Hospital's activity-based financing system and manager - physician interaction[*]

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Abstract

Hospital financing systems determine major decisions made by physicians and managers within hospitals. This paper examines the impact of the transition toward an activity-based reimbursement system that has emerged in most OCDE countries. We consider two initial situations, one for a private for-profit sector where both hospitals and physicians are paid on a fee-for-service basis and the other for a public sector under prospective budget and salaried physicians. For the private sector, our model focuses on the type of interaction (simultaneous, sequential or joint decision-making games) that should emerge between agents after the indroduction of the activity-based financing system. In the public sector, the elasticity of the demand to the level of inputs seems to play a more crucial rôle in the transition.

JEL Classification: I11, D4, D2

Key words: Hospital's financing system, Strategic interaction, Activity-based payment system.

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1 Introduction

The provision of health care services now constitutes one of the largest industries in OECD countries, representing on average 8.5% of the per capita GDP of all OECD countries in 2002 (10.2% of the GDP for the seven most industrialized countries and 14.6% for United States only). During the last decade 1990-2001, the annual growth rate of health care expenditures was still significantly higher than the GDP growth rate (3.4% in average versus 2.1% in OECD countries) and the share of hospitals' expenditures in total health spending was about 40% during this period[1]. As a consequence, hospitals have attracted the attention of policymakers attempting to curb growth in health care costs by changing the financial landscape.

Three main issues associated to hospital financing system are mostly considered in the economic literature. Namely, the ability to control the total cost, to induce efficiency (minimal unit cost or maximal level of activity by unit of input) and to ensure a high level of the quality of care delivered. Among industrialized countries and until the 1980s cost reimbursement was the main form of payment for public or private not-for-profit hospitals. While it allows for high quality of care, this system neither offers incentives to reduce costs nor to increase efficiency. In the early 1980s, policy makers began to consider the switch from the cost-based reimbursement to prospective budgets to cope with continuously increasing growth of hospital spending; this capped hospital expenditure at an exogenous growth rate. While this system allows for cost containment, it is completely disconnected from the real activity of hospitals and creates no incentives for efficiency or a high level of quality of care. On the other hand, the private for-profit hospitals were traditionally financed on a fee-for-service basis. Finally, in the last decade, most of the OECD countries joined the US who had initiated an activity-based payment for both public and private hospitals as early as in 1983 for the Medicare program. This activity-based system works on a flat amount per admission given the patient's diagnosis and thus encourages the hospital to lower its unit cost in order to turn a profit. Clearly, this activity-based payment creates huge incentives for efficiency. Actually, most countries opt for a mix of financing systems where strong incentives are placed on efficiency by the activity-based system while external controls ensure an expected level on the quality of health care services and a global expenditure cap policy aims to contain the total spending. In Western Europe combinations of prospective budgeting with activity-based payment are found in Austria, Belgium, France, Finland, Germany, Italy, Ireland, Norway, Portugal, Spain and Sweden.

When comparing different hospital payment systems, two main topics have been con-

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[1]Source: OECD Health Data 2004.

sidered in the economic literature. First, the comparison of the systems from a social welfare standpoint has been a major concern in the health economics literature. Ma (1994) and Chalkley and Malcomsom (1998) have shown that an activity-based payment system will imply both productive efficiency (the minimization of per-patient costs) and allocative efficiency (the treatment of the socially optimal number of patients) provided that the demand depends on the quality of health care services. Mougeot and Naegelen (2004) have analyzed the strategies of the providers facing a global expenditure cap policy and evaluate its effects on provider and patient surplus. More generally, Pope (1990) or Newhouse (1996) have pointed out the value of a payment system based on a mix between a prospective and a retrospective system. An alternative to this social optimum approach is to analyze the impact of an exogenous change in the financing policy on the behavior of the economic agents (hospital's managers, physicians, patients). Much less literature has been devoted to this issue. To our knowledge, only Custer et al. (1990) and Dor and Watson (1995) have analyzed how different payment systems affect hospital-physicians interactions. Custer et al. (1990) have treated hospital-physician interactions from a productive efficiency angle without directly taking into account the impact on patients' demand. Dor and Watson (1995) have compared two kind of prospective payment systems: a single fee to be shared between hospital and physicians and distinct fees for each of them.

A major issue in the introduction of an activity-based financing system is how it will affect the decisions of managers and physicians when they both have their own and separated economic objectives and when they interact within the hospital to satisfy the demand. This issue has first been considered in Coudeville, Mauleon and Dervaux (2004) for the private for-profit sector. In this paper, we depart from their model for the private-for-profit sector by focusing on the type of interaction that should be promoted by an activity-based financing system. We also extend the analysis to the public sector since both behaviors and objectives differ among physicians and managers in the two sectors. Moreover, current financing system are quite different (prospective budget and salaried physicians in the public sector and fee-for-service for both the hospital and physicians in the private sector). Our main focus is how the transition to a common activity-based financing scheme may affect differently public and private hospitals and how it may modify the type of interactions between hospital's managers and physicians depending they have conflicting interests or incentives to cooperate under the new payment system. Since we are mainly interested in the modification of the behavior, we consider a neutral financing reform which does not affect the amount of the global budget but only the reimbursement schemes.

The paper is organized as follows. In Section 2, the model is presented. Section 3 analyzes the impact on the manager-physician interaction of the introduction of an activity-based financing system for the private for-profit sector while Section 4 is devoted to the public sector. Section 5 concludes and discusses some possible extensions.

2   The model

We suppose that major decisions taken within hospitals are made by physicians and managers. The former make decisions about a level of effort that corresponds to a number of acts (denoted by e and that can be medical or surgical acts, pre or post surgery consultations...) they undertake per day while the latter define the input provided by the hospital (denoted by q and which includes expenses related to the operating rooms, beds, technical equipment, nursing care, administrative and technical staff...). We also suppose that a given number a of acts is required to treat the representative disease for homogeneous patients. The patient's average length of stay (denoted by h) is therefore directly related to the level of effort supplied by physicians per day (with $h(e) = a/e$ by definition). The issue of the quality of treatment is not dealt with through the physician's daily effort (e) - that must be considered as a variable that implicitly determines patients' length of stay at the hospital - but rather through the hospital input (q). Since we assume that no minimal duration is required for the administration of the treatment and that at least one act is made per day, the bounds for e and h are such that: $e \in [1, a]$ and $h \in [1, a]$.

Patients are sensitive to the input q and to the daily effort e provided by hospitals and physicians respectively. Patients' utility function is assumed to be additive and increasing, continuous and strictly concave in both arguments.

$$U(e, q) = E(e) + Q(q)$$

with $E_e > 0$, $E_{ee} < 0$, $Q_q > 0$ and $Q_{qq} < 0$.

The first assumption simply states that patients prefer to be treated as quickly as possible. There are no quality differences between treatments since each treatment - whether administered in a short or a long period of time - has the same impact on the patient's health state. Other things being equal, patients thus prefer not to spend time in hospitals[2]. The assumptions about the second argument of the utility function (hospitals' input) are obvious.

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[2]Instead of assuming that the patient's utility depends on the physician's effort level e, we could have considered that it depends on the length of stay h. We have though preferred to consider e as the argument of the utility function since it is a control variable determined by the physician. However this modification in the model setting does not affect our final results.

We consider the situation of a single hospital that does not face competition. In that case patients decide to go to the hospital only if the utility associated to the treatment is higher than a certain threshold that is patient specific and that depends on elements such as patient's preferences for private vs. public hospital, physical or psychological distance... If this threshold is uniformly distributed between $\underline{U}$ and $\overline{U}$ and if the population size is normalized to 1, the demand faced by the hospital (that is, the number of patients treated) can be defined as follows:

$$D(e,q) = \begin{cases} 0 & if & U \leq \underline{U} \\ \frac{U(e,q)}{\overline{U}-\underline{U}} & if & \underline{U} < U < \overline{U} \\ 1 & if & U \geq \overline{U} \end{cases}$$

Interior solutions will only be considered ($0 < D(e,q) < 1$). Let D_e, D_{ee}, D_q and D_{qq} denote the first and second derivatives of the demand with respect to the effort level and to the hospital input respectively with $D_e > 0$, $D_{ee} < 0$, $D_q > 0$ and $D_{qq} < 0$ given the assumptions made about the patients' utility function.

Since we focus on the impact of the financing reform on the interaction between physicians and managers within private (for-profit) and public (not-for-profit) hospitals, we have to consider four agents (a representative physician and a representative manager for each type of hospital) who determine the four decision variables (effort and input within each type of hospital) of the model. To do so, let us first define the agents' objectives.

Physicians and managers working in private hospitals aim at maximizing their profits. The representative physician tries to maximize his/her daily net income $\Pi^p(e)$ when defining his/her daily level of effort e. Physicians' net income is written in the following way:

$$\Pi^p(e) = D(e,q)\left[RP(e) - CP(e)\right] \tag{1}$$

where $RP(e)$ represents his/her total fee per patient and $CP(e)$ represents the financial cost per patient associated to the medical activity (borne by physicians themselves in private hospitals) plus the monetary equivalent of the effort disutility. $RP(e) > CP(e)$ since we assume that the agents present on the market make a positive profit. Both variables depend obviously on the effort level. There is a linear relationship between fees and the medical activity such that $RP(e) = r_e e$ (we thus implicitly assume that a given fee is granted per medical intervention; the fee is constant across the various interventions). The cost $CP(e)$ is assumed to be continuous, increasing and convex in e ($CP_e > 0, CP_{ee} > 0$) and $CP(0) = 0$. The convexity of the cost function is justified by the increasing disutility of the effort expressed in monetary terms.

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Hospital managers maximize the daily hospital profit $\Pi^h(q)$ defined as follows[3]:

$$\Pi^h(q) = D(e,q)\left(\frac{RH - CH(h)}{h}\right) - CQ(q) \qquad (2)$$

The fee RH is received by hospitals for the whole patients' length of stay. The structure of the hospital's revenue depends on the financing system (fee-for-service vs. activity-based payment) examined in the next section[4]. There are two types of costs borne by the hospital: those related to the patient length of stay denoted $CH(h)$ (supposed to be continuous, increasing and strictly concave in h ($CH_h > 0, CH_{hh} < 0$ and $CH(0) = 0$) and that include expenses related to drugs, bedding, food...; and those related to the hospital input expressed per day (supposed to be linear in the input q such that $CQ(q) = c_q q$). The concentration of care during the first part of the length of stay justifies the strict concavity of $CH(h)$ while the linearity of $CQ(q)$ is explained by the relative stability of equipment and staff expenses. The hospitals present in the market make a positive profit which implies that $RH > CH(h)$.

Let us notice that physicians' and managers' decisions are related. Managers' decisions about the hospital input affect the demand and thus the profit made by physicians. In the same way, physicians' efforts have an impact on the demand and on the patients' length of stay which both enter into the hospital profit. The type of interaction between physicians and managers within the hospital is thus crucial in the choice of the two decision variables e and q.

Turning now to the public sector, physicians working in public hospitals earn a fixed wage that is independent of their activity. They thus maximize their utility instead of their profits. This utility depends on the number of patients treated (because of the conscientiousness or because of the pleasure and the prestige of working in a highly demanded hospital for example) and on the disutility related to the effort (because the time spent next to their patients prevent them from other activities such as leisure or paid consultations outside the hospital). Their utility function is written as follows:

$$U^p(e) = D(e,q) - ED(e,q) \qquad (3)$$

where $ED(e,q)$ stands for the effort disutility which is supposed to be continuous, increasing and convex in the effort ($ED_e > 0$ and $ED_{ee} > 0$ meaning that the disutility

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[3]We suppose that hospitals maximize their daily profits - instead of their profits evaluated along the whole length of stay for example - in order to be consistent with the physician objective. This will be useful when examining situations of cooperation between physicians and hospitals managers that imply the maximization of their joint profits.

[4]A mix of these two payments systems, called two-parts tariffs, is most often used in practice. Our model remains however valid to deal with the impact of the introduction of any intermediate financing between the fee-for-service payment and the activity-based system.

related to each additional effort is increasing). The effort disutility also depends on the hospital input q since we suppose that physicians enjoy more their work and that medical treatments take less time if physicians can take advantage of a developed medical input ($ED_q < 0$ and $ED_{qq} > 0$). The convexity of the effort disutility is justified by the increasing strenuousness of work and by the increasing opportunity cost of forgone leisure.

In public hospitals, managers are responsible of the whole cost related to the hospital activity: those related to the medical acts (e), to the length of stay (h) and to the hospital input (q). The assumptions made previously about the costs related to the length of stay and to the inputs hold for both private and public hospitals. The public hospital only bears the financial charge of the effort that is supposed to be linear ($CP(e) = c_e e$) since the disutility of the effort is a burden for the physician and thus enters in his/her objective function[5]. Public hospital managers have at their disposal a budget that depends on the financing system and are supposed to be responsible of the hospital financial equilibrium. In other words, managers choose the public hospital input level in order to respect the following daily budgetary constraint:

$$BC \equiv D(e,q)\left(c_e e + \frac{CH(h)}{h}\right) + c_q q \leq \frac{B}{h} \tag{4}$$

where B stands for the hospital budget granted to cover expenses related to all patients entire length of stay.

Public hospitals managers are also concerned with patient's utility so that they spend the budget left by improving the hospital input so that the expression (4) is always satisfied as an equality.

3 Financing systems and private hospitals

This section defines the impact of the hospital financing system on effort and input equilibrium values and seeks to determine which type of interaction between physicians and managers is promoted by the financing system in private hospitals. We consider here a transition from a fee-for-service payment to an activity-based financing system but the latter only affects payments related to charges supported directly by the hospital (nursing care, use of operating rooms, drug consumption, etc.). Fees-for-service paid to physicians working in these hospitals are not affected. Unlike the fee-for-service system, the activity-based payment allows hospitals a fixed fee per patient independent of the patients' length

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[5]We must make the distinction between the cost of the effort that physicians totally bear in private hospital and that is split up between physicians (for the disutility) and managers (for its financial part) in public hospitals. The convexity of the cost of the effort is thus not justified for public hospital (the convex part of the cost being borne by physicians).

of stay. The introduction of the latter payment system thus gives direct incentives to reduce the patient's length of stay. In order to highlight the impact of the new financing system on physicians and managers behavior, we suppose that the amount allocated to the representative hospital in the activity-based payment system remains the same than in the previous reimbursement system. Doing so, we focus on the way the various financing systems affect physicians and hospital activity and isolate our model from changing behaviors explained by per patient endowment variations.

We consider three possible types of interactions between physicians and hospital managers (simultaneous decision-making, sequential decision-making or joint decision-making) and show how an activity-based financing system for the hospital improves physicians and managers incentives to coordinate their activities by promoting a sequential decision-making interaction or a joint decision-making interaction. For each type of decision-making game, we first define the equilibrium values of e and q under both financing systems and then show how the introduction of the activity-based payment system modifies agents' behavior.

3.1 The simultaneous decision-making game

We first consider the transition from a fee-for-service payment to an activity-based payment system under a simultaneous decision-making game. Under the fee-for-service reimbursement system, the physician's objective function is given by equation (1) and the first-order condition (5) associated to this optimization program defines the effort level equilibrium value $\widehat{e}_s$:

$$D_e\left[r_e e - CP(e)\right] + D(e, q)\left[r_e - CP_e\right] = 0 \tag{5}$$

where the first term of the equation represents the marginal gain associated to an additional effort (the product of the average gain per patient and the increase in demand due to the extra effort) while the second term represents the marginal cost due to that effort (the reduction of the average gain per patient due to the extra effort). Let us indeed notice that $r_e - CP_e < 0$ at the equilibrium.

The second-order condition is satisfied since:

$$D_{ee}\left[r_e e - CP(e)\right] + 2D_e\left[r_e - CP_e\right] + D(e, q)\left[-CP_{ee}\right] < 0$$

Under the fee-for-service system, hospitals revenues depend on the length of stay h with a constant fee r_h granted per patient and per day (for the entire hospitalization period) so that $RH = r_h h$ in the objective function (2). The hospital optimization program (2) is thus written:

$$\underset{q}{Max}\,\Pi^h(q) = D(e, q)\left(r_h - \frac{CH(h)}{h}\right) - c_q q$$

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The first-order condition that defines $\widehat{q}_s$ is:

$$D_q \left(r_h - \frac{CH(h)}{h} \right) - c_q = 0 \qquad (6)$$

which states that the marginal gain of an additional input (the product of the average gain per day and the increase in demand due to the extra input) is equal to its marginal cost (c_q) at the equilibrium.

The second-order condition for a maximum is satisfied since:

$$D_{qq} \left(r_h - \frac{CH(h)}{h} \right) < 0$$

We now consider the activity-based payment system. First, it is obvious that the physician optimization program remains the one that prevailed under the fee-for-service system (see first-order condition (5)) since we assume that the new payment system only modifies the hospital financing system. Therefore, the effort level equilibrium value does not change, $\widehat{\widehat{e}}_s = \widehat{e}_s$. However, under the new system, hospitals revenues are independent of the length of stay, and then $RH = \overline{RH}$ in the objective function (2). The hospital still maximizes its daily profit defined now by the following expression:

$$\underset{q}{Max}\, \Pi^h(q) = D(e,q) \left(\frac{\overline{RH} - CH(h)}{h} \right) - c_q q$$

The first-order condition (defining $\widehat{\widehat{q}}_s$) associated to this maximization program is:

$$D_q \left(\frac{\overline{RH} - CH(h)}{h} \right) - c_q = 0 \qquad (7)$$

The second-order condition required to obtain a maximum is satisfied:

$$D_{qq} \left(\frac{\overline{RH} - CH(h)}{h} \right) < 0$$

Since the transition between the two systems is done assuming the condition of budget neutrality ($\overline{RH} = r_h \widehat{h}_s$), the reform does not modify the Nash equilibrium when physicians and managers interact simultaneously. Therefore $\widehat{\widehat{e}}_s = \widehat{e}_s$ and $\widehat{\widehat{q}}_s = \widehat{q}_s$. This result is summarized in the following proposition.

Proposition 1 *The transition from a fee-for-service payment system to an activity-based payment system in private hospitals does not modify the physician's effort level and the hospital's input level under a simultaneous decision-making game.*

The financing reform has no impact on the agents' behavior within the private for-profit hospitals if they are engaged in a simultaneous decision-making game. The intuition behind this result is straightforward. The new payment system does not affect the physician

directly while the latter controls the length of stay, the key variable for maximizing the hospital's profit. Since both agents play simultaneously, the physician does not take into account the hospital incentives to reduce the length of stay. This status quo allows us to use the simultaneous Nash equilibrium as a benchmark to analyze the incentives for the physician and the manager to better coordinate their decisions under the other decision-making interactions.

3.2 The sequential decision-making game

3.2.1 Hospital manager leader

We first consider the hospital manager as the leader in the sequential decision-making game. Under the fee-for-service reimbursement system, the hospital manager optimization program (see equation (2)) is:

$$\underset{q}{Max}\,\Pi^h(q) = D(e,q)\left(r_h - \frac{CH(h)}{h}\right) - c_q q$$

When the hospital manager is acting as the leader, the first-order condition that defines $\widehat{q}_{sml}$ is written:

$$\left(D_q + D_e\frac{de}{dq}\right)\left(r_h - \frac{CH(h)}{h}\right) + D(e,q)\frac{de}{dq}\frac{dh}{de}\left(-\left(\frac{CH_h h - CH(h)}{h^2}\right)\right) - c_q = 0 \quad (8)$$

Compared to the first-order condition under the simultaneous decision-making game (equation (6)), we notice that the manager takes into account the fact that his/her input level decision implies a physician reaction $\frac{de}{dq}$ that affects the demand but also a variation in the length of stay, $\frac{de}{dq}\frac{dh}{de}$, that affects the cost. The first order condition defining $\widehat{e}_s$ (equation (5)) and the implicit function theorem allows us to state that:

$$\frac{de}{dq} = -\frac{D_q\left[r_e - CP_e\right]}{D_{ee}\left[r_e e - CP(e)\right] + 2D_e\left[r_e - CP_e\right] + D(e,q)\left[-CP_{ee}\right]} < 0 \quad (9)$$

We also have by definition of $h(e) = a/e$:

$$\frac{de}{dq}\frac{dh}{de} > 0 \text{ and } D(e,q)\frac{de}{dq}\frac{dh}{de}\left(-\left(\frac{CH_h h - CH(h)}{h^2}\right)\right) > 0$$

since the total cost related to the patients' length of stay $CH(h)$ is concave with $CH(0) = 0$.

By comparing equation (8) to the simultaneous Nash equilibrium (equation (6)), we are unable to determine if the hospital input level will be lower or higher compared to the simultaneous case $(\widehat{q}_{sml} \gtrless \widehat{q}_s)$ because the two new terms that appear in equation (8) have opposite signs. Because of its first-mover advantage, the hospital profit is necessarily higher than in the simultaneous case but the effect on the physician profit is ambiguous

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(the impact on the demand is indeterminate since e and q move in opposite directions). Therefore, the fee-for-service payment system does not bring clear incentives for both agents to act in a sequential game (with hospital leader) instead of the simultaneous decision-making game.

We now consider the activity-based payment system. The modification of the payment system does not change the physician's reaction function (equation (9)) defined under the fee-for-service payment system since the reform does not directly affect physician's first order condition (equation (5)). Thus $\frac{de}{dq}$ is still negative. But the activity-based payment modifies the hospital first order condition:

$$\left(D_q + D_e \frac{de}{dq}\right)\left(\frac{\overline{RH} - CH(h)}{h}\right) - c_q + D(e,q)\frac{de}{dq}\frac{dh}{de}\left(-\left(\frac{\overline{RH} - CH(h) + CH_h h}{h^2}\right)\right) = 0 \tag{10}$$

where

$$D(e,q)\frac{de}{dq}\frac{dh}{de}\left(-\left(\frac{\overline{RH} - CH(h) + CH_h h}{h^2}\right)\right) < 0$$

In the activity-based payment system, a decrease in the length of stay increases the hospital per patient profit because the cost falls while the payment $\overline{RH}$ remains fixed. This leads the hospital manager to reduce the level of input $(\widehat{\widehat{q}}_{sml} < \widehat{\widehat{q}}_s)$ compared to the simultaneous Nash equilibrium. However, as $\frac{de}{dq}$ is still negative, the physician effort increases $(\widehat{\widehat{e}}_{sml} > \widehat{\widehat{e}}_s)$ and the effect on the demand and on the physician profit are still ambiguous.

Proposition 2 *Compared to the simultaneous Nash equilibrium, both payment systems do not give clear incentives to the hospital manager and to the physician to act in a sequential game with the hospital moving first. While the hospital profit necessarily increases, the effect on the physician profit is ambiguous in both systems and the activity-based payment system does not give incentives to the agents to better coordinate their decisions by using this type of sequential game.*

The intuition behind the result is that since the optimal level of effort and input move in opposite direction compared to the simultaneous interaction situation (benchmark case), an increase in demand and thus higher profits for both agents are not guaranteed. The effort and the input are therefore strategic substitutes in this case. Things are different if the physician acts as the leader in the sequential game.

3.2.2 Physician leader

We now consider the physician leader in the sequential decision-making game. Under the fee-for-service reimbursement system, the physician optimization program (see equation

(1)) is:

$$Max_{e} \Pi^{p}(e) = D(e, q) [r_{e}e - CP(e)]$$

The first-order condition that defines $\widehat{e}_{spl}$ is thus written:

$$\left(D_e + D_q \frac{dq}{de} \right) [r_e e - CP(e)] + D(e, q) [r_e - CP_e] = 0 \qquad (11)$$

Compared to the first-order condition under the simultaneous decision-making game (equation 5), we notice that the physician takes into account the fact that his/her effort decision implies an indirect effect on the demand (and therefore on his/her profit) through the managers reaction to this effort variation. If $\frac{dq}{de}$ is positive (resp. negative), this indirect effect of e raises (resp. lowers) the demand and thus generates a higher (resp. lower) marginal benefit and equilibrium level of effort. The first order condition defining $\widehat{q}_s$ (equation 6) and the implicit function theorem allows us to state that:

$$\frac{dq}{de} = \frac{D_q \left[\frac{CH_h h - CH(h)}{h^2} \right] \frac{dh}{de}}{D_{qq} [r_h h - CH(h)]} < 0 \qquad (12)$$

The sign of the expression (12) expresses the fact that a lower length of stay (resulting from a higher effort e made by the physician) reduces the hospital daily margin per patient since the total cost related to the patients' length of stay $CH(h)$ is concave. The indirect impact of the effort on the hospital input is thus negative under a fee-for-service payment. This prompts physicians to reduce their efforts $(\widehat{e}_s > \widehat{e}_{spl})$ in order to increase patients length of stay $(\widehat{h}_s < \widehat{h}_{spl})$ and give incentives to managers to increase the hospital input $(\widehat{q}_s < \widehat{q}_{spl})$ compared to the simultaneous game equilibrium (equations (11) and (5)). Profits made by physicians necessarily increase (because of their leading position) but the effect on the hospital profit is ambiguous (they increase their profit per patient because of the increase in h but their input costs rises with q and the impact on the demand is indeterminate since e and q move in opposite directions).

We now consider the activity-based payment system. The physician optimization program defining his/her optimal effort $(\widehat{e}_{spl})$ remains the one defined under the fee-for-service payment system (equation (11)) since the reform does not directly affect physician's payment. But the modification of the payment system changes the hospital's reaction function (which defines $\widehat{q}_{spl}$) such that $\frac{dq}{de}$ is now positive:

$$\frac{dq}{de} = \frac{D_q \left[\frac{\overline{RH} - CH(h) + Ch_h h}{h^2} \right] \frac{dh}{de}}{D_{qq} \left[\frac{\overline{RH} - CH(h)}{h} \right]} > 0 \qquad (13)$$

The positive sign of the reaction function is explained by the fact that incentives to attract new patients by raising the hospital input are enhanced when physicians increase their

efforts because the activity-based payment system rewards hospitals with short lengths of stay. From which it follows that $\widehat{\widetilde{e}}_{spl} > \widehat{e}_{spl}$ and $\widehat{\widetilde{q}}_{spl} > \widehat{q}_{spl}$ that lead to a higher demand and to a higher profit for both the physician and the hospital. Patients' satisfaction also benefits from higher levels of physician's effort and hospital's input. We note the fact that, the hospital also benefits from that sequential decision-making game because its profit is higher than in the fee-for-service payment system since it enjoys both a higher demand and a reduced length of stay. It actually illustrates how the activity-based payment system introduces a strategic complementarity between decisions made by agents within the hospital.

This strategic complementarity between e and q also gives better incentives for the physician and the manager to act in a sequential decision-making game. Since the indirect impact of the effort on the hospital input is positive under the activity-based payment system, this prompts physicians to increase their efforts $(\widehat{\widetilde{e}}_{spl} > \widehat{e}_s)$ in order to decrease patients length of stay $(\widehat{\widetilde{h}}_{spl} < \widehat{h}_s)$ and give incentives to managers to increase the hospital input $(\widehat{\widetilde{q}}_{spl} > \widehat{q}_s)$ compared to the simultaneous game equilibrium (equations (5) and (7)). An additional effort made by the physician indeed reduces the length of stay, improves the per-patient profit made by the hospital and thus its input expenditure. Therefore, an increase in e and q simultaneously increases the per-patient profit and the demand and results in a greater profit for the hospital compared to the simultaneous Nash equilibrium.[6] This contrasts with the fee-for-service case and leads to the following proposition.

Proposition 3 *The transition from a fee-for-service payment system to an activity-based payment system gives better incentives to the physician and the hospital manager to act in a sequential game if the physician benefits from the first-mover advantage. While, under the fee-for-service payment system, the hospital manager may have lower profits in the sequential game than in the simultaneous game, both agents can be better off in the sequential game after the financing reform. The activity-based payment system gives incentives to the physician and to the hospital manager to better coordinate their decisions by using this type of sequential game.*

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[6]The strategic complementarity between decisions in case of physician leadership contrasts with the strategic substitutability between decisions in case of manager leadership. Following Hamilton and Slutsky (1990) and Amir (1995), we can assert that only one player prefers his Stackelberg follower payoff to his simultaneous Nash payoff: the player whose best response function slopes up. See also Vives (1999), chapter 7.

3.3 The joint decision-making game

Under the fee-for-service reimbursement system, the physician and the hospital manager acting together maximize now their joint profit given by the following expression:

$$\underset{e,q}{Max}\,\Pi^j(e,q) = D(e,q)\left(r_e e - CP(e) + r_h - \frac{CH(h)}{h}\right) - c_q q$$

The first-order conditions (defining $\widehat{e}_j$ and $\widehat{q}_j$) are the following:

$$
\begin{aligned}
D_e\left[r_e e - CP(e) + r_h - \frac{CH(h)}{h}\right] + \\
D(e,q)\left[r_e - CP_e - \left(\frac{CH_h h - CH(h)}{h^2}\right)\frac{dh}{de}\right] = 0
\end{aligned}
\tag{14}
$$

$$D_q\left(r_e e - CP(e) + r_h - \frac{CH(h)}{h}\right) - c_q = 0 \tag{15}$$

Compared to the first-order condition defining the simultaneous decision-making game equilibrium (equation (5)), the benefit of an additional effort made by the physician increases since the extra patients attracted also benefit to the hospitals ($r_h - \frac{CH(h)}{h} > 0$). But this additional effort also increases the marginal cost of the effort by reducing the length of stay (and thus the margin per day since the total cost related to the patient length of stay $CH(h)$ is concave). The variation in the effort level thus cannot be determined and leads to an indetermination in the change of the optimal input level (equation (15)) compared to the one in the simultaneous decision-making game (equation (6)). Because of the cooperation, the joint profit made by physicians and managers rises compared to the sum of the agents' individual profits under the simultaneous decision-making equilibrium. We however cannot say whether this profit improvement is achieved through an increase or a decrease of e and q and nothing can therefore be said about individual profit variations (effort and input are strategic substitutes).

Under the activity-based payment system, the physician and the hospital manager optimize the following program:

$$\underset{e,q}{Max}\,\Pi^j(e,q) = D(e,q)\left(r_e e - CP(e) + \frac{\overline{RH} - CH(h)}{h}\right) - c_q q$$

First-order conditions defining $\widehat{\widehat{e}}_j$ and $\widehat{\widehat{q}}_j$ respectively are given by:

$$
\begin{aligned}
D_e\left[r_e e - CP(e) + \frac{\overline{RH} - CH(h)}{h}\right] + \\
D(e,q)\left[r_e - CP_e - \left(\frac{\overline{RH} - CH(h) + CH_h h}{h^2}\right)\frac{dh}{de}\right] = 0
\end{aligned}
\tag{16}
$$

$$D_q\left(r_e e - CP(e) + \frac{\overline{RH} - CH(h)}{h}\right) - c_q = 0 \tag{17}$$

Here again the introduction of the activity-based payment system creates a strategic complementarity between decisions made by the agents who have therefore more incentives to cooperate than under the fee-for-service payment system. The reason is the same (even if the interaction is different) that under the sequential decision-making game with physicians acting as leaders. An additional effort made by the physician indeed reduces the length of stay, improves the per-patient profit made by the hospital and thus increases its input expenditure. The consideration of the joint profit increases - compared to the simultaneous decision-making game equilibrium - the marginal benefit of the effort and of the input (comparisons of equations (5) and (16) and of equations (7) and (17)). Therefore, an increase in e and q simultaneously increases the per-patient profit and the demand. We can thus conclude that $\widehat{\widehat{e}}_s < \widehat{\widehat{e}}_j$ and $\widehat{\widehat{q}}_s < \widehat{\widehat{q}}_j$ but also that $\widehat{e}_j < \widehat{\widehat{e}}_j$ and $\widehat{q}_j < \widehat{\widehat{q}}_j$ when comparing equations (14) with (16) and (15) with (17). Finally, because e and q are strategic complements, the joint profit under the activity-based payment system is higher than the joint profit in the fee-for-service-system.

Proposition 4 *The transition from a fee-for-service payment system to an activity-based payment system gives better incentives to the physician and the hospital manager to act in a joint decision-making game. The strategic complementarity between the decisions made by the agents in an activity-based payment leads to a higher joint profit compared to the fee-for-service system.*

4 Financing systems and public hospitals

This section analyses the impact of the introduction of an activity-based payment system on the number of acts undertaken daily by physicians, on the length of stay and on the input invested within public hospitals. The initial revenue granted to public hospitals was - unlike the revenue granted to private hospitals - a prospective budget independent of both the number of patients and the length of stay (see the budget constraint (4)). The political will to harmonize financing systems across all type of hospitals (for-profit, not-for-profit) therefore implies that the transition to the activity-based payment system is not similar between private and public hospitals. The activity-based payment system gives however an indirect incentive to reduce the patients' length of stay since the financing depends on the demand $D(e, q)$. We show that the impact of an activity-based payment system on the public hospital's equilibrium values of e and q depends on the elasticity of demand with respect to the input (input elasticity of demand).

4.1 The simultaneous decision-making game

We first examine how the transition from a prospective budget system to an activity-based payment system affects the decision variables when physicians and managers interact in a simultaneous way within the public hospital. Here again we suppose that the financing reform only affects hospitals' payment. The physician objective is given by the equation (3) that implies the following first-order condition:

$$D_e - ED_e(e, q) = 0 \tag{18}$$

Equation (4) defines the daily budget constraint faced by a public hospital under a prospective budget. When the payment is based on the activity, this constraint becomes:

$$BC \equiv D(e, q)\left(CP(e) + \frac{CH(h)}{h}\right) + CQ(q) \leq D(e, q)\frac{\overline{RH}}{h} \tag{19}$$

Since we are interested in the agent's behavior modification resulting from payment system changes, the switch from a financing system to the other is assumed to be financially neutral. The daily per-patient fee under the new system $(\overline{RH})$ is then defined in the following way:

$$\overline{RH} = \frac{B}{D(\widehat{e}, \widehat{q})} \tag{20}$$

where $D(\widehat{e}, \widehat{q})$ denotes the equilibrium demand under the prospective financing system.

Public hospitals are concerned with the demand (patients' utility) so that they spend their whole budgets. The expression (19) is thus always satisfied as an equality:

$$D(e, q)\left(\frac{\overline{RH}}{h} - CP(e) - \frac{CH(h)}{h}\right) - c_q q = 0 \tag{21}$$

Proposition 5 *The transition from a prospective budget system to an activity-based payment system within public hospitals increases the input invested, the effort made by physicians and the demand if the input elasticity of demand is higher than unity. It does not affect the optimal values of these variables if the input elasticity of demand is lower than or equal to unity.*

We establish the above proposition by evaluating the variation of the budget constraint (21) with q.

$$\frac{\delta BC}{\delta q} = D_q\left(\frac{\overline{RH}}{h} - CP(e) - \frac{CH(h)}{h}\right) - c_q \tag{22}$$

We know from equation (21) that $\frac{\overline{RH}}{h} - CP(e) - \frac{CH(h)}{h} = \frac{c_q q}{D(e, q)}$ such that (22) can after rearrangements be written:

$$\frac{\delta BC}{\delta q} = c_q\left(D_q\frac{q}{D(e, q)} - 1\right) = c_q\left(\varepsilon_{D,q} - 1\right) \tag{23}$$

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The intuition of Proposition 5 is straightforward. By raising the input, managers increase both the revenue and the expense of the hospital. But since the hospital's revenue is related to the demand, its increase is higher than that of the cost (whose growth is constant) if the input elasticity of demand is higher than unity. Managers thus raise q as long as $\varepsilon_{D,q} > 1$. This increase in the level of input caused by the implementation of an activity-based payment system reduces the physician disutility of effort (see (18)) and thus increases his/her equilibrium effort level (and reduces the length of stay at the same time). Both modifications (e and q) lead to an increase in demand. We may thus conclude that the transition from a prospective budget system to an activity-based payment system benefits to the managers of the hospital, to the physicians and to the patients if the input elasticity is initially (i.e. before the implementation of the reform) higher than unity. In the opposite case, the financing system reform does not modify the equilibrium in public hospitals.

4.2   Other forms of interactions between agents

We briefly consider in this section the sequential interaction and the cooperation between physicians and managers within public hospitals and show why the impact of the implementation of an activity-based payment system is indeterminate in these situations. These indeterminations are explained by the fact that we cannot - given the very general assumptions made about the cost functions - determine whether the simultaneous variation of e and h leads to a budgetary surplus that allows the improvement of the hospital input or if it brings a budget deficit that forces the managers to reduce q. Additional assumptions about the marginal costs of e and h should then be made to answer this question. Expression (24) evaluates the variation of the hospital financial constraint with e under the activity-based payment system (equation (21)).

$$\frac{dq}{de} = \frac{D_e \left[\frac{\overline{RH}}{h} - CP(e) - \frac{CH(h)}{h} \right] + D(e,q) \left[\left(\frac{-\overline{RH} - CH_h h + CH(h)}{h^2} \right) \frac{a}{e^2} - c_e \right]}{D_q \left[\frac{\overline{RH}}{h} - CP(e) - \frac{CH(h)}{h} \right] - c_q} \tag{24}$$

A physician trying to influence the manager's input decision cannot determine whether his/her change in effort (combined with a change in the length of patient's stay) improves or deteriorates the hospital financial constraint and thus whether managers would have money left to increase the input or would be forced to cut back on expenses. In the same way, a manager leader in the sequential interaction with the physician cannot - for the same reason - determine which combination of e, h and q is preferable to increase the demand while keeping the budget balanced. Therefore our model does not tell how a manager could take advantage of his/her first-mover advantage. Further assumptions

would be required to solve this problem but we prefer to remain within the limits of the model at this stage.

The same reasoning holds when we deal with the joint decision-making game. A manager and a physician - when acting together - cannot define the best policy (in terms of e, h and q) to maximize their joint profits without further assumptions on costs functions.

5 Conclusion

The comparison of retrospective versus prospective payment systems in the hospital sector has been a major concern of health economics literature during the last decade. But now, since most OECD countries have opted for an activity-based financing system, the question is no longer to discuss the economic superiority of one system over another but instead to investigate how will the economic agents within the hospital sector respond to the financial reform in place. Our paper gives some insights on the expected impact involved by the introduction of an activity-based system in the private and public hospital sectors. For the former, the benefit of a transition from a fee-for-service system to an activity-based system relies on the type of interaction between managers and physicians. Under a simultaneous interaction, the status quo prevails while more coordination under a sequential or a cooperative interaction could be beneficial for both agents in the private sector. In that case, the patients' satisfaction is also enhanced by an increase in the physician's effort and a higher level of hospital's input. In the public sector, the initial financing system is different and the transition goes from a prospective budget system to the activity-based system. Here, the key parameter is the input elasticity of demand and both the physician and the manager will be better off after the reform if the patient's demand reacts sufficiently to an increase in the hospital's services. The latter case also induces an increased patients' satisfaction.

We are aware that our model has some limitations and we now discuss some possible extensions. First, our conclusions are drawn when hospitals are considered in isolation. The demand for private and public hospitals is therefore not constrained and higher levels of efforts or inputs necessarily increase the demand for both hospitals. It could be interesting to analyze whether these results are still robust once competition is introduced and when the demand faced by hospitals is exogenously given. Some of our conclusions might indeed be altered once competition is introduced in the model. As such an example, assume that, previous to the financing reform, the input elasticity of the demand is greater than unity for the public hospital while in the private sector the physician and the manager interact in a simultaneous way and have therefore no incentives to react to the introduction of the prospective payment system. The expected results from our model are

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a higher level of the public hospital's input and a higher level of the public physician's effort that lead to a higher demand and patients' utility in the public sector while a status quo prevails in the private sector. But if an exogenous given demand is now considered in a competition framework, the increase in the public hospital demand will result in a decrease in the private hospital demand. Our model shows that the private agents react to this variation. A simple examination of the private physician's first order condition (5) indeed shows that the marginal cost of the effort made by the physician depends on the overall demand and hence that the physician should increase her/his level of effort if the demand falls short. This in turn triggers an increase in the private hospital input since the effort increase reduces the patients' length of stay and gives - under an activity-based payment system - incentives to managers to raise the input level. Therefore, when competition is considered, the private agents necessarily react to any variation in their demand and at the new equilibrium, we cannot exclude that the private sector could gain market shares even if the public hospital was initially the only beneficiary of the financing reform. While we have examined some of these competition's issues, our very general model - where no functional form are specified for the demand, the disutility and the cost functions - precludes to compute definite equilibria in an oligopoly setting. Competition's effects could be introduced in a simplified framework.

Second, we initially consider a representative disease for homogenous patients. This latter assumption could be relaxed in order to analyze hospital's and physician's reactions when they face different types of patients who differ in severity of illness. This extension could allow for analyzing strategic behavior such as creaming—over-provision of services to low severity patients; skimping—under-provision of services to high severity patients; and dumping—the explicit avoidance of high severity patients as described in Ellis (1998). Third, different types of pathologies with specific level of costs and reimbursement rates could be considered to analyze the impact of an activity-based financing system on the mix of hospital's activities. Again, these two extensions must clearly take place in an oligopoly framework as discussed above in order to take into account the competition among hospitals for low severity patients or low cost patients.

Another possible extension is to consider a prospective payment system for the physician in the private sector. While we keep a fee-for-service basis in our model, it seems likely that physicians could be prospectively paid in the near future if countries cannot curb the growth in health care costs. The increase in total health care costs can be induced from our results since we show that the activity-based payment system tends to increase the level of physicians' efforts and hospitals' services while the demand reacts positively to all of these arguments. This finally leads to the possibility of introducing the regulator

into our model via a global budget cap on health expenditures. However, as shown in Mougeot and Naegelen (2004) or van de Ven (1995), incentives given by a prospective payment system may be partly destroy by a global budget constraint. This lets room for future research.

Acknowledgments

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