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

David Crainich
CRESGE/LEM/FLSEG,
Université Catholique de Lille.
email: dcrainich@cresge.fr

Hervé Leleu
CNRS and CORE,
Université Catholique de Louvain
and LEM (UMR 8179),
Université Catholique de Lille
email: leleu@core.ucl.ac.be

Ana Mauleon
FNRS and CEREC,
Facultés Universitaires Saint-Louis,
and CORE.
email: mauleon@fusl.ac.be

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Abstract

In a paper published by Ma (1994) it was argued that the prospective payment system in the hospital industry was superior to the cost based reimbursement system to achieve both cost reduction and quality improvement objectives. In the analysis, it was assumed that quality and costs decisions were made by a single agent. Our paper compares these two financing systems assuming that the main decisions taken within the hospital are shared between physicians (quality of treatment) and hospital managers (cost reduction). If Ma's conclusions hold in the US context (where the hospital managers bear the whole cost of treatment), we show that the ability of a prospective payment system to achieve both objectives is very depending of the type of interaction between the agents when physicians bear a part of the treatment cost as it is the case in many European countries.

JEL Classification: H51, I18, D21

Key words: Hospital's financing system, strategic interaction, prospective payment system.

1 Introduction

From the seventies, Harris (1977) 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 firms: 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 as a necessary condition to the definition of well-designed economic policy that would otherwise be doomed to fail.

The issue of the relative strengths and weaknesses of various hospital financing systems has been largely dealt with in health economics literature (Ma (1994), Chalkley and Malcomsom (1998), Pope (1990) and Newhouse (1996) for example). These papers do not however consider that the decisions made within hospitals are shared between various agents. Since Harris (1977) a few papers explicitly consider 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 in their models.

By comparing two hospital's financing systems, Ma (1994) shows that - whenever a provider cannot refuse to patients the 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 an optimally 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 taken by a single agent within hospitals. Our paper analyses the ability of these two payment systems to achieve quality and cost reduction objectives when two decisions units are integrated within the hospital: the medical staff that defines the quality of care and the 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 bear the totality of the treatment cost. It can easily be shown that his conclusions about the superiority of the prospective payment system over the cost based reimbursement system hold in that context. The situation is however quite different in many European for-profit hospitals where physicians bear part of the cost of treatment. Once this specificity is integrated - while keeping Ma's assumptions intact - into the model, we show that the implementation of the optimal level of treatment quality and cost reduction efforts within the hospital is very depending on the type of interaction between the agents (simultaneous decision making, dominant-reactive or sequential decision making, or joint decision making). It thus follows that regulation policies in the hospital sector should not be exclusively focused on the financing system but also take the interaction between physicians and hospital managers into account.

The paper is organized as follows. Ma's model is summarized in Section 2 and physicians-managers interactions are considered in Section 3. Section 4 concludes.

2 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 to the agents who undertake them a total disutility 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 hospitals financing methods are considered in Ma's paper: the cost reimbursement system and the prospective payment system. Hospital's expenses are completely paid for and a margin m is introduced in order to provide incentives for efforts to reduce costs and enhance quality under the former payment system[1] while the hospital receives a fixed amount p per patient treated under the latter system. The hospital's net profit under cost reimbursement and prospective payment are respectively:

$$\pi_{cr} = (c(t_1, t_2) + m)\mu(t_1) - c(t_1, t_2)\mu(t_1) - \gamma(t_1 + t_2) = m\mu(t_1) - \gamma(t_1 + t_2) \qquad (1)$$

$$\pi_{pp} = p\mu(t_1) - c(t_1, t_2)\mu(t_1) - \gamma(t_1 + t_2) \qquad (2)$$

The gross social benefit generated by the hospitals' activity is denoted $W(t_1)$. It depends on the number of patients using the hospital 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 $W''(t_1) < 0$).

[1] Let us notice that Ma's reimbursement systmem is actually a mixed system since a part of the payment ($m\mu(t_1)$) depends on the demand. This is quite important in the model we introduce at the next section so that we will rather call it a mixed system. We although keep Ma's terminology in this section.

2.1 Optimal efforts levels

The regulator's objective function given by Equation (3) is the sum of consumer surplus (gross social benefit minus what they pay through taxes for these services) and hospitals' profits:

$$W(t_1) - c(t_1, t_2)\mu(t_1) - \gamma(t_1 + t_2) \tag{3}$$

The values of t_1 and t_2 that maximizes Equation (3) 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:

$$W'(t_1^*) - c_1(t_1^*, t_2^*)\mu(t_1^*) - c(t_1^*, t_2^*)\mu'(t_1^*) - \gamma'(t_1^* + t_2^*) = 0 \tag{4}$$

$$-c_2(t_1^*, t_2^*)\mu(t_1^*) - \gamma'(t_1^* + t_2^*) = 0 \tag{5}$$

The following second-order conditions are both negatives 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 compares the relative efficiency of the cost based reimbursement system and of the prospective payment system to achieve the optimal efforts levels of quality enhancement t_1^* and cost reduction t_2^*.

2.2 The cost based reimbursement system

It is easy to show that a cost based reimbursement system cannot enable the implementation of t_2^* since no incentives to reduce costs are provided by such a payment. This is shown by the derivative of the hospital's net profit (1) with respect to t_2 that is negative for any value of t_2 higher than zero:

$$-\gamma'(t_1 + t_2) = 0$$

A corner solution ($t_2 = 0$) arises which means that no effort to reduce costs is provided by the hospital under a cost reimbursement payment.

The derivative of (1) with respect to t_1 defines the effort undertook to enhance quality:

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

The fact that t_2 is necessarily equal to zero under the cost based reimbursement system modifies the optimal social value of the quality enhancement effort which is defined from Equation (4) as follows:

$$W'(t_1^+) - c_1(t_1^+, 0)\mu(t_1^+) - c(t_1^+, 0)\mu'(t_1^+) - \gamma'(t_1^+) = 0 \tag{7}$$

Using (6) and (7), Ma defines the value of m that enables the implementation of t_1^+ :

$$m = \frac{\gamma'(t_1^+)}{\mu'(t_1^+)} = \frac{W'(t_1^+) - c_1(t_1^+,0)\mu(t_1^+) - c(t_1^+,0)\mu'(t_1^+)}{\mu'(t_1^+)} \tag{8}$$

One can compare t_1^* and t_1^+ using Equations (4) and (7). When t_2 is reduced to zero, the cost of treating patients increases and the disutility of effort falls. It follows that the specification of the model does not enable the comparison of t_1^* and t_1^+.[2]

2.3 The prospective payment system

The implementation of t_1^* and t_2^* can in contrast be achieved through a well designed prospective payment system. The first-order conditions associated to the hospital's net profit under prospective payment (2) are given by Equations (9) and (10):

$$p\mu'(t_1) - c_1(t_1,t_2)\mu(t_1) - c(t_1,t_2)\mu'(t_1) - \gamma'(t_1+t_2) = 0 \tag{9}$$

$$-c_2(t_1,t_2)\mu(t_1) - \gamma'(t_1+t_2) = 0 \tag{10}$$

The hospital's first-order condition defining t_2 corresponds to that of the regulator (5). 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 Equations (4) and (9), p must be such that:

$$p = \frac{W'(t_1^*)}{\mu'(t_1^*)} \tag{11}$$

Ma thus concludes that the prospective payment system in the health industry is superior to the cost based reimbursement system to achieve cost reduction and quality improvement objectives.

3 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 clearly made by physicians while cost reduction efforts are decided by managers. Payment and disutility functions can also be obviously individualized. However the main issue is related

[2] Because within the "marginal social cost" of quality $c_1(t_1,t_2)\mu(t_1) - c(t_1,t_2)\mu'(t_1) - \gamma'(t_1+t_2)$, the term $\gamma'(t_1+t_2)$ also changes with t_2. This does not appear clearly in Ma's paper.

to the share of the costs between physicians and hospital managers. Two approaches can be considered: the hospital either grants admitting privileges to physicians and bears 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 borne 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 agents ($c(t_1,\, t_2) = CP(t_1,\, t_2) + CM(t_2)$, where $CP(t_1,\, t_2)$ refers to the physician's cost and $CM(t_2)$ stands for the manager's cost) and we suppose that the institutional agreement between the physician and the hospital is 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. The cost borne by the physician and the manager can thus be written as follows:

$$CP(t_1, t_2) = CPA(t_1) + CPR(t_2)$$

$$CM(t_2) = CMA(t_2) - CPR(t_2)$$

where $CPR(t_2)$ indicates the part of the fee retroceded by the physician to the hospital manager[3] and where $CPA(t_1)$ and $CMA(t_2)$ are the costs related to the quality and cost reduction made by the physician and the manager respectively. This simple but quite realistic framework enables us to keep the assumption made by Ma about the costs *i.e.* $CP_1(t_1, t_2) \geqslant 0; CP_{11}(t_1, t_2) \geqslant 0; CP_2(t_1, t_2) < 0; CP_{22}(t_1, t_2) \geqslant 0; CM_2(t_2) < 0; CM_{22}(t_2) \geqslant 0$ and $CP_{12}(t_1, t_2) = 0$. Notice that the efforts made by the manager to reduce costs have also an impact on the total cost borne by the physician ($CP_2(t_1,\, t_2) < 0$ and $CP_{22}(t_1, t_2) \geqslant 0$) but not on his/her cost to improve quality ($CP_{12}(t_1, t_2) = 0$). In contrast, the efforts made by the physicians to improve quality have no impact on the managers costs ($CM_1(t_1, t_2) = 0$) but well on the demand which enters in the manager's objective function. All 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 the shape of 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

[3] It would be more realistic to consider that the amount retroceded by the physician to the hospital is the result of a negociation between the two parties and depends both on the quality improvements efforts made by the physician to attract new patients and on the cost reduction efforts made by the manager. Since a retroceded fee depending on these two arguments would not change our results, we denote it $CPR(t_2)$ instead of $CPR(t_1, t_2)$ in order not to weight the model.

$\mu'' \leqslant 0$). Finally, we suppose - in line with Ma - that the physician and manager's total cost function ($CP(t_1, t_2)\mu(t_1)$ and $CM(t_2)\mu(t_1)$ respectively) are convex in order to ensure that second order conditions related to equations (20), (24), (28), (31), (33), (35), (38), (40) and (42) are negatives.

3.1 Case 1: the manager bears 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:

$$W(t_1) - c(t_1, t_2)\mu(t_1) - \gamma_p(t_1) - \gamma_m(t_2) \tag{12}$$

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

$$W'(t_1^*) - c_1(t_1^*, t_2^*)\mu(t_1^*) - c(t_1^*, t_2^*)\mu'(t_1^*) - \gamma_p'(t_1^*) = 0 \tag{13}$$

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

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

$$\pi_{pp}^p = RP\mu(t_1) - \gamma_p(t_1) \tag{15}$$

$$\pi_{pp}^m = RM\mu(t_1) - c(t_1, t_2)\mu(t_1) - \gamma_m(t_2) \tag{16}$$

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

$$RP\mu'(t_1) - \gamma_p'(t_1) = 0 \tag{17}$$

$$-c_2(t_1, t_2)\mu(t_1) - \gamma_m'(t_2) = 0 \tag{18}$$

The comparison of the first order conditions (14) and (18) 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 regulator can thus 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, the hospital manager is financially responsible of the whole cost that is therefore fully internalized under a prospective payment system. 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. 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 Equation (15)). Finally, for the same reasons than those developed in the previous section, it is obvious that a cost based payment system is unable to achieve the optimum whatever the interaction between the agents.

3.2 Case 2: 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 thus becomes crucial to analyze in details the two financing systems under the various interactions: simultaneous decision-making, sequential decision-making or cooperation.

3.2.1 The social welfare

The social welfare function is now written:

$$W(t_1) - CP(t_1, t_2)\mu(t_1) - CM(t_2)\mu(t_1) - \gamma_p(t_1) - \gamma_m(t_2) \tag{19}$$

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

$$W'(t_1^*) - CP_1(t_1^*, t_2^*)\mu(t_1^*) - CP(t_1^*, t_2^*)\mu'(t_1^*) - CM(t_2^*)\mu'(t_1^*) - \gamma_p'(t_1^*) = 0 \tag{20}$$

$$-CP_2(t_1^*, t_2^*)\mu(t_1^*) - CM_2(t_2^*)\mu(t_1^*) - \gamma_m'(t_2^*) = 0 \tag{21}$$

3.2.2 The prospective payment system

The profits π_p and π_m made by physicians and managers can be written:

$$\pi_{pp}^p = RP\mu(t_1) - CP(t_1, t_2)\mu(t_1) - \gamma_p(t_1) \tag{22}$$

$$\pi_{pp}^m = RM\mu(t_1) - CM(t_2)\mu(t_1) - \gamma_m(t_2) \tag{23}$$

The case of cooperation between managers and physicians corresponds obviously to Ma's model and thus enables the implementation of t_1^* and t_2^* defined by Equations (20) and (21) respectively. It can also be shown that the sequential decision-making situation with the hospital moving first can also implement the optimal outcome in case of prospective payment system. These results are developed in appendix A.

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 Equations (20) and (21) in case of simultaneous decision-making between physicians and managers. In such a case, the first-order conditions defining t_1 and t_2 are:

$$RP\mu'(t_1) - CP_1(t_1, t_2)\mu(t_1) - CP(t_1, t_2)\mu'(t_1) - \gamma_p'(t_1) = 0 \tag{24}$$

$$-CM_2(t_2)\mu(t_1) - \gamma_m'(t_2) = 0 \tag{25}$$

Since the hospital manager cannot modify the demand through its effort level, the payment per patient RM received by the hospital does not modify the cost reduction effort undertaken by the managers. This effort level is thus lower than t_2^* since - unlike the cooperative situation - the hospital does not integrate the physician's gain that results from its cost reduction effort. The regulator has however at its disposal RP to reach the optimal quality enhancing effort level t_1^*. This can be done using Equations (20) and (24):

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

This 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 appendix A that this is also the case under another form of interaction between physicians and managers: the sequential decision-making situation with the physician being the first-mover.

3.2.3 The mixed payment system

We consider in this section the equivalent of the cost based reimbursement system introduced by Ma. We although mention it as a mixed system since a part of this payment ($m\mu(t_1)$) is prospective as it depends on the demand. A payment system that fully pays hospital for all the costs incurred seems unlikely - as pointed out by Ma - to provide to hospitals the right incentive to undertake any cost reduction effort. Once the interaction between physicians and hospital managers is considered, we show that this is indeed true if the agents cooperate (Ma's model), interact in a simultaneous way or in a sequential way with physicians being first-movers (see Appendix B for the development of these three cases). Quite interestingly, the mixed payment system enables the simultaneous achievement of t_1^* and t_2^* in case of a sequential interaction with the hospital manager moving first. Under this payment system, the profits made by physicians and hospitals are defined in the following way:

$$\pi_{cb}^p = RP\mu(t_1) - CP(t_1, t_2)\mu(t_1) - \gamma_p(t_1) \tag{26}$$

$$\pi_{cb}^m = m\mu(t_1) - \gamma_m(t_2) \tag{27}$$

Let us notice that the mixed payment system only concerns the hospital. The physician fee remains the one defined under the prospective payment system[4].

The first order conditions corresponding to (26) and (27) are:

$$RP\mu'(t_1) - CP_1(t_1,t_2)\mu(t_1) - CP(t_1,t_2)\mu'(t_1) - \gamma_p'(t_1) = 0 \tag{28}$$

$$m\mu'(t_1)\frac{dt_1}{dt_2} - \gamma_m'(t_2) = 0 \tag{29}$$

The first term of the left hand side of the first order condition (29) expresses the fact that the manager - knowing that he/she can influence the physician's decision - increases its cost reducing effort level in order to bring a higher demand which is beneficial to the hospital as well. The manager can induce a higher quality enhancing effort by increasing its own effort t_2 as shown by the following Equation (using the first order condition (28) and the implicit function theorem):

$$\frac{dt_1}{dt_2} = \frac{CP_2(t_1,t_2)\mu'(t_1)}{RP\mu''(t_1) - CP_{11}(t_1,t_2)\mu(t_1) - 2CP_1(t_1,t_2)\mu'(t_1) - CP(t_1,t_2)\mu''(t_1) - \gamma_p''(t_1)} > 0 \tag{30}$$

The regulator now has two instruments (RP and m) to achieve its two objectives. To reach the optimal level of efforts t_1^* and t_2^* the regulator sets the value of RP and m such that the equalization between Equations (20) and (28) on one hand and Equations (21) and (29) on the other hand are simultaneously satisfied. We thus define these values as follows:

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

$$m = \frac{-\left[CP_2(t_1^*,t_2^*) + CM_2(t_2^*)\right]\mu(t_1^*)}{\mu'(t_1^*)\frac{dt_1}{dt_2}}$$

The fact that the manager can influence the physician's decision introduces the payment granted to hospital m into the hospital first-order condition (while this is not the case for the other forms of interactions). It therefore appears that even if the hospital does not bear the production cost $CM(t_2)$ (since it is fully reimbursed), the hospital manager undertakes a cost reduction effort in order to induce greater quality effort from the physician and thus a higher demand. The mechanism just described points out the crucial role played by the prospective part of the mixed payment system. A payment purely based on the reimbursement of costs could not bring the optimal values of t_1 and t_2.

[4] Our results would nevertheless remain if we had considered instead a fee-for-service payment for the physician i.e. $RP.t_1$ with the quality enhancing effort t_1 corresponding to the number of medical acts undertaken.

4 Conclusion

The ability of two payment systems (the prospective payment and the mixed payment system) to reach a 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 unambiguously stressed the superiority of the prospective payment system. His model however did not take into account the fact that the main decisions made within hospitals are shared between the physician and the hospital's manager. Assumption that we introduce in our model where 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 bear any part of the cost of treatment. Since the cost is fully borne 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. The same equilibrium cannot be obtained under a payment system based - even partly - on the reimbursement of costs that does not make any agent financially responsible.

Things are different when physicians support - 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 a simultaneous interaction or a sequential interaction when physicians are first-movers. Moreover one form of interaction ensures the optimum whatever the financing system implemented: the sequential interaction with hospital managers moving first. The type of interaction between agents is therefore crucial in the implementation of efficiency and quality objectives.

The inability of the two financing systems to guarantee both objectives when hospital physicians bear some part of the treatment cost would thus justify a more extensive hospital regulation in Europe (to encourage specific forms of interactions between the agents) than in the US where efficiency and quality can be reached only through the financial instrument.

In the absence of regulation, no specific form of interaction should *a priori* emerge (the four forms of interactions analyzed in the paper seem as 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 "contrats 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 stages contracts: between the government and the hospital manager who define 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 leader seems therefore to be the only interaction that public authorities could implement through hospitals regulations.

It then follows that if the regulator succeed in giving the first-mover advantage to the hospital, the mixed payment could be preferred to the prospective payment if issues such as patient selection or economic credentialing cannot be overcome under the latter payment system. A definite conclusion cannot however be drawn until these themes are not introduced in a model that considers physicians and managers interactions within the hospital.

Appendix

A The prospective payment system (case 2)

We show in this appendix that the cooperation between physicians and hospitals and the sequential interaction with hospital moving first lead to the optimal values of t_1^* and t_2^* under a prospective payment system when the production cost is shared between the physician and the manager (case 2). These two results confirm Ma's findings. We then show that the sequential interaction with physicians being first-movers is - beside the simultaneous interaction already developed - another case where the prospective payment system cannot implement the efficient levels of quality enhancing and cost reduction efforts.

A.1 Cooperation between physicians and managers

This case corresponds to the one developed by Ma. They maximize the following joint profit.

$$\pi_{pp}^{coop} = [RP + RM]\,\mu(t_1) - [CP(t_1,t_2) + CM(t_2)]\,\mu(t_1) - \gamma_p(t_1) - \gamma_m'(t_2)$$

The first order condition defining the quality enhancing and cost reduction effort are:

$$[RP + RM]\,\mu'(t_1) - CP_1(t_1,t_2)\mu(t_1) - [CP(t_1,t_2) + CM(t_2)]\,\mu'(t_1) - \gamma_p'(t_1) = 0 \quad (31)$$

$$-\left[CP_2(t_1,t_2)+CM_2(t_2)\right]\mu(t_1)-\gamma_m'(t_2)=0 \tag{32}$$

Using these two first-order conditions and Equations (20) and (21), it is easy to show that one can reach t_1^* and t_2^* if:

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

Which is equivalent to the result shown by Ma (Equation (11)).

A.2 Sequential interaction - the hospital is the first-mover

The physician and the manager maximize the profits expressed through Equations (22) and (23) respectively. The first order conditions are:

$$RP\mu'(t_1)-CP_1(t_1,t_2)\mu(t_1)-CP(t_1,t_2)\mu'(t_1)-\gamma_p'(t_1)=0 \tag{33}$$

$$-CM_2(t_2)\mu(t_1)-\gamma_m'(t_2)+\left[\left(RM-CM(t_2)\right)\mu'(t_1)\right]\frac{dt_1}{dt_2}=0 \tag{34}$$

Using the Equation (33) one can define the way the hospital manager can influence the physician's decision:

$$\frac{dt_1}{dt_2}=\frac{CP_2(t_1,t_2)\mu'(t_1)}{RP\mu''(t_1)-CP_{11}(t_1,t_2)\mu(t_1)-2CP_1(t_1,t_2)\mu'(t_1)-CP(t_1,t_2)\mu''(t_1)-\gamma_p''(t_1)}>0$$

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:

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

$$RM=CM(t_2^*)+\frac{CP_2(t_1^*,t_2^*)\mu(t_1^*)}{\mu'(t_1^*)\frac{dt_1}{dt_2}}$$

When the hospital is the first-mover in a sequential interaction with the physician, it can influence the physician's decision and thus indirectly the demand it faces. The payment the hospital receives influences the manager's decision and the regulator may use this payment - along with the payment the physician receives - in order to reach the optimal efforts t_1^* and t_2^*.

A.3 Sequential interaction - the physician is the first-mover

The first-order conditions are:

$$RP\mu'(t_1)-CP_1(t_1,t_2)\mu(t_1)-\left[CP_2(t_1,t_2)\frac{dt_2}{dt_1}+CP(t_1,t_2)\right]\mu'(t_1)-\gamma_p'(t_1)=0 \tag{35}$$

$$-CM_2(t_2)\mu(t_1)-\gamma_m'(t_2)=0 \tag{36}$$

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

$$\frac{dt_2}{dt_1} = \frac{CM_2(t_2)\mu'(t_1)}{-CM_{22}(t_2)\mu(t_1) - \gamma''_m(t_2)} > 0 \tag{37}$$

The first order condition (36) makes appear that the hospital does not take the cost borne by the physicians into account and there is thus an underprovision of cost reducing effort. Moreover the payment given to the hospital has no impact on manager's decisions. The regulator cannot therefore correct the value of t_2 to reach its optimal value.

B The cost reimbursement system (case 2)

B.1 Cooperation between physicians and managers

$$\pi_{cr}^{coop} = (RP + m)\,\mu(t_1) - CP(t_1,t_2)\mu(t_1) - \gamma_p(t_1) - \gamma_m(t_2)$$

The first order conditions defining the quality enhancing and cost reduction efforts are:

$$(RP + m)\,\mu'(t_1) - CP_1(t_1,t_2)\mu(t_1) - CP(t_1,t_2)\mu'(t_1) - \gamma'_p(t_1) = 0 \tag{38}$$

$$-CP_2(t_1,t_2)\mu(t_1) - \gamma'_m(t_2) = 0 \tag{39}$$

Here, t_2 is not equal to zero since all the costs are not reimbursed (the physician bears $CP(t_1,t_2)\mu(t_1)$), in contrast to Ma's model. The level of cost reduction effort t_2^+ is included between zero (as in Ma's model) and its optimal value t_2^*. Since $t_2^+ \neq t_2^*$, the optimal value of the quality enhancing effort t_1^+ can be lower, equal or higher than t_1^*. To reach that level of effort, the regulator can either use RM or m in the following way:

$$RP = \frac{W'(t_1^+)}{\mu'(t_1^+)} - CM(t_2^+) - m$$

or

$$m = \frac{W'(t_1^+)}{\mu'(t_1^+)} - RP$$

B.2 Simultaneous interaction

The maximization of Equations (26) and (27) respectively by the physician and the manager gives the following first order conditions:

$$(RP - CP(t_1,t_2))\,\mu'(t_1) - CP_1(t_1,t_2)\mu(t_1) - \gamma'_p(t_1) = 0 \tag{40}$$

$$-\gamma'_m(t_2) = 0 \tag{41}$$

It is obvious from Equation (41) that the cost reduction effort level t_2 is null. The corresponding quality enhancing effort level is lower, equal to or above t_1^* but the efficient level of efforts cannot be reached under a simultaneous interaction between physicians and managers.

B.3 Sequential interaction - the physician is the first-mover

That case leads to the same outcome that the simultaneous case. The first order conditions are:

$$(RP - CP(t_1, t_2))\,\mu'(t_1) - CP_1(t_1, t_2)\mu(t_1) - CP_2(t_1, t_2)\mu(t_1)\frac{dt_2}{dt_1} - \gamma'_p(t_1) = 0 \qquad (42)$$

$$-\gamma'_m(t_2) = 0 \qquad (43)$$

>From Equation (43) one can notice that the physician has no influence on the manager's decision ($\frac{dt_2}{dt_1} = 0$). The first order condition (42) defining t_1 consists merely of the one under the simultaneous case (40) and one obtain a suboptimal outcome.

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