

Hospital's activity-based financing system and manager: physician interaction

David Crainich · Hervé Leleu · Ana Mauleon

Received: 8 September 2009 / Accepted: 3 May 2010
© Springer-Verlag 2010

Abstract This paper examines the consequences of the introduction of an activity-based reimbursement system on the behavior of physicians and hospital's managers. We consider a private for-profit sector where both hospitals and physicians are initially paid on a fee-for-service basis. We show that the benefit of the introduction of an activity-based system depends on the type of interaction between managers and physicians (simultaneous or sequential decision-making games). It is shown that, under the activity-based system, a sequential interaction with physician leader could be beneficial for both agents in the private sector. We further model an endogenous timing game *à la* Hamilton and Slutsky (Games Econ Behav 2: 29–46, 1990) in which the type of interaction is determined endogenously. We show that, under the activity-based system, the sequential interaction with physician leader is the unique subgame perfect equilibrium.

Keywords Hospital's financing system · Strategic interaction · Activity-based payment system

JEL Classification I1 · D4 · D2

D. Crainich · H. Leleu
CNRS/LEM (UMR 8179), IÉSEG School of Management,
Lille, France
e-mail: d.crainich@ieseg.fr

H. Leleu
e-mail: h.leleu@ieseg.fr

A. Mauleon (✉)
FNRS and CEREC, Facultés Universitaires Saint-Louis,
and CORE, UCLouvain, Brussels, Belgium
e-mail: mauleon@fusl.ac.be

Introduction

During the two last decades, 1990–2007, the annual growth rate of health care expenditures was still significantly higher than the GDP growth rate (39% higher in average among the 30 OECD countries) and the share of hospitals' expenditures in total health spending was about 38% during this period¹. As a consequence, hospitals have attracted the attention of policymakers attempting to curb growth in health care costs by changing the financial landscape. In the last years, 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 now found in Austria, Belgium, France, Finland, Germany, Italy, Ireland, Norway, Portugal, Spain and Sweden (de Pourvoirville [7]).

The impact of various hospital financing systems on social welfare has been a major concern in the health economics literature. Ma [13] and Chalkley and Malcolmson [3] have shown that an activity-based payment system implies both productive efficiency (the minimization of per-patient costs) and allocative efficiency (the treatment of

¹ Source: OECD Health Data 2009.

the socially optimal number of patients) provided that the demand depends on the quality of health care services. Mougeot and Naegelen [16] have analyzed the strategies of the providers facing a global expenditure cap policy and evaluated its effects on provider and patient surplus. More generally, Pope [20] or Newhouse [18] have pointed out the value of a payment system based on a mix between a prospective and a retrospective system.

An alternative which has received less attention to this social optimum approach is the analysis of the impact of an exogenous change in the financing policy on the behavior of the entities that are thought to share decisions within the hospital: the medical staff and the administration (see Harris [12]). Some major economic models of hospital behavior have been developed in the seventies, going from Pauly and Redisch [19], who assume that hospitals are dominated by physicians trying to maximize their incomes, to Newhouse [17], who considers that hospitals are non-profit organizations dominated by managers maximizing a utility function defined over the quantity and the quality of the output. The importance of a proper definition of the internal structure of the hospital has therefore been stressed by McGuire [14] who identified several issues within this area, among which, those of the objectives and of the decision-making within the organization. More recent models (see for example Ellis and McGuire [10] who analyze physicians' decision-making about the level of services to be provided to patients) have considered that these various objectives (profit, benefit to patients) may coexist but do not analyze how decisions are shared within the organization. This literature actually assumes that the behavior of the hospital coincides with that of the dominant group. As pointed out by Crilly and LeGrand [5], models of hospital behavior "*treat the hospital as a profit maximizing entity, in general assuming that clinicians are the primary decision-maker; models that predict other forms of maximization tend to identify administrators as the decision-making unit*". There is however no consensus on whether either the managers or the physicians dominate (MacPake and Normand [15]).

Few economic models explicitly consider multiple decision units among the hospital. Among these, Custer et al. [6] analyze the impact of different payment systems on the hospital production process considering as given the type of interaction between the hospital and medical staff (non-cooperative, cooperative, dominant-reactive). Dor and Watson [8] compare two kinds of prospective payment systems (a single fee to be shared between hospital and physicians and distinct fees for each of them) and consider non-cooperative and various forms of cooperative behaviors. Boadway et al. [2] show how the principal-agent relationship within the hospital affects the government's choice of the hospital financing mechanism assuming a

sequential game where the hospital is leader in a dominant-reactive scheme. More recently, Crainich et al. [4] analyze whether the prospective financing system is superior to the cost-based reimbursement system when the main decisions made within the hospital are shared between physicians and hospital managers according to various potential interactions (non-cooperative, cooperative, dominant-reactive). These papers however consider that the interaction between managers and physicians is exogenously given.

Our paper attempts to determine which of the physician or the manager dominates by considering that their interaction is endogenous and affected by the hospital financing system. Theories on organizational behavior try to capture the way organizations work. Among these theories, our model is in line with the behavioral models of organization which analyze the internal bargaining between multiple groups—with potentially conflicting objectives—within the organization.

We consider that the hospital is split into two parts: the managers and the physicians. Both maximize their own profits since we consider a private for-profit hospital. Each part of the organization has its own decision-making power: the level of effort made by physicians define the patients' length of stay while hospital managers define the hospital input (operating rooms, beds, technical equipment,...). Hospitals and physicians are initially paid on a fee-for-service basis and we then introduce an activity-based financing reform that only modifies payments related to charges supported directly by the hospital (while fees-for-service paid to physicians are not affected²). Three type of interactions are analyzed in the paper: the simultaneous (non-cooperative) interaction under which physicians and managers make decisions while considering that their actions do not modify decisions made by the other agent, and two sequential (dominant-reactive) decision-making games where the dominant actor in the interaction (physicians and managers in turn) knows that the other part of the organization adapts its behavior to its own decisions. Under this setting, we highlight that the benefit of the introduction of an activity-based system depends on the type of interaction between managers and physicians. It is shown that, under the activity-based system, a sequential interaction with physician leader could be beneficial for both agents. Moreover, under the activity-based system, the sequential interaction with physician leader is the unique subgame perfect equilibrium of the endogenous timing game of Hamilton and Slutsky [11] in which the type of interaction

² Indeed, these are the main characteristics of the payment system implemented in France for all the hospitals in 2004 and known as "Tarification à l'Activité" or T2A. The system is based on a fixed payment identical for all hospital stays classified in the same Diagnosis Related Group.

(i.e., whether the physician and the manager play a simultaneous or a sequential move game) is determined endogenously. Hence, the transition from a fee-for-service payment system to an activity based payment system gives incentives to the physician and the hospital's manager to act in a sequential game in which the physician benefits from the first-mover advantage.

The paper is organized as follows. In sect. "The model", the model is presented. Section "Financing systems and private hospitals" analyzes the impact on the manager-physician interaction of a financing reform that looks at replacing the existing fee-for-service payment by an activity-based financing system. Section "Endogenous timing game" investigates the equilibrium of the endogenous timing game of Hamilton and Slutsky [11] in which the type of interaction (i.e., whether the physician and the manager play a simultaneous or a sequential move game) is determined endogenously. Section "Conclusion" concludes and discusses some possible extensions.

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, e , that is the production and the quality of medical or surgical acts, pre or post surgery consultations, etc., while the latter defines the input provided by the hospital, q , which includes expenses and quality related to the operating rooms, beds, technical equipment but also the size and the professional training of the nursing care, administrative and technical staff, etc. In what follows, we assume that e represents the physician's activity from which he is reimbursed (i.e., the number of medical acts) and, hence, that e is observable. Indeed, there is no reimbursement system based on the quality of medical acts. The production function of health care depends on the input level q and the effort e provided by hospitals and physicians respectively. The production function is assumed to be additive and increasing, continuous and strictly concave in both arguments.

$$S(e, q) = E(e) + Q(q) \text{ with } E_e > 0, E_{ee} < 0, \\ Q_q > 0 \text{ and } Q_{qq} < 0.$$

Following Willke et al. [24], the demand faced by the physician and the hospital's manager depends on the amount and the quality of services offered to each patient:

$$D = D(S(e, q)).$$

Since D is increasing and concave in S , and S is a function increasing and concave in e and q , we can write the demand as follows:

$$D(e, q) \text{ with } D_e > 0, D_q > 0, D_{ee} < 0 \text{ and } D_{qq} < 0.$$

We suppose that the patient's length of stay, h , is directly related to the level of effort supplied by physicians, i.e., $h(e)$ with $h'(e) < 0$. Hence, we assume that the patient's length of stay decreases with the level and the quality of physician's effort.

Physicians and managers working in private hospitals aim at maximizing their profits. Physicians' net income $\Pi^p(e)$ and the hospital profit $\Pi^h(q)$ are written in the following way:

$$\Pi^p(e) = D(e, q)[RP(e) - CP(e)] \quad (1)$$

$$\Pi^h(q) = D(e, q)[RH - CH(h)] - CQ(q) \quad (2)$$

where $RP(e)$ represents physician's 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. Note that $RP(e) > CP(e)$ since we assume that the agents present on the market make a positive and finite profit. Both variables depend 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. Hospital managers maximize the hospital profit $\Pi^h(q)$ where 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 section³. The costs related to the patient length of stay $CH(h)$ that includes expenses related to drugs, bedding, food, etc., and the costs related to the hospital input $CQ(q)$ are assumed to be continuous, increasing and strictly convex ($CH_h > 0$, $CH_{hh} > 0$ and $CH(0) = 0$; $CQ_q > 0$, $CQ_{qq} > 0$ and $CQ(0) = 0$). We therefore adopt usual assumptions of concavity for the demand function justified by the decreasing marginal utility of patients and of convexity for the cost functions justified by decreasing returns in the production functions.

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

³ A mix of these two-payment systems, called two-part 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.

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 .⁴

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 financing reform that looks at replacing the existing fee-for-service payment by an activity-based financing system that only modifies 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 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. By imposing this condition of budget neutrality, 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 two possible types of interactions between physicians and hospital managers (simultaneous decision-making or sequential decision-making) and show that, under the activity-based system, a sequential interaction with physician leader could be beneficial for both agents. 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.

The simultaneous decision-making game

We first analyze the behavior of the physician and the hospital's manager under both the fee-for-service and the

activity-based payment systems in a simultaneous decision-making game. Under the fee-for-service reimbursement system, the physician's objective function is given by Eq. 1 and the first-order condition (3) associated to this optimization program defines the effort level equilibrium value \hat{e}_s :

$$D_e[r_e e - CP(e)] + D(e, q)[r_e - CP_e] = 0 \quad (3)$$

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:

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

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

$$\text{Max}_q \Pi^h(q) = D(e, q)[r_h h - CH(h)] - CQ(q)$$

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

$$D_q[r_h h - CH(h)] - CQ_q = 0 \quad (4)$$

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

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

$$D_{qq}[r_h h - CH(h)] - CQ_{qq} < 0$$

We now consider the activity-based payment system. The physician optimization program remains the one that prevailed under the fee-for-service system (see first-order condition (3)) since we assume that the new payment system only modifies the hospital financing system. Therefore, the effort level equilibrium value does not change, $\hat{e}_s = \hat{e}_s$. 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 profit defined now by the following expression:

$$\text{Max}_q \Pi^h(q) = D(e, q)[\overline{RH} - CH(h)] - CQ(q)$$

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

⁴ In general, the interaction between the hospital and the physician is not restricted to the length of stay. As suggested by an anonymous referee, the hospital may press the physician to curb costs on variable expenditures in the operation theatre. In this case, one could model the physician costs as $CP(e, q)$. However, our very general model (where no functional forms are specified for the demand and the cost functions) precludes to compute definite equilibria when modelling the physician costs in such a way. Hence, we have decided to keep our very general model and assuming that $CP(e)$.

$$D_q[\overline{RH} - CH(h)] - CQ_q = 0 \tag{5}$$

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

$$D_{qq}[\overline{RH} - CH(h)] - CQ_{qq} < 0$$

Since the introduction of the activity-based system is done assuming the condition of budget neutrality ($\overline{RH} = r_h \hat{h}_s$), the reform does not modify the Nash equilibrium when physicians and managers interact simultaneously.⁵ Therefore $\hat{e}_s = \hat{e}_s$ and $\hat{q}_s = \hat{q}_s$. This result is summarized in the following proposition.

Proposition 1 The equilibrium levels of the physician's effort and the hospital's input in the simultaneous decision-making game are not affected by the introduction of an activity-based payment system in private hospitals.

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 in order to analyze the behavior of the physician and the hospital's manager under the other decision-making interaction.

As mentioned before, the hypothesis of budget neutrality has been made in order to highlight the impact of the new financing system on physicians and managers behavior. Under this hypothesis, we isolate our model from changing behaviors explained by per patient endowment variations. But, which would be the consequences if the amount allocated to the representative hospital in the activity-based payment system increases or decreases with respect to the amount received in the fee-for-service reimbursement system? Examining Eqs. 3, 4, and 5, we see that the introduction of the activity-based payment system will not modify the effort level equilibrium value but could increase (decrease) the input equilibrium level provided by the hospital whenever $\overline{RH} > r_h \hat{h}_s$ (respectively, whenever $\overline{RH} < r_h \hat{h}_s$). Thus, higher (lower) input level would lead to a higher (lower) demand and to higher (lower) profits for

⁵ The assumption of budget neutrality has been imposed due to the fact that regulators ask the transition from a reimbursement system to another payment system to be budget neutral. For instance, the original legislation enabling Medicare's prospective payment system for hospitals commanded that the transition from cost-plus reimbursement to prospective payment system be budget neutral. (A similar assumption has been made by Custer et al. [6])

the physician. However, the effect on the profits of the hospital would be ambiguous since the increase (decrease) in demand is due to an increase (decrease) in the input costs.

The sequential decision-making game

Hospital manager leader

We first consider the hospital's manager as the leader in the sequential decision-making game. Under the fee-for-service reimbursement system, the hospital's manager optimization program (see Eq. 5) is:

$$Max_q \Pi^h(q) = D(e, q)[r_h h - CH(h)] - CQ(q)$$

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

$$\left(D_q + D_e \frac{de}{dq} \right) [r_h h - CH(h)] + D(e, q) \frac{de}{dq} \frac{dh}{de} [r_h - CH_h] - CQ_q = 0 \tag{6}$$

Compared to the first-order condition under the simultaneous decision-making game (Eq. 4), 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 gain per patient. The first-order condition defining \hat{e}_s (Eq. 3) and the implicit function theorem allows us to state that:

$$\frac{de}{dq} = - \frac{D_q[r_e - CP_e]}{D_{ee}[r_e e - CP(e)] + 2D_e[r_e - CP_e] + D(e, q)[-CP_{ee}]} < 0 \tag{7}$$

We also have assumed that $h'(e) < 0$ and hence:

$$\frac{de}{dq} \frac{dh}{de} > 0 \text{ and } D(e, q) \frac{de}{dq} \frac{dh}{de} [r_h - CH_h] > 0$$

since the hospital's manager only increases the level of input if marginal benefit is greater than marginal costs, i.e., if $r_h - CH_h > 0$.

By comparing Eq. 6 to the simultaneous Nash equilibrium (Eq. 4), we are unable to determine whether the hospital input level will be lower or higher compared to the simultaneous case ($\hat{q}_{sml} \gtrless \hat{q}_s$) because the two new terms that appear in Eq. 6 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 (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 in a simultaneous game.

We now consider the activity-based payment system. The modification of the payment system does not change the physician's reaction function (Eq. 7) defined under the fee-for-service payment system since the reform does not directly affect physician's first-order condition (Eq. 3). Thus $\frac{de}{dq}$ is still negative. But the activity-based payment modifies the hospital first-order condition:

$$\left(D_q + D_e \frac{de}{dq}\right) [\overline{RH} - CH(h)] + D(e, q) \frac{de}{dq} \frac{dh}{de} (-CH_h) - CQ_q = 0 \quad (8)$$

where

$$D(e, q) \frac{de}{dq} \frac{dh}{de} (-CH_h) < 0$$

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 ($\widehat{q}_{sml} < \widehat{q}_s$) compared to the simultaneous Nash equilibrium. However, as $\frac{de}{dq}$ is still negative, the physician effort increases ($\widehat{e}_{sml} > \widehat{e}_s$) and the effect on the demand and on the physician profit are still ambiguous.

Proposition 2 Under both the fee-for-service and the activity-based systems, the equilibrium levels of the physician's effort and the hospital's input in the sequential game with hospital manager leader do not guarantee higher profit levels for both the hospital's manager and the physician compared to the simultaneous Nash equilibrium' profits. Hence, the introduction of the activity-based payment system does not give incentives to the agents to act in a sequential game with hospital's manager leader.

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.

Notice that an overall modification of reimbursement conditions (i.e., $\overline{RH} > r_h \widehat{h}_{sml}$ or $\overline{RH} < r_h \widehat{h}_{sml}$) does not contradict our result. Since $\frac{de}{dq}$ is still negative after the introduction of an activity-based payment system, such a modification will essentially have an impact on the level of profits of the physician and the hospital, but not on the sign of the variation in such profits due to the transition from a reimbursement system to the other.

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 Eq. 1) is:

$$\text{Max}_e \Pi^p(e) = D(e, q)[r_e e - CP(e)]$$

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

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

Compared to the first-order condition under the simultaneous decision-making game (Eq. 3), 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 (Eq. 4) and the implicit function theorem allows us to state that:

$$\frac{dq}{de} = \frac{-D_q[r_h - CH_h] \frac{dh}{de}}{D_{qq}[r_h h - CH(h)] - CQ_{qq}} < 0 \quad (10)$$

The sign of the expression (10) 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. 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 to give incentives to managers to increase the hospital input ($\widehat{q}_s < \widehat{q}_{spl}$) compared to the simultaneous game equilibrium (Eqs. 3, 9). 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 (Eq. 9) 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:

$$\frac{dq}{de} = \frac{-D_q[-CH_h] \frac{dh}{de}}{D_{qq}[\overline{RH} - CH(h)] - CQ_{qq}} > 0 \quad (11)$$

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 $\widehat{e}_{spl} > \widehat{e}_{spl}$ and $\widehat{q}_{spl} > \widehat{q}_{spl}$ 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 under the activity-based payment system 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 ($\widehat{e}_{spl} > \widehat{e}_s$) in order to decrease patients length of stay ($\widehat{h}_{spl} < \widehat{h}_s$) and give incentives to managers to increase the hospital input ($\widehat{q}_{spl} > \widehat{q}_s$) compared to the simultaneous game equilibrium (Eqs. 3, 5). An additional effort made by the physician indeed reduces the length of stay and 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 Under the fee-for-service system, the equilibrium levels of the physician's effort and the hospital's input in the sequential game with physician leader do not guarantee higher profit levels for both the physician and the hospital's manager compared to the simultaneous Nash equilibrium' profits. However, under the activity-based system, the equilibrium levels of the physician's effort and the hospital's input in the sequential game with physician leader guarantee higher profit levels for both the physician and the hospital's manager compared to the simultaneous Nash equilibrium' profits. Hence, the introduction of the

activity-based payment system gives incentives to the agents to act in a sequential game with physician leader.

Again, notice that having $\overline{RH} > r_h \widehat{h}_{spl}$ or $\overline{RH} < r_h \widehat{h}_{spl}$, does not contradict our result. The transition from a fee-for-service reimbursement system to an activity-based payment system implies the change in the sign of $\frac{dq}{de}$ that first was negative and is now positive. An overall modification of reimbursement conditions will essentially have an impact on the level of profits of the physician and the hospital but not on the sign of the variation in such a profits due to the transition from a reimbursement system to the other.

Graphical interpretation

How do payoffs compare between the simultaneous move Nash equilibrium and the two possible types of Stackelberg equilibria? Since each player has a best-response function to the action of the rival, we know that the leader in a Stackelberg equilibrium does strictly better than at the Nash equilibrium. Furthermore, if best-response functions are monotone and with slopes of the same sign then either: (a) each player prefers his simultaneous Nash payoff to his Stackelberg follower payoff or (b) the opposite happens (each player prefers his Stackelberg follower payoff to his simultaneous Nash payoff). If best-response functions have slopes of different signs, then (c) only one player prefers his Stackelberg follower payoff to his simultaneous Nash payoff (Hamilton and Slutsky [11]; Amir [1]).

The following graphical argument checks the results. Under the assumption that the payoff to each player is monotone in the rival's action, the isoprofit contours of any player are functions of the rival action. The Pareto preferred (in terms of profits) to the simultaneous Nash equilibrium is bounded by the isoprofit curves and must lie in one of the four quadrants because the isoprofits lines have slopes zero or infinite at the simultaneous Nash equilibrium. Then, case (a) corresponds to the situation in which neither best-response function intersects the Pareto preferred set to the Nash equilibrium (see Fig. 1). The usual situation in Cournot competition with downward-sloping best responses will yield case (a) (where $\alpha = q_1$ and $\beta = q_2$), since the Pareto preferred set to the Cournot equilibrium does not intersect the best-response functions.

Notice that, under the fee-for-service reimbursement systems, the reaction functions of both the physician and the manager are downward-sloping and, hence, the conditions under which each player prefers his simultaneous Nash payoff to his Stackelberg follower payoff hold.

Case (b) corresponds to the situation where both best-response functions intersect the Pareto preferred set to the Nash equilibrium (see Fig. 2). The usual situation of

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 [11] and Amir [1], 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 [23], Chap. 7.

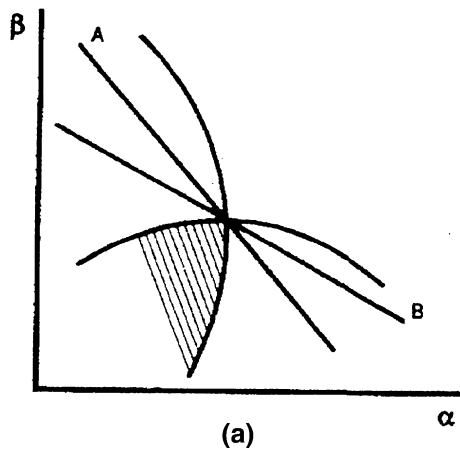


Fig. 1 Case (a)

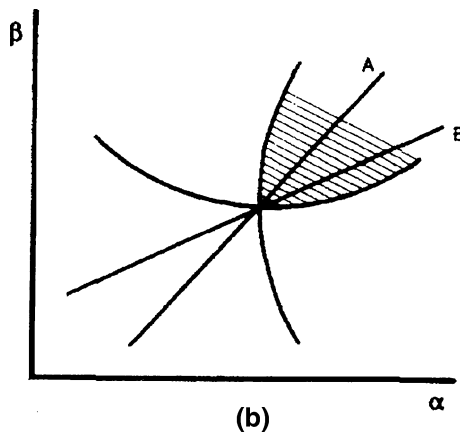


Fig. 2 Case (b)

Bertrand competition and differentiated substitute products with upward-sloping best responses (where $\alpha = p_1$ and $\beta = p_2$), will yield case (b). Obviously Stackelberg equilibria will lie in the shaded area (respectively) on the follower's best-response function.

Finally, case (c) corresponds to the situation where only one best-response function intersects the Pareto preferred set to the Nash equilibrium (see Fig. 3). Standard oligopoly games where both players choose prices or both choose quantities never fit this third case. This case arises, for instance, when player 1 has quantity as a strategic variable and player 2 has price as a strategic variable (i.e., $\alpha = q_1$ and $\beta = p_2$). Note that the best-response function of the quantity-setting (price-setting) player is upward (downward) sloping in Fig. 3 because it is responding to the price (quantity) set by the rival. That is, the quantity-setting (price-setting) player is on his Bertrand (Cournot) best-response function. (See Singh and Vives [21]). In this case, the price-setting player is the only one to prefer his Stackelberg follower payoff to the Nash payoff.

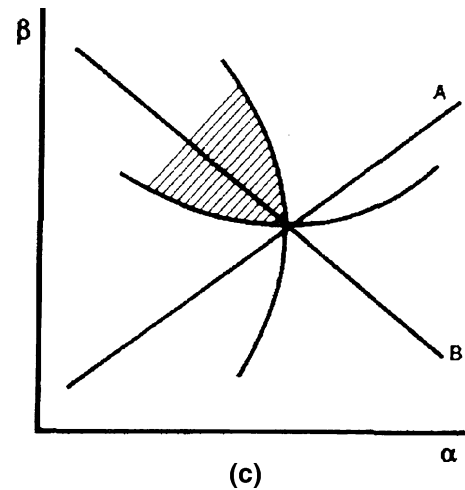


Fig. 3 Case (c)

Notice that, under the activity-based payment system, the reaction function of the manager is upward-sloping (in the quantities' space) while the reaction function of the physician is downward-sloping (in the quantities' space). Hence, the conditions under which case (c) arises hold, and the manager will prefer his Stackelberg follower payoff to his simultaneous Nash payoff.

Endogenous timing game (Hamilton and Slutsky [11])

In the previous section, we have assumed that the type of interaction between the physician and the hospital's manager is exogenously given. That is, we have simply compared the equilibrium outcomes of the simultaneous and the sequential decision-making games both under the fee-for-service payment system and under the activity-based payment system. But one could argue that whether the physician and the manager play a simultaneous or a sequential move game should not be exogenous but should result from the agents' decisions. In this section, we adopt one of the two games proposed by Hamilton and Slutsky [11] in order to investigate this issue. They proposed to construct an extended game out of a basic game with unique and distinct Nash and Stackelberg equilibria in pure strategies, by adding an initial stage at which players simultaneously decide whether to move early or late. The basic game is then played according to these timing decisions: with simultaneous play if both players decide to move at the same time and with sequential play otherwise.

The resulting set of subgame-perfect equilibria is then: (i) the Nash equilibrium of the basic game if each player prefers his Nash payoff to his Stackelberg follower payoff, (ii) the two Stackelberg equilibria of the basic game (with both role configurations) if each player prefers his follower

payoff to his Nash payoff, and (iii) the Stackelberg equilibrium with one set player as leader if only the other player prefers his follower payoff to his Nash payoff.

Theorem V in Hamilton and Slutsky [11] relates the resulting subgame perfect equilibria to the slopes of the reaction functions as follows:

- (A) If both reaction functions are monotone in the same direction, then the set of subgame perfect equilibria of the extended game is either as in (i) or (ii) above.
- (B) If the reaction functions are monotone in different directions, (iii) above holds.

Amir [1] has shown, via counterexample, that monotonicity of the best-response functions in a two-player game is not sufficient to derive predictions about the order of moves. Rather, this requires, additionally, the monotonicity of each payoff in the other player's actions. Without this monotonicity assumption, the relationship between the subgame perfect equilibria and the slopes of the reaction functions is as follows.

First, if both reaction functions slope in the same direction and neither intersects the Pareto preferred set, then (i) above holds. Second, if both reaction functions slope in the same direction and both intersect the Pareto preferred set, all three type of outcomes are possible. Finally, if the reaction functions slope in different directions two possibilities exist: a unique leader-follower outcome with the player whose reaction function intersects the Pareto preferred set moving second and the simultaneous move Nash equilibrium depending on whether the Stackelberg point on the reaction function intersecting the Pareto preferred set is or is not Pareto preferred to the simultaneous move equilibrium.

Notice that, under the fee-for-service payment system, we are unable to determine the subgame perfect equilibrium of the extended game (because both reaction functions slope in the same direction). On the contrary, we can determine the unique subgame perfect equilibrium of the extended game under the activity-based payment system: the Stackelberg equilibrium with physician leader. Hence, we could generalize our result in Proposition 3 as follows.

Proposition 4 The introduction of the activity-based payment system results in a unique subgame perfect equilibrium of the extended game: the Stackelberg equilibrium with physician leader.

In case the type of interaction (i.e., whether the physician and the manager play a simultaneous or a sequential move game) is determined endogenously, we can conclude that the introduction of the activity-based payment system will lead to a sequential game with physician leader. Hence, the transition from a fee-for-service payment system to an activity-based payment system gives incentives

to the physician and the hospital's manager to act in a sequential game in which the physician benefits from the first-mover advantage.

Conclusion

The implementation of prospective payment systems in the hospital sector has been a major concern in the health economics literature. Among the issues considered that of the way physicians and managers make decisions within hospitals has not yet received a definitive answer. In this paper we wonder whether the activity-based financing system creates conditions such that a dominant agent should emerge.

We show that the benefit of the introduction of an activity-based system depends on the type of interaction between managers and physicians. Under the activity-based system, a sequential interaction with physician leader could indeed 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. Moreover, under the activity-based system, the sequential interaction with physician leader is the unique subgame perfect equilibrium of the endogenous timing game of Hamilton and Slutsky [11] in which the type of interaction (i.e., whether the physician and the manager play a simultaneous or a sequential move game) is determined endogenously. Hence, the transition from a fee-for-service payment system to an activity-based payment system gives incentives to the physician and the hospital's manager to act in a sequential game in which the physician benefits from the first-mover advantage.

Let us also mention here what would have been the implications of the financing reform in which the physician and the hospital's manager play a joint decision-making game maximizing their joint profit. It can be shown that under both the fee-for-service and the activity-based systems, the equilibrium levels of the physician's effort and the hospital's input in the joint decision-making game guarantee higher joint profit levels for the hospital's manager and the physician compared to the simultaneous Nash equilibrium' joint profits. The stronger strategic complementarity between the decisions made by the agents in an activity-based payment leads to a higher joint profit compared to the one in the fee-for-service system. Although the joint profits are higher at the equilibrium of the joint decision-making game, nothing can be said about individual profits of the physician and the hospital's manager. Because of the well-known issue of the redistribution of the joint profit within a cartel, the unique equilibrium of the extended game could also be preferred by either the

physician or the hospital's manager to the equilibrium of the joint decision-making game.

Before discussing the likelihood of the effects shown in our model, it has to be reminded that our results have been derived in a context in which average per-patient fees perceived by hospitals are not affected by the implementation of the activity-based payment system. This derives from the fact that we are interested in behavioral consequences of the new system, not in consequences related to an overall improvement or worsening of reimbursement conditions provided by health authorities. However, it has been shown that our main results also apply to other situations: an overall modification of reimbursement conditions does not, by itself, eliminate potential gains associated to the switch from a fee-for-service to an activity-based payment system. Such a modification will essentially have an impact on the importance of these gains not on the sign of the gains.

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 hospital is therefore not constrained and higher levels of efforts or inputs necessarily increase the demand for the hospital. This increase in demand is clearly positive from the patients' viewpoint since it is a consequence of an improvement of their satisfaction. But, it also implies an increase in the funding level which has to be accepted by health authorities. 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. Our very general model—where no functional forms are specified for the demand and the cost functions—precludes to compute definite equilibria in an oligopoly setting.⁷ 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 [9]. 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 [16] or van de Ven [22], incentives given by a prospective payment system may be partly destroyed by a global budget constraint.

Finally, mixed payment systems implemented in most developed countries should also be considered from a theoretical point of view since they raise the issue of the optimal weighting scheme between prospective and retrospective financing. This is left for future research.

Acknowledgments Ana Mauleon is Research Associate of the National Fund for Scientific Research (FNRS). We would like to thank Paul Belleflamme and two anonymous referees for helpful comments and suggestions. Part of this research was made while Hervé Leleu was visiting the CORE at the University of Louvain. David Crainich has benefited from the financial support of Merck Santé France. Financial support from Spanish Ministry of Sciences and Innovation under the project ECO2009-09120 and support of a SSTC grant from the Belgian Federal government under the IAP contract P6/09 (FUSL) are gratefully acknowledged.

References

1. Amir, R.: Endogenous timing in two-player games: a counterexample. *Games and Econ. Behav.* **9**, 234–237 (1995)
2. Boadway, R., Marchand, M., Motohiro, S.: An optimal contract approach to hospital financing. *J. Health Econ.* **23**, 85–110 (2004).
3. Chalkley, M., Malcomson, J.M.: Contracting for health services with unmonitored quality. *Econ. J.* **108**, 1093–1110 (1998)
4. Crainich, D., Leleu, H., Mauleon, A.: The optimality of hospital financing system: the role of physician-manager interactions. *Int. J. Health Care Finance Econ.* **8**(4), 245–256 (2008)
5. Crilly, T., Le Grand, J.: The motivation and behaviour of hospital trusts. *Soc. Sci. Med.* **58**(10), 1809–1823 (2004)
6. Custer, W.S., Moser, J.W., Musacchio, R.A., Willke, R.J.: The production of health care services and changing hospital reimbursement—the role of hospital-medical staff relationships. *J. Health Econ.* **9**, 167–192 (1990)

⁷ The choice of not specifying functional forms for the demand and the cost functions have forced us to make many other simplifying assumptions. For instance, we have assumed that the length of stay is only related to physicians' effort and that this effort is observable. Moreover, no asymmetric information has been introduced into the model. This lets room for future research.

7. de Pouvourville, G.: Hospital funding and competition. *Eur. J. Health Econ.* **5**(1), 3–5 (2004)
8. Dor, A., Watson, H.: The hospital-physician interaction in US hospitals: evolving payment schemes and their incentives. *Eur. Econ. Rev.* **39**(3/4), 795–802 (1995)
9. Ellis, R.P.: Creaming, skimping, and dumping: provider competition on the intensive and extensive margins. *J. Health Econ.* **17**, 537–555 (1998)
10. Ellis, R.P., McGuire, A.: Provider behavior under prospective reimbursement. *J. Health Econ.* **5**, 129–151 (1986)
11. Hamilton, J., Slutsky, S.: Endogenous timing in duopoly games: Stackelberg or Cournot equilibria. *Games Econ. Behav.* **2**, 29–46 (1990)
12. Harris, J.E.: The internal organization of hospitals: some economic implications. *Bell J. Econ.* **3**(1): 467–485 (1977)
13. Ma, C.A.: Health care payment systems: cost and quality incentives. *J. Econ. Manag. Strategy* **3**(1), 93–112 (1994)
14. McGuire, A.: The theory of the hospital: a review of the models. *Soc. Sci. Med.* **20**(11): 1177–1184 (1985)
15. McPake, B., Normand, C.: *Health Economics: An International Perspective*. second edition, Routledge (2008)
16. Mougeot, M., Naegelen, F.: Hospital price regulation and expenditure cap policy. *J. Health Econ.* **24**, 55–72 (2004)
17. Newhouse, J.P.: Towards a theory of non-profit institutions: an economic model of a hospital. *Am. Econ. Rev.* **60**, 87–92 (1970)
18. Newhouse, J.P.: Reimbursing health plans and health providers : selection versus efficiency in production. *J. Econ. Lit.* **34**, 1236–1263 (1996)
19. Pauly, M.V., Redish, M.: The not-for-profit hospital as a physicians' cooperative. *Am. Econ. Rev.* **63**, 87–99 (1973)
20. Pope, G.C.: Using hospital-specific costs to improve the fairness of prospective reimbursement. *J. Health Econ.* **9**, 237–251 (1990)
21. Singh, N., Vives, X.: Price and quantity competition in a differentiated duopoly. *Rand J. Econ.* **15**, 546–554 (1984)
22. van de Ven, W.P.M.M.: Regulated competition in health care: with or without a global budget?. *Eur. Econ. Rev.* **39**, 786–794 (1995)
23. Vives, X.: *Oligopoly Pricing: Old Ideas and New Tools*. The MIT Press, Cambridge (1999)
24. Willke, R.J., Custer, W.S., Moser, J.W., Musacchio, R.A.: Collaborative production and resource allocation: the consequences of prospective payment for hospital care. *Q. Rev. Econ. Bus.* **31**(1), 28–47 (1991)