{s.t. } c' \geq 0, \; c' < c,$$

where $q(\Delta, c')$ is given by (5). We first analyze regime A and then turn to regime C.

- The regulator chooses $c' = 0$ iff

$$\frac{\partial q\left(\Delta, 0\right)}{\partial c'}\left[(1-c) - 2\gamma q(\Delta, 0)\right] \leq 0.$$

Since $q\left(\Delta, 0\right) = P/2t\gamma\Delta$, this condition reduces to:

$$P \leq (1-c)\, t\Delta. \tag{20}$$

Using equation (8), the level of differentiation is given by:

$$\Delta\left(P\right) = \left(\frac{P}{2\gamma t^2}\right)^{1/3}, \tag{21}$$

which yields

$$q\left(P\right) = \left(\frac{P}{2\gamma}\right)^{2/3} t^{-1/3}.$$

The optimal P is the result of:

$$\max_{P} \; W = (1-c)q(P) - \gamma q^2(P) + \frac{t\left[3\left(\Delta(P) - \Delta^2\left(P\right)\right) - 1\right]}{12}.$$

The first order condition is:

$$\frac{\partial W}{\partial P} = (1 - c - 2\gamma q)\frac{dq}{dP} + \frac{t}{4}(1-2\Delta)\frac{d\Delta}{dP} = 0.$$

After some manipulation, this yields:

$$\frac{\partial W}{\partial P} = \left(\frac{tP}{2\gamma}\right)^{1/3}(1-c) - P + \frac{t}{8} - \frac{t}{4}\Delta = 0. \tag{22}$$

Using (21), equation (22) thus defines implicitly $P^A\left(t\right)$ as:

$$P^A\left(t\right) \equiv P^A = (1-c)\, t\Delta\left(t, P^A\left(t\right)\right) + \frac{t}{8} - \frac{1}{4}t\Delta\left(t, P^A\left(t\right)\right). \tag{23}$$

Thus condition (20) is fulfilled if and only if $t/8 - (1/4)\, t\Delta\left(t, P^A\right) \leq 0$ *i.e.* if and only if $\Delta\left(t, P^A\right) \geq 1/2$. We know from proposition 3 that for any $t \leq \underline{t}$, this policy is credible since it is the result of the optimal policy in regime A for the full commitment case.

Suppose now that for any $t > \underline{t}$, $\Delta\left(t, P^A\right) \geq 1/2$ and (21) is fulfilled. Using (21), straightforward computations show that the conditions $t \geq \underline{t}$ and $\Delta\left(t, P^A\right) \leq 1/2$ imply $P^A > (1-c)^2/\gamma$ while the conditions $t \geq \underline{t}$ and (21) imply $P^A < (1-c)^2/\gamma$ which contradicts (20). It thus turns out that regime A is credible if and only if $t \leq \underline{t}$.

- The regulator chooses $c' = c$ iff

$$\frac{\partial q\left(P,c\right)}{\partial c'}\left[(1-c) - 2\gamma q(P,c)\right] \geq 0,$$

where $q\left(P,c\right) = \left(P - ct\Delta\right)/\left(c + 2t\gamma\Delta\right)$ i.e. iff:

$$P \geq t\Delta + \frac{c(1-c)}{2\gamma}. \tag{24}$$

The level of differentiation $\Delta\left(P\right)$ is thus given by (8) where $c' = c$ which also defines the equilibrium value $q\left(P\right)$. The optimal P is the result of:

$$\max_P \; (1-c)q(P) - \gamma q^2(P) + \frac{t\left[3\left(\Delta(P,c) - \Delta^2\left(P,c\right)\right) - 1\right]}{12}.$$

The first order condition is given by:

$$\frac{\partial W}{\partial P} = (1 - c - 2\gamma q)\frac{dq}{dP} + \frac{t}{4}(1-2\Delta)\frac{d\Delta}{dP} = 0.$$

Using the comparative statics given in appendix B, the first order condition yields:

$$P^C = t\Delta\left(P^C\right) + \frac{c(1-c)}{2\gamma} + \frac{t}{4}\left(1 - 2\Delta\left(P^C\right)\right)\left(\frac{2t\gamma\Delta + c}{4t\gamma\Delta + c}\right),$$

so that condition (24) is fulfilled if and only if $\Delta\left(P^C\right) \leq 1/2$. By proposition 3, the optimal price leads to $\Delta \leq 1/2$ if and only if $t \geq \overline{t}$ so that regime C is credible only if $t \geq \overline{t}$.

F Proof of proposition 5

(i) At the optimum, the welfare levels can be rewritten as:

$$W^k\left(t\right) = (1-c)q(P^k,t) - \gamma q^2(P^k\left(t\right),t) + \frac{t\left[3\left(\Delta(P^k,t) - \Delta^2\left(P^k,t\right)\right) - 1\right]}{12},$$

where P^C is given implicitly by equation (23) and P^B is independent of t. Differentiating $W^k(t)$ with respect to t and using the envelop theorem yields:

$$\begin{aligned}\frac{\partial W^A}{\partial t} &= (1-c-2\gamma q(P^k,t))\frac{\partial q}{\partial t}+\frac{t}{4}(1-2\Delta(P^k,t))\frac{\partial \Delta}{\partial t} \\ &\quad +\frac{1}{12}\left[3\left(\Delta(P^k,t)-\Delta^2\left(P^k,t\right)\right)-1\right], \qquad (25)\end{aligned}$$

Using the first order condition (22), one can show that:

$$(1-c-2\gamma q(P^k,t)) = \frac{-\left(1-2\Delta(P^k,t)\right)}{8\Delta\left(P^k,t\right)}.$$

Substituting this expression in (25) yields after some rearrangements:

$$\begin{aligned}\frac{dW^A}{dt} &= \frac{\Delta^A}{8}-\frac{1}{12}, \\ \frac{dW^B}{dt} &= \frac{(1-c)\left(1-\Delta^B\right)}{4\left[4t\gamma\Delta^B+(1-c)\right]}-\frac{1}{12},\end{aligned}$$

where $\Delta^k = \Delta\left(P^k,t\right)$. After some manipulations, one has:

$$\begin{aligned}&\frac{dW^A}{dt}-\frac{dW^B}{dt} \\ =& \frac{8t\gamma\Delta^A\Delta^B+(1-c)\left[\left(\Delta^B\right)^2+2\Delta^A-1\right]}{8\left[4t\gamma\Delta^B+(1-c)\right]},\end{aligned}$$

which is strictly positive since $\Delta^A \geq 1/2$. Since regimes B and A respectively lead to a first best optimum at $t=\underline{\underline{t}}$ and $t=\underline{t}$, there exists a threshold value of t under which regime B dominates regime C and this threshold value lies between $\underline{\underline{t}}$ and $\underline{t}$.

(ii) See figures 2 and 3 in section 4.3.