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The optimality of hospital financing system: the role of physician–manager interactions

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Abstract The ability of a prospective payment system to ensure an optimal level of both quality and cost reducing activities in the hospital industry has been stressed by Ma (Ma, J Econ Manage Strategy 8(2):93–112, 1994) whose analysis assumes that decisions about quality and costs are made by a single agent. This paper examines whether this result holds when the main decisions made within the hospital are shared between physicians (quality of treatment) and hospital managers (cost reduction). Ma's conclusions appear to be relevant in the US context (where the hospital managers pay the whole cost of treatment). Nonetheless, when physicians partly reimburse hospitals for the treatment cost as it is the case in many European countries, we show that the ability of a prospective payment system to achieve both objectives is sensitive to the type of interaction (simultaneous, sequential or joint decision-making) between the agents. Our analysis suggests that regulation policies in the hospital sector should not be exclusively focused on the financing system but should also take the interaction between physicians and hospital managers into account.

Keywords Hospital's financing system · Strategic interaction · Prospective payment system

JEL Classifications H51 · I18 · D21

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Introduction

Already 30 years ago, Harris (1997) pointed out the lack of an adequate economic theory of the hospital. He indeed suggested that it was time to give this industry a special treatment since hospitals are made up of two separate entities: a medical staff (or demand division) and an administration (supply division). Following this stance the integration of this specific feature in economic models describing the hospital industry is considered to be desirable both from a theoretical as from a policy perspective.

The issue of the relative strengths and weaknesses of various hospital financing systems has been extensively dealt with in the health economics literature (Ma 1994; Chalkley and Malcomsom 1998; Pope 1990; Newhouse 1996 for example). These papers do not consider, however, that the decisions made within hospitals are shared between various agents. After the contribution by Harris (1997) few authors have explicitly considered that physicians and managers act as separate decision makers. To our knowledge, only Custer et al. (1990), Dor and Watson (1995) and Boadway et al. (2004) introduced this specification into their models.

By comparing two hospital financing systems, Ma (1994) shows that—whenever a provider cannot refuse access to treatment—the prospective payment system in the hospital industry is superior to the cost based reimbursement system to achieve both cost reduction and quality improvement objectives. The paper indeed shows that a well designed prospective payment implements the efficient quality and cost reduction effort, but that cost reimbursement cannot induce any cost reduction efforts. In this analysis, it is implicitly assumed that decisions are made by a single agent within hospitals. Our paper seeks to determine whether the ability of the prospective payment system to achieve quality and cost reduction objectives is confirmed when two decisions units are integrated within the hospital: a medical staff that decides the quality of care and an administrative staff that determines cost reduction policies.

Ma's paper was written in the spirit of the organization of US hospitals where physicians get the privilege to admit and treat patients in hospitals that pay the cost of treatment in full. In that case, we show that Ma's result is robust to the existence of two decision units. The situation is however quite different in many European for-profit hospitals where physicians reimburse to the hospital part of the cost of treatment. Once this specificity is integrated into the model—while keeping Ma's assumptions intact—we establish that the implementation of the optimal level of treatment quality and cost reduction efforts within the hospital is sensitive to the type of interaction between the agents (simultaneous decision making, sequential decision making, or joint decision making). The main result of our paper is that a prospective payment system is unable to bring the optimal quality and cost reduction efforts under simultaneous interaction or sequential interaction when physicians are first-movers. However, both objectives could be reached through a prospective payment system under sequential interaction when managers are first-movers or under joint decision-making. It follows from our analysis that regulation policies in the hospital sector should not be exclusively focused on the financing system but also should take the interaction between physicians and hospital managers into account.

The paper is organized as follows. Ma's model is summarized in section "Ma's model: a summary" and physicians–managers interactions are considered in section "The physician–manager interaction considered". Section "Conclusion" concludes.

Ma's model: a summary

Ma (1994) considers that efforts dedicated to the improvement of the quality (denoted t_1) and to the reduction of costs (denoted t_2) are implemented within hospitals. These efforts impose a disutility to the agents who undertake them which monetary equivalent is $\gamma(t_1 + t_2)$ with the function γ being increasing and convex ($\gamma' > 0$ and $\gamma'' \geqslant 0$). The treatment technology exhibits constant returns to scale. The unit cost of treating a patient denoted $c(t_1, t_2)$ is increasing in $t_1 (c_1 \geqslant 0)$, decreasing in t_2 ($c_2 < 0$) and convex in both arguments ($c_{11} \geqslant 0$ and $c_{22} \geqslant 0$). Moreover, it is implicitly assumed that $c_{12} = 0$. The hospital's demand depends on the quality of treatment. It is denoted $\mu(t_1)$ and according to intuition μ is increasing and concave ($\mu' > 0$; $\mu'' \leqslant 0$). The hospital's total cost is therefore $c(t_1, t_2)\mu(t_1)$. Ma assumes that this last function is convex in order to ensure negative second order conditions.

Two hospital financing systems are compared in Ma's paper: the cost reimbursement system and the prospective payment system. We only summarize the results of the latter under which the hospital receives a fixed amount p per patient treated. The hospital's net profit under such a financing system can be written:

$$\pi = p\mu(t_1) - c(t_1, t_2)\mu(t_1) - \gamma(t_1 + t_2) \tag{1}$$

The gross social benefit generated by the hospitals' activity is denoted $W(t_1)$. It depends on the number of patients using the hospital's services and on the quality of care they receive. But since the first variable depends on the second ($\mu(t_1)$), the gross social benefit is written as a function of t_1 alone. Ma moreover assumes that the gross social benefit function is increasing and concave ($W'(t_1) > 0$ and $W''(t_1) < 0$).

The regulator's objective function given by Eq. 2 is the sum of consumer surplus (gross social benefit minus what they pay through taxes for these services) and hospitals' profits:

$$W(t_1) - c(t_1, t_2)\mu(t_1) - \gamma(t_1 + t_2) \tag{2}$$

The values of t_1 and t_2 that maximize Eq. 2 are the efficient levels of effort on quality enhancement and on cost reduction. They are, respectively, denoted t_1^* and t_2^* and satisfy the following first-order conditions:

$$W'(t_1^*) - c_1(t_1^*, t_2^*)\mu(t_1^*) - c(t_1^*, t_2^*)\mu'(t_1^*) - \gamma'(t_1^* + t_2^*) = 0 \tag{3}$$

$$-c_2(t_1^*, t_2^*)\mu(t_1^*) - \gamma'(t_1^* + t_2^*) = 0 \tag{4}$$

The following second-order conditions are both negative given the assumption made about the convexity of the total cost function.

$$W''(t_1^*) - c_{11}(t_1^*, t_2^*)\mu(t_1^*) - 2c_1(t_1^*, t_2^*)\mu'(t_1^*) - c(t_1^*, t_2^*)\mu''(t_1) - \gamma''(t_1^* + t_2^*) < 0$$

$$-c_{22}(t_1^*, t_2^*)\mu(t_1^*) - \gamma''(t_1^* + t_2^*) < 0$$

The optimal values of t_1^* and t_2^* being defined, Ma then analyzes the ability of a prospective payment system to reach these optimal efforts levels.

The first-order conditions associated with the hospital's net profit (1) are given by Eqs. 5 and 6:

$$p\mu'(t_1) - c_1(t_1, t_2)\mu(t_1) - c(t_1, t_2)\mu'(t_1) - \gamma'(t_1 + t_2) = 0 \tag{5}$$

$$-c_2(t_1, t_2)\mu(t_1) - \gamma'(t_1 + t_2) = 0 \tag{6}$$

The hospital's first-order condition defining t_2 corresponds to that of the regulator (4). By enforcing a prospective payment system, the regulator can make the hospital internalize the cost of treatment and the optimal value of cost reduction effort t_2^* can be reached.

The payment p per patient treated can thus be used to achieve the optimal value of quality effort t_1^*. Using Eqs. 3 and 5, p must be such that:

$$p = \frac{W'(t_1^*)}{\mu'(t_1^*)} \tag{7}$$

The implementation of a prospective payment system in the health industry is thus recommended for its ability to achieve both cost reduction and quality improvement objectives.

The physician–manager interaction considered

Our paper tackles the issue dealt with by Ma (1994) while introducing the assumption that decisions made within hospitals are shared between physicians and managers. If we adapt the model to introduce a double decision unit, quality improvement efforts are made by physicians while cost reduction efforts are decided by managers. Payment and disutility functions can also be individualized. The share of the costs between physicians and hospital managers can be considered under two approaches: the hospital either grants admitting privileges to physicians and pays the whole production cost or share the cost with physicians. While the first type of relation prevails in the US hospital industry, the second is more common in European for-profit hospitals.

In the US model the total production cost $c(t_1, t_2)$ is paid by the manager and the effort disutility is the only cost supported by the physician. In the European model the total production cost is split between the physician ($\alpha c(t_1, t_2)$ with ($\alpha \in [0, 1]$) and the manager ($(1-\alpha)c(t_1, t_2)$) and there is an institutional agreement between the physician and the hospital such that the physician transfers a negotiated part of his/her fee to the hospital manager for the resources (rooms, equipment, nursing and administrative staff,...) put at his/her disposal.[1] The assumptions made by Ma about the cost function are kept (i.e. $c_1 \geqslant 0$, $c_2 < 0$, $c_{11} \geqslant 0$ and $c_{22} \geqslant 0$) and the higher order cost derivatives and cross derivatives are assumed to be equal to zero.

The monetary equivalent of the total disutility of effort is also split between physicians ($\gamma_p(t_1)$) and hospital managers ($\gamma_m(t_2)$) and we keep the assumptions made about these functions (i.e. $\gamma_p'(t_1) > 0$, $\gamma_p''(t_1) \geqslant 0$, $\gamma'(t_2) > 0$ and $\gamma_m''(t_2) \geqslant 0$). The assumptions made about the demand function remain the same ($\mu(t_1)$ with $\mu' > 0$ and $\mu'' \leqslant 0$). We assume—in line with Ma—that the total cost function ($c(t_1, t_2)\mu(t_1)$) is convex with respect to t_1 in order to ensure that second order conditions related to Eqs. 9, 16, 20, 22, 24 and 27 are negatives. Finally, the efforts are supposed to be observable but not verifiable so that no explicit contract based on the efforts levels can be established.

The manager pays the whole production cost

Compared to Ma's model the only difference lies in the fact that the disutilities and payments are now split between physicians and managers. Therefore the social welfare function is written:

$$W(t_1) - c(t_1, t_2)\mu(t_1) - \gamma_p(t_1) - \gamma_m(t_2) \tag{8}$$

[1] Note that $\alpha = 0$ corresponds to the US model.

And the first-order conditions defining t_1^* and t_2^* are:

$$W'(t_1^*) - c_1(t_1^*, t_2^*)\mu(t_1^*) - c(t_1^*, t_2^*)\mu'(t_1^*) - \gamma_p'(t_1^*) = 0 \tag{9}$$

$$-c_2(t_1^*, t_2^*)\mu(t_1^*) - \gamma_m'(t_2^*) = 0 \tag{10}$$

Following Dor and Watson (1995) physicians and managers face separate fees, denoted *RP* and *RM*, respectively, under a prospective payment system and the profits made by the physician and the hospital manager are, respectively, written:

$$\pi^p = RP\mu(t_1) - \gamma_p(t_1) \tag{11}$$

$$\pi^m = RM\mu(t_1) - c(t_1, t_2)\mu(t_1) - \gamma_m(t_2) \tag{12}$$

If we assume a situation where physicians and managers choose simultaneously t_1 and t_2 the first-order conditions are written:

$$RP\mu'(t_1) - \gamma_p'(t_1) = 0 \tag{13}$$

$$-c_2(t_1, t_2)\mu(t_1) - \gamma_m'(t_2) = 0 \tag{14}$$

The comparison of the first-order conditions (10) and (14) defining, respectively, the optimal cost reduction effort and the level of effort chosen by the manager reveals that the optimal level is reached under the prospective payment system. The payment granted to the hospital modifies its profit but not the decision made by the manager. The optimal level of cost reducing effort (t_2^*) is therefore achieved independently of the level of RM.

The regulator can achieve the optimal level of t_1 by defining the physician payment *RP* in the following way:

$$RP = \frac{W'(t_1^*) - c_1(t_1^*, t_2^*)\mu(t_1^*)}{\mu'(t_1^*)} - c(t_1^*, t_2^*)$$

In line with Ma's model, under a prospective payment the hospital manager is financially responsible for the whole cost that is therefore fully internalized. In that case, the ability of the prospective payment system to achieve both cost reduction and quality improvement objectives is independent of the type of interaction between physicians and hospital-managers. Thus, if the agents cooperate and decide jointly t_1 and t_2, we find again the economic incentives and thus the outcome that prevailed in Ma's model. Also in the dominant-reactive cases in which the decisions on t_1 and t_2 are taken sequentially, it is straightforward to show that we get the same result since the physician is unaffected by the manager's decision (t_2 does not appear in Eq. 11).

The production cost is shared between the agents

The share of the cost between the agents gives to hospital managers the opportunity to influence physicians decisions. In this case, it becomes crucial to analyze in detail the prospective payment system under the various interactions: simultaneous decision-making, sequential decision-making or cooperation.

The social welfare function and the related first-order conditions correspond to those developed in the US model. The social welfare function writes:

$$W(t_1) - c(t_1, t_2)\mu(t_1) - \gamma_p(t_1) - \gamma_m(t_2) \tag{15}$$

And the first-order conditions defining the values of t_1^* and t_2^* are:

$$W'(t_1^*) - c_1(t_1^*, t_2^*)\mu(t_1^*) - c(t_1^*, t_2^*)\mu'(t_1^*) - \gamma_p'(t_1^*) = 0 \tag{16}$$

$$- c_2(t_1^*, t_2^*)\mu(t_1^*) - \gamma_m'(t_2^*) = 0 \tag{17}$$

Under a prospective payment system the profits π^p and π^m made by physicians and managers are written:

$$\pi^p = RP\mu(t_1) - \alpha c(t_1, t_2)\mu(t_1) - \gamma_p(t_1) \tag{18}$$

$$\pi^m = RM\mu(t_1) - (1-\alpha)c(t_1, t_2)\mu(t_1) - \gamma_m(t_2) \tag{19}$$

We now consider four different interactions between physician and managers and determine under which interactions a prospective payment system can achieve the optimal values of t_1^* and t_2^* as defined by (16) and (17), respectively.

Cooperation between the physician and the manager

The physician and the manager define t_1 and t_2 in order to maximize their joint profit ($\pi^p + \pi^m$) which writes:

$$\pi^p + \pi^m = (RP + RM)\mu(t_1) - c(t_1, t_2)\mu(t_1) - \gamma_p(t_1) - \gamma_m(t_2)$$

The first-order condition used by the agents to define t_2 corresponds to (17) so that the optimal cost reduction effort t_2^* is spontaneously reached. The cost of production is fully internalized when the agents cooperate so that the manager undertakes the optimal level of t_2^* whatever the value of RM.

The physician and the manager define t_1 in accordance with the first-order condition (20):

$$(RP + RM)\mu'(t_1) - c_1(t_1, t_2)\mu(t_1) - c(t_1, t_2)\mu'(t_1) - \gamma_p'(t_1) = 0 \tag{20}$$

Using the Eqs. 16 and 20 we determine the physician and the manager fees that implement the optimal quality level t_1^*:

$$RP + RM = \frac{W'(t_1^*)}{\mu'(t_1^*)} \tag{21}$$

We give in Appendix A a sufficient condition under which the participation constraint is satisfied. This condition says that the elasticity of the gross social benefit with respect to the quality level should be higher than the elasticity of the demand with respect to the quality level. Under such condition we conclude that the regulator can implement the optimal level of quality and cost reduction through a prospective payment system when physicians and managers cooperate within the hospital.

Simultaneous decision making

Let us show that the prospective payment system cannot—in contrast with Ma's result—induce the optimal values of t_1^* and t_2^* as defined by Eqs. 16 and 17 when the decision-making between physicians and managers is simultaneous. The maximization of the profits (18) and (19) by the physician and the manager, respectively, leads to the following first-order conditions defining t_1 and t_2:

$$RP\mu'(t_1) - \alpha[c_1(t_1, t_2)\mu(t_1) + c(t_1, t_2)\mu'(t_1)] - \gamma_p'(t_1) = 0 \tag{22}$$

$$-(1-\alpha)c_2(t_1, t_2)\mu(t_1) - \gamma_m'(t_2) = 0 \tag{23}$$

Since the manager cannot modify the demand through her/his effort level, the payment per patient RM received by the hospital does not modify the cost reduction effort undertaken. Moreover, we notice from (23) that the effort provided to reduce the cost is lower than t_2^* since the manager only takes into account the part of the total cost that he pays $((1-\alpha)c(t_1, t_2)\mu(t_1))$ when defining her/his optimal effort level $\widehat{t_2}$ (with $\widehat{t_2} < t_2^*$). An under-investment in cost reducing activities thus results from the partial internalization of the cost from the manager that does not—in contrast with the cooperative situation—integrate the physician's gain from this activity.

The regulator can only use RP in order to reach the optimal quality enhancing effort level. This optimal level (denoted $\widehat{t_1}$) is now different from the one defined by (16) since it incorporates the sub-optimal cost reducing effort made by the manager ($\widehat{t_2}$). The optimal physician fee is defined using the Eqs. 16 and 22:

$$RP = \frac{W'(\widehat{t_1}) - (1-\alpha)[c_1(\widehat{t_1}, \widehat{t_2})\mu(\widehat{t_1}) + c(\widehat{t_1}, \widehat{t_2})\mu'(\widehat{t_1})]}{\mu'(\widehat{t_1})}$$

The impossibility to reach the optimal values of both t_1^* and t_2^* is, however, not due to the specificity of the simultaneous decision-making situation. We show in the next section that this is also the case under another form of interaction between physicians and managers: sequential decision-making with the physician being the first-mover.

Sequential interaction—the physician is the first-mover

When the physician moves first and knows the manager takes t_1 as given when defining t_2, the first-order conditions related to the maximization of the profits (18) and (19) become:

$$RP\mu'(t_1) - \alpha\left[c_1(t_1, t_2)\mu(t_1) + c(t_1, t_2)\mu'(t_1) - c_2(t_1, t_2)\mu(t_1)\frac{dt_2}{dt_1}\right] - \gamma_p'(t_1) = 0 \tag{24}$$

$$-(1-\alpha)c_2(t_1, t_2)\mu(t_1) - \gamma_m'(t_2) = 0 \tag{25}$$

The way the physician can influence the manager's decision is given by:

$$\frac{dt_2}{dt_1} = \frac{(1-\alpha)c_2(t_1, t_2)\mu'(t_1)}{-(1-\alpha)c_{22}(t_1, t_2)\mu(t_1) - \gamma_m''(t_2)} > 0 \tag{26}$$

The regulator cannot implement both t_1^* and t_2^* but only the optimal level of one of these two variables. The first-order condition (25) indeed reveals that the manager does not take the part of the cost shared by the physicians into account when defining t_2 and that RM has no impact on the manager's decisions. But since the physician can influence the manager's activity through t_1 (see Eq. 26) and since t_1 is affected by RP, the regulator can (indirectly) implement the optimal cost reducing activity level t_2^*. Doing so, the regulator must give up implementing t_1^*.

Having only one instrument (*RP*) at its disposal to reach two objectives (t_1^* and t_2^*), the regulator therefore faces a trade-off between a public health and a cost containment objective.

Quite surprisingly, cooperation is not the only type of interaction under which a well-designed prospective payment system can implement the optimal quality enhancing and cost reducing activities t_1^* and t_2^*. We show in the next section that the same outcome can be achieved under a sequential interaction where the manager is the first-mover.

Sequential interaction—the manager is the first-mover

The physician and the manager maximize the profits expressed through Eqs. 18 and 19, respectively. The first-order conditions are:

$$RP\mu'(t_1) - \alpha\left[c_1(t_1, t_2)\mu(t_1) + c(t_1, t_2)\mu'(t_1)\right] - \gamma_p'(t_1) = 0 \quad (27)$$

$$-(1-\alpha)c_2(t_2)\mu(t_1) + \left[RM\mu'(t_1) - (1-\alpha)[c_1(t_1, t_2)\mu(t_1) + c(t_1, t_2)\mu'(t_1)]\right]\frac{dt_1}{dt_2} - \gamma_m'(t_2) = 0 \quad (28)$$

Using (27) one can define the way the hospital manager can influence the physician's decision:

$$\frac{dt_1}{dt_2} = \frac{\alpha c_2(t_1, t_2)\mu'(t_1)}{RP\mu''(t_1) - \alpha[c_{11}(t_1, t_2)\mu(t_1) + 2c_1(t_1, t_2)\mu'(t_1) + c(t_1, t_2)\mu''(t_1)] - \gamma_p''(t_1)} > 0 \quad (29)$$

The term in between brackets in the denominator is positive since the total cost function $(c(t_1, t_2)\mu(t_1))$ has been assumed to be convex with respect to t_1.

In order to reach the optimal quality enhancing and cost reduction effort levels t_1^* and t_2^*, the regulator must thus set payments RP and RM such that:

$$RP = \frac{W'(t_1^*) - (1-\alpha)\left[c_1(t_1^*, t_2^*)\mu(t_1^*) + c(t_1, t_2)\mu'(t_1^*)\right]}{\mu'(t_1^*)} \quad (30)$$

$$RM = \frac{(1-\alpha)\left[c_1(t_1^*, t_2^*)\mu(t_1^*) + c(t_1^*, t_2^*)\mu'(t_1^*)\right]}{\mu'(t_1^*)} - \frac{\alpha c_2(t_1^*, t_2^*)\mu(t_1^*)}{\mu'(t_1^*)\frac{dt_1}{dt_2}} \quad (31)$$

In order to keep the expression of RM short, we implicitly express its value as a function of RP through dt_1/dt_2 in (31). This equation system could however be solved for the explicit values of RP and RM. This can be easily be done by including the value of *RP* given by Eq. 30 into Eq. 29 and then the value of dt_1/dt_2 into Eq. 31.

Let us give an intuition of this result. In order to avoid overproduction of quality enhancing efforts by the physician, the level of RP rises along with α. When $\alpha = 1$, one finds back the level of RP that implements the optimal quality enhancing effort when the decision-maker pays the treatment cost in full (see Eqs. 7 and 21). When the manager is the first mover, RM becomes a regulation instrument that can be used—along with the payment the physician receives—in order to reach the optimal efforts t_1^* and t_2^*. Besides, the value of RM given by the Eq. 31 falls with α. We indeed know from Eq. 23 that the level of t_2 is sub-optimal when the decision-maker does not fully support the cost of treatment. The incentive to increase t_2 beyond that level, however, exists since the manager can boost the level of t_1 through its influence on the physician's decision (Eq. 29) and thus indirectly the demand it faces.

This is all the more so as α increases ($\frac{\partial(\frac{dt_1}{dt_2})}{\partial\alpha} > 0$; a cost reduction effort has more impact on the physician's decision when the latter reimburses a higher proportion of the treatment cost) and as *RM* is high (the return associated to an extra patient is higher). As α rises, this incentive must thus be tempered by a decrease in *RM* in order to deter an overproduction of cost reducing effort.

We show in Appendix B that the physician's participation constraint is always met. We also give a condition under which the hospital manager's participation constraint is satisfied. We have assumed throughout the paper that $\alpha \in [0, 1]$. We show in Appendix B that the manager's participation constraint could be satisfied for cost sharing agreements established outside that interval. A sufficient condition for the manager's participation constraint to be satisfied is also highlighted. It states that the part of the cost that the physician bears must be higher than the demand elasticity with respect to the cost reducing effort.

Conclusion

The ability of a the prospective payment system to reach the double objective of treatment quality and cost reduction (efficiency) within hospitals is examined in this paper. The issue has been previously dealt with by Ma who stressed the efficiency of the prospective payment system in that respect. His model however does not take into account the fact that the main decisions made within hospitals are shared between the physician and the hospital's manager. The assumption that we introduce in our model is that the former determines the quality of treatment while the latter defines the level of cost reduction efforts.

Ma's conclusions are not affected by the introduction of two decision units when the relationship between physicians and managers is organized as in US hospitals where physicians do not share any part of the cost of treatment. Since the cost is fully paid and internalized by the manager under a prospective payment system, the regulator just sets a physician fee that gives them the incentives to provide the optimal quality of treatment.

Things are different when physicians reimburse—as it is the case in for-profit hospitals in many European countries—a part of the cost related to their activity inside the hospital. We highlight in that context the importance of the type of interaction (simultaneous, sequential or cooperation) between physicians and managers in the achievement of both objectives (quality and cost reduction). The main result of our paper is that a prospective payment system is unable to bring the optimal quality and cost reduction efforts under simultaneous interaction or sequential interaction when physicians are first-movers. However, both objectives could be reached through a prospective payment system under sequential interaction when managers are first-movers or under joint decision-making.

In the absence of regulation, no specific form of interaction should a priori emerge (the four forms of interactions analyzed in the paper seem plausible and depend on the specific relationship between physicians and managers). However, regulations imposed on the hospitals—rather than on the physicians whose activity is based on the liberal medicine principles—seem to give them a first-mover advantage. Regulation instruments such as "certificate of needs" contracts in the US or "contracts d'objectifs et de moyens" in France indeed fix the investment made by hospitals for a while, constraining the physicians to take it as given and to adapt their decisions. This sequence appears in Boadway et al. (2004) who assume two stage contracts: between the government and the hospital manager that defines the size of the equipment (fixed inputs) in the first stage, and between the hospital managers and the physicians about non-medical resources and the equipment available for physicians (variable inputs) in the second stage. Given these two contracts, physicians determine the type of treatment (low tech or high tech therapy). The sequential game with hospital's manager as first mover seems therefore to be the only interaction that public authorities could implement through hospitals regulations.

Some extensions may be worthwhile. In the paper we have considered that the part of the cost that managers and physicians share is exogenously given. It would be interesting to endogenize it by introducing a two-stage game in which first the physician and the manager negotiate the share of the cost and then they choose the quality of treatment and the cost reduction effort, respectively. But in order to do that one should specify the demand, the cost and the disutility functions. We have modelled the interaction between physicians and the hospital's manager as in Custer et al. (1990), in order to extend earlier work of Ma (1994). One could also model this interaction as in Boadway et al. (2004). In that case, the existence of asymmetric information and of incomplete contracts could be incorporated into the model. This extension is left as further work.

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Appendix A: The participation constraint under cooperation

The participation constraint is satisfied whenever:

$$(RP + RM)\mu(t_1^*) - c(t_1^*, t_2^*)\mu(t_1^*) - \gamma_p(t_1^*) - \gamma_m(t_2^*) > 0$$

Given the optimal value of the physicians and managers fees as defined by (21), the participation constraint can be written:

$$\frac{W'(t_1)}{\mu'(t_1)}\mu(t_1^*) - c(t_1^*, t_2^*)\mu(t_1) - \gamma_p(t_1^*) - \gamma_m(t_2^*) > 0 \tag{32}$$

From the social welfare perspective, the hospital activity is worth implementing if:

$$W(t_1^*) - c(t_1^*, t_2^*)\mu(t_1^*) - \gamma_p(t_1^*) - \gamma_m(t_2^*) > 0 \tag{33}$$

From (32) and (33) it follows that the participation constraint is satisfied under the following (sufficient) condition (34):

$$\frac{W'(t_1^*)}{\mu'(t_1^*)}\mu(t_1^*) > W(t_1^*) \tag{34}$$

Re-arranging the terms of Eq. 34, the participation constraint is satisfied whenever:

$$\epsilon_{W,t_1} = W'(t_1^*)\frac{t_1^*}{W(t_1^*)} > \mu'(t_1^*)\frac{t_1^*}{\mu(t_1^*)} = \epsilon_{\mu,t_1}$$

where ϵ_{W,t_1} represents the elasticity of the gross social benefit with respect to the quality level and ϵ_{μ,t_1} represents the elasticity of the demand with respect to the quality level.

Appendix B: The participation constraint under a sequential interaction where the hospital manager moves first

The participation constraints are satisfied whenever:

$$RP\mu(t_1^*) - \alpha c(t_1^*, t_2^*)\mu(t_1^*) - \gamma_p(t_1^*) > 0$$

$$RM\mu(t_1^*) - (1-\alpha)c(t_1^*, t_2^*)\mu(t_1^*) - \gamma_m(t_2^*) > 0$$

The physician participation constraint

Replacing RP by its value given by (30) modifies the physician participation constraints in the following way:

$$\left[\frac{W'(t_1^*) - (1-\alpha)[c_1(t_1^*, t_2^*)\mu(t_1^*) + c(t_1^*, t_2^*)\mu'(t_1^*)]}{\mu'(t_1^*)}\right]\mu(t_1^*) - \alpha c(t_1^*, t_2^*)\mu(t_1^*) - \gamma_p(t_1^*) > 0$$

We know from (16) that $W'(t_1^*) - c_1(t_1^*, t_2^*)\mu(t_1^*) - c(t_1^*, t_2^*)\mu'(t_1^*) = \gamma_p'(t_1^*)$ so that the constraint can be rewritten as follows:

$$\left[\gamma_p'(t_1^*) + \alpha(c_1(t_1^*, t_2^*)\mu(t_1^*) + c(t_1^*, t_2^*)\mu'(t_1^*))\right]\frac{\mu(t_1^*)}{\mu'(t_1^*)} - \alpha c(t_1^*, t_2^*)\mu(t_1^*) - \gamma_p(t_1^*) > 0$$

Since $\gamma_p(t_1)$ is convex in t_1 $\left(\text{and thus } \gamma_p'(t_1) > \frac{\gamma_p(t_1)}{t_1}\right)$ and $\mu(t_1)$ is concave in t_1 $\left(\text{and thus } \mu'(t_1) < \frac{\mu(t_1)}{t_1}\right)$ we have that:

$$\gamma_p'(t_1^*)\mu(t_1^*) > \gamma_p(t_1^*)\mu'(t_1^*)$$

and then the following condition is sufficient for the participation constraint to be satisfied:

$$\alpha\left[c_1(t_1^*, t_2^*)\mu(t_1^*) + c(t_1^*, t_2^*)\mu'(t_1^*)\right]\frac{\mu(t_1^*)}{\mu'(t_1^*)} - \alpha c(t_1^*, t_2^*)\mu(t_1^*) > 0$$

After simplification, this last condition become:

$$\alpha c_1(t_1^*, t_2^*)\frac{\mu(t_1^*)^2}{\mu'(t_1^*)} > 0$$

which is always satisfied.

The manager participation constraint

Replacing RM by its value given by (31) modifies the manager participation constraints in the following way:

$$\left[\frac{(1-\alpha)[c_1(t_1^*, t_2^*)\mu(t_1^*) + c(t_1^*, t_2^*)\mu'(t_1^*)]}{\mu'(t_1^*)} - \frac{\alpha c_2(t_1^*, t_2^*)\mu(t_1^*)}{\mu'(t_1^*)\frac{dt_1}{dt_2}}\right]\mu(t_1^*) - (1-\alpha)$$
$$\times c(t_1^*, t_2^*)\mu(t_1^*) - \gamma_m(t_2^*) > 0$$

After some simplifications and using (17) which states that $-c_2(t_1^*, t_2^*)\mu(t_1^*) = \gamma_m'(t_2^*)$ the participation constraint becomes:

$$(1-\alpha)c_1(t_1^*, t_2^*)\frac{\mu(t_1^*)^2}{\mu'(t_1^*)} + \frac{\alpha\gamma_m'(t_2^*)\mu(t_1^*)}{\mu'(t_1^*)\frac{dt_1}{dt_2}} - \gamma_m(t_2^*) > 0$$

From the expression above, it can be shown that the participation constraint could be met for a level of α outside the [0, 1] interval.

Since $(1-\alpha)c_1(t_1^*, t_2^*)\frac{\mu(t_1^*)^2}{\mu'(t_1^*)} > 0$, a sufficient condition for the participation constraint to be satisfied is:

$$\frac{\alpha\gamma_m'(t_2^*)\mu(t_1^*)}{\mu'(t_1^*)\frac{dt_1}{dt_2}} - \gamma_m(t_2^*) > 0$$

Denoting by ϵ_{μ,t_2} the demand elasticity with respect to t_2 with $\epsilon_{\mu,t_2} = \frac{d\mu}{dt_2}\frac{t_2}{\mu} = \frac{d\mu}{dt_1}\frac{dt_1}{dt_2}\frac{t_2}{\mu} = \mu'(t_1)\frac{dt_1}{dt_2}\frac{t_2}{\mu}$, the sufficient condition becomes:

$$\frac{\alpha\gamma_m'(t_2^*)t_2}{\epsilon_{\mu,t_2}} - \gamma_m(t_2^*) > 0$$

But since $\gamma_m(t_2)$ is convex in t_2 $\left(\text{and thus } \gamma_m'(t_2) > \frac{\gamma_m(t_2)}{t_2}\right)$, a sufficient condition for the manager's participation constraint to be satisfied is thus:

$$\alpha > \epsilon_{\mu,t_2}$$

This sufficient condition simply states that the part of the cost that the physician bears must be high enough (higher than the indirect demand elasticity with respect to the cost reducing effort) to ensure that the optimal values of RP and RM gives a positive profit to the hospital manager.

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