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Abstract

This paper studies the design of doctors' remuneration schemes. Two for-profit hospitals compete to attract patients and to affiliate doctors. The numbers of patients and doctors determine (at least in part) a hospital's quality level which is valued on both sides. Quality can be enhanced by doctors through (costly) effort. We first consider pure salary, case payment or fee-for-service schemes on the doctors' side. Then, we study schemes that mix fee-for-service with either salary or case payments. We show that case payment schemes (either pure or in combination with fee-for-service) are more patient friendly than (pure or mixed) salary schemes. This comparison is exactly reversed on the doctors' side. Quite surprisingly, patients always lose when a fee-for-service scheme is introduced (pure or mixed). This is true even though the fee-for-service is the only way to induce the doctors to exert effort, whatever the patients' valuation of this effort. In other words, the increase in doctors' effort brought about by fee-for-service is more than compensated by the increase in fees faced by patients.

Jel codes: D42, I1, L1.

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1 Introduction

The trade-off between quality and cost control in the health sector has been widely examined in the literature. Many papers compare the incentives generated by different remuneration schemes for health care providers. In particular, they analyze how remuneration schemes affect providers' output, typically measured by health care quality and by the number of patient consultations (Devlin and Sarma, 2008). While health care quality is often difficult to measure, it is usually recognized that doctors are encouraged to provide more services under a fee-for-service scheme than under other remuneration schemes such as capitation/case payment or salary.

The design of doctors' remuneration schemes is usually analyzed in a monopoly setting by using a principal-agent framework. In this article, we revisit this issue under imperfect competition and consider two for-profit hospitals that compete in a two-sided market. On one side, they compete in prices and qualities to attract patients; on the other side, to affiliate doctors. Patients' utility depends on prices, the health care quality delivered by hospital and the number of services they receive from their doctor. Doctors also care for the quality provided to their patients.[1] In addition, their utility depends on their remuneration (paid by hospitals) and there is a desutility of effort associated with the services provided.[2] We examine how doctors' remuneration schemes molds the competition between hospitals and how it affects both sides of the market. We show that switching from one scheme to another may have conflicting effects on the two sides of the market. For instance, we show that case payment schemes (either pure or in combination with fee-for-service) are more patient-friendly than (pure or mixed) salary schemes. This comparison is exactly reversed on the doctors' side.

Our imperfect competition falls into the category of "two-sided markets" because

[1] As long as we do not consider risk tranfers between different types of patients, our model applies to a competitive hospital sector but not to integrated health insurance industries like HMOs.

[2] In reality many hospitals are not for profit. It would be interesting to extend our analysis to mixed oligopoly (see the conclusion).

we specify quality of a hospital as being determined (in part) by its respective numbers of patients and doctors which, generate network externalities between the two sides.[3] Empirically, it is a well-established fact that the quality of health care delivered in hospitals depends on the doctors' "workload". This is documented, for instance, by Tarnow-Mordi *et al.* (2000) who use UK data to show that variations in mortality can be explained in part by excess workload in the intensive care unit. Accordingly, health care quality is frequently related to the doctor/patient ratio; see Mc Gillis Hall (2004).[4] In other words, it increases when the number of health care professionals increases (for a given number of patients), but decreases when the number of patients increases (for a given number of providers). In this paper, we adopt a rather general expression for the quality provided by hospitals. We assume that quality always increases in the number of doctors but we do not rule out the possibility that it can also increase in the number of patients for low values because of a "learning-by-doing effect". For larger patients' numbers, on the other hand, the congestion effect can be expected to dominate and we return to the negative relationship between number of patients and quality.

In all cases, both sides benefit from a higher quality albeit for different reasons and possibly with different intensity.[5] This is quite obvious on the patients' side, where one can expect a higher quality to translate into an improvement in patients' health state. For instance, a higher quality may mean a reduction in waiting times for appointments or an improvement of the doctors' attention.[6] Doctors also benefit from a higher quality through a reduction in their workload,[7] or indirectly, through their altruism (or simply job satisfaction).[8] Nevertheless, the achievement of a higher quality can conflict with

[3] See Rochet and Tirole (2006) for a standard presentation of the two-sided mechanism.

[4] For instance, the attempt of the California Assembly Bill 394, which mandated maximum levels of patients per nurse in the hospital setting, was precisely to ensure a satisfactory level of quality.

[5] This property defines a specific type of externality, namely the "common network externality" (CNE) introduced by Bardey *et al.* (2010).

[6] See for instance Cleary and McNeil (1988).

[7] See, for instance, Fergusson-Paré (2004) for the nursing workload. Griffin and Swan (2006) also find a strong relationship between nurses' workload and quality of health care.

[8] See Liu and Ma (2012).

doctors' income maximization according to the remuneration schemes used by hospitals. For instance, case payment gives incentives to doctors to be affiliated with a hospital with more patients even if, on the other hand, it may reduce the quality when the congestion effect dominates. Both effects are at play in our two-sided competition framework.[9]

To enhance the quality supplied by hospitals doctors may exert effort, which is measured by the number of *additional* services provided during consultations.[10] Doctors may perform additional exams to refine their diagnosis, which increases the efficiency of their consultations and the probability of their patients' recovery. In other words, a doctor's effort is viewed (by patients) as a substitute to the health care quality determined by the network externality. For instance, extra effort can compensate for a delay in obtaining a first appointment.

The general remuneration scheme we define includes a salary, a case payment and a fee-for-service component. On the patients' side, we concentrate on schemes with only a fixed fee. In a first step, we consider *pure* payment schemes. Not surprisingly, we find that doctors' effort is higher under a fee-for-service scheme than under other schemes, which corroborates the results typically obtained in principal-agent models. As a matter of fact, when doctors are remunerated solely *via* a salary or a case payment, they provide the minimum level of effort. The hospitals' equilibrium profits are the same under salary and under case payment schemes. However, patients pay a lower price and doctors are less remunerated when they receive case payments rather than salary schemes. In other words, a case payment scheme favor patients while doctors are better off under a salary scheme. These results suggest that the intensity of competition on the patients' side is stronger when case payments are adopted while competition is weaker on the doctors' side. Next, we turn to (pure) fee-for-service payments, which appear to have rather surprising properties. While patients value the number of services provided, they appear

[9] What we are saying is that *for a given total remuneration* a doctor prefers to have less patients.

[10] Additional services play essentially the role of endogenous labor supply in our model.

to be worse off when doctors are paid *via* a fee-for-service rather than when they receive a salary (and exert only the minimum effort). We show this analytically for the case when the doctors' effort provides only small benefits to patients. For larger levels of benefits, numerical simulations appear to corroborate this result. Surprisingly, we find that hospitals' profit may be higher when doctors are remunerated *via* a fee-for-service scheme rather than under a case payment or salary.

Second, we consider payment schemes mixing fee-for-service with either salary or case payments. We show that in both cases, hospitals set the fee-for-service rate just equal to the patients' valuation of doctors' effort. Consequently, an efficient level of effort is achieved and total welfare is maximum. Nevertheless, the introduction of a fee-for-service along with either a wage or a case payment always reduces patients' welfare, while doctors' welfare is enhanced. Consequently, there may well be a conflict between the maximization of social welfare and the pursuit of patients' interests. Finally, exactly like in the pure remuneration case, the presence of a case payment element favors patients, while a salary term favors doctors.

The paper is organized as follows. Section 2 presents the set up. Section 3 provides equilibrium conditions under general payment schemes. Pure salary and case payment schemes are considered in Section 4, while a pure fee-for-service system on the doctors' side is studied in Section 5. Mixed schemes are considered in Section 6. Finally, simulations are provided in Section 7.

2 The model

Consider two hospitals $j = \{1, 2\}$ located at the respective endpoints of a Hotelling line. They compete for patients (group P of mass 1) on one side and for doctors (group D of mass m) on the other side. Both groups are uniformly distributed over an interval of length 1. The utilities of both groups exhibit linear transportation costs with parameters

t_P and t_D respectively.[11]

Let n_j^i denote the *share* of type $i = P, D$ individuals affiliated with hospital $j = 1, 2$, while N_j^i denotes the *number* of affiliates. With our normalizations, we have $N_j^P = n_j^P$ and $N_j^D = mn_j^D$. We assume that the quality q_j offered by a hospital j depends on the numbers of patients and doctors. More precisely, we have $\partial q_j / \partial N_j^D > 0$, so that quality increases with the number of doctors. This assumption can be interpreted in two ways. First, the more doctors there are in a hospital, the larger is the choice of providers offered to patients.[12] Furthermore, more doctors means less delay in obtaining a first appointment. We allow for a more general relationship between the number of patients and quality. While, we assume $\partial q_j / \partial N_j^P < 0$ for sufficiently large levels of N_j^P, $\partial q_j / \partial N_j^P > 0$ is not ruled out for small patient numbers. In other words, for sufficiently large patient numbers quality is negatively related to the doctors' workload, while for small ones it may be positively related to patient numbers due to a learning-by-doing effect.[13] For the sake of illustration, it is often useful to assume that quality is determined by the doctor/patient ratio. We then have $\partial q_j / \partial N_j^D > 0$, $\partial q_j / \partial N_j^P < 0$ and $q_j \left(N_j^P, N_j^D \right)$ is homogenous of degree 0.[14]

We assume that quality q_j has a positive effect on both patients' and doctors' utilities. On the patients' side, this assumption is quite obvious. For instance, if this quality captures the delay to obtain a first appointment, every patients will enjoy a shorter delay. A similar reasoning applies if the quality supplied represents the quality of the doctors' attention toward patients. On the doctors' side, the positive relationship can

[11] None of our results would change if transportation costs were quadratic rather than linear.

[12] This interpretation is close to the concept of *ex post* horizontal differentiation suggested by Gal-Or (1999). It is also related to the notion of "diversity value" used by Bardey and Rochet (2010). In the hospital context, a higher number of doctors may increase the quality of the matching that results from the patient-doctor interaction.

[13] The characterization of the various equilibria we study does not depend on the sign of $\partial q / \partial N_j^P$, but their interpretation may differ according to the sign of this expression.

[14] When the quality function is homogenous the equilibrium has specific features; see Bardey *et al.* (2010).

be justified by altruism.[15] In addition, following the delay interpretation, a higher quality can also reduce the severity of the patient and consequently the doctors' workload. Either way the positive effect of quality on doctors' utility is to be understood *for a given level of remunerations.*[16]

During or after the first consultation, doctors may provide their patients with additional services (observed by hospitals), which have a marginal utility (for patients) of $\zeta \geq 0$. Since these services require effort, we represent them simply by the required level of effort (per patient) which is denoted e_j. The total effort exerted by a doctor at hospital j is then defined by $E_j = \left(n_j^P / mn_j^D\right) e_j$.

Formally, the utility of a patient, located at z, who patronizes hospital j and faces a total bill of K_j (a fixed fee)[17] is given by

$$V_j = \overline{V} + \gamma q_j + \zeta e_j - K_j - t_P \left(z - x_j\right), \tag{1}$$

where $\overline{V}$ represents the gross utility for obtaining health care, while $\gamma > 0$ is the marginal utility of quality. Observe that, q_j and e_j are substitutes. In other words, a low level of quality q_j can be compensated by a higher level of (doctors') effort.

The utility of a doctor, located at y, and working for hospital j is given by

$$U_j = \overline{U} + \theta q_j + T_j - t_D \left(y - x_j\right) - \Psi(E_j), \tag{2}$$

where $\overline{U}$ is a constant, $\theta > 0$ is the preference for quality q_j. The doctors' remuneration is denoted by T_j, while $\Psi(E_j)$ represents the desutility of effort. For simplicity, we assume a quadratic desutility of effort throughout the paper so that $\Psi(E_j) = E_j^2/2$. The total remuneration of a doctor working for hospital j, treats $n_j^P/(mn_j^D)$ patients

[15] See Choné and Ma (2010) for instance.
[16] See expression (2) below.
[17] As most of patients may benefit from an health insurance plan, the price K_j can be interpreted as the patient's out-of-pocket payment to hospital j. Our analysis remains valid under this interpretation as long as there is not too much heterogeneity in health insurance coverage among patients.

and provides services of e_j per patient is given by[18]

$$T_j = w_j + d_j \frac{n_j^P}{mn_j^D} + c_j \frac{n_j^P}{mn_j^D} e_j.$$

In words, it may include a fixed salary $w_j \geq 0$, a case payment $d_j \geq 0$ and a fee-for-service rate $c_j \geq 0$.

Doctors choose their level of effort such that:

$$e_j \in \arg\max \left[\frac{c_j n_j^P}{mn_j^D} e_j - \Psi(\frac{n_j^P}{mn_j^D} e_j) \right],$$

which (using the quadratic specification of Ψ) yields

$$e_j^* = \frac{mn_j^D}{n_j^P} c_j, \tag{3}$$

and

$$E_j^* = c_j. \tag{4}$$

Not surprisingly, e_j^* increases with the fee-for-service rate c_j.[19] Furthermore, $c_j = 0$ implies $e_j^* = 0$. In such a case, effort is costly, but does not give any direct benefits to doctors. Consequently, a positive effort level can only be achieved through financial incentives. Moreover, a doctor's effort increases as the number of doctors affiliated with their hospital increases and as the number of patients decreases. For future reference one may note that our set up is somewhat biased towards fee-for-service remuneration scheme (particularly when ζ is large). This is because, additional effort enhances the quality perceived by patients, *i.e.* $\gamma q_j + \zeta e_j$, and positive levels of effort can only be achieved through a positive fee-for-service rate. This property is important for the interpretation of our results. In particular, we will show that, in spite of this optimistic

[18] Recall that services are represented by the effort they require.

[19] In a more general setting a fee-for-service rate increase would have a (negative) income effect in addition to the (positive) substitution effect. In our setting with quasilinear preferences there is no income effect.

view of the fee-for-service remuneration, the introduction (or addition) of a fee-for-service element always makes patients worse off. For future reference, observe that a doctor's *total* effort E_j^* does not depend on the number of patients.

The parameters $\bar{U}$ and $\bar{V}$ are assumed to be sufficiently large to ensure full coverage on both sides of the market. Then, demand levels are equivalent to market shares and they are determined by the respective "marginal consumer" (patient or doctor) on each side of the market. Defining the quality differential between hospitals as

$$g\left(n_1^P, mn_1^D\right) = q_1\left(n_1^P, mn_1^D\right) - q_2\left(1 - n_1^P, m(1 - n_1^D)\right),$$

the demand functions for hospital 1 on the patients' and the doctors' side are respectively given by

$$\begin{aligned}
n_1^P =& \frac{1}{2} + \frac{1}{2t_P}\left[\gamma g\left(n_1^P, mn_1^D\right) + \zeta\left(e_1 - e_2\right) - (K_1 - K_2)\right], \\
n_1^D =& \frac{1}{2} + \frac{1}{2t_D}\left[\theta g\left(n_1^P, mn_1^D\right) + w_1 - w_2 + d_1\frac{n_1^P}{mn_1^D} - d_2\frac{(1 - n_1^P)}{m(1 - n_1^D)}\right. \\
&\left. + \left[\frac{c_1 n_1^P}{mn_1^D}e_1 - \Psi\left(\frac{n_1^P}{mn_1^D}e_1\right) - \left(\frac{c_2(1 - n_1^P)}{m(1 - n_1^D)}e_2 - \Psi\left(\frac{n_1^P}{mn_1^D}e_2\right)\right)\right]\right].
\end{aligned}$$

Not surprisingly, the quality differential increases hospital 1's market shares in both markets (patients and doctors). The patient fees and salaries have the expected effect on demand levels. Using (3) to substitute for the effort levels chosen by the doctors yields

$$\begin{aligned}
n_1^P =& \frac{1}{2} + \frac{1}{2t_P}\left\{\gamma g\left(n_1^P, mn_1^D\right) + \zeta\left(c_1\frac{mn_1^D}{n_1^P} - c_2\frac{m\left(1 - n_1^D\right)}{1 - n_1^P}\right)\right. \\
&\left. - (K_1 - K_2)\right\}, \qquad (5) \\
n_1^D =& \frac{1}{2} + \frac{1}{2t_D}\left\{\theta g\left(n_1^P, mn_1^D\right) + w_1 - w_2\right. \\
&\left. + d_1\frac{n_1^P}{mn_1^D} - d_2\frac{(1 - n_1^P)}{m(1 - n_1^D)} + \frac{1}{2}\left[(c_1)^2 - (c_2)^2\right]\right\}. \qquad (6)
\end{aligned}$$

Because of the quality definition on one hand, and on the use of case payments and the fee-for-service schemes by hospitals on the other hand, demand levels on both sides are interdependent. A price variation on one side may also affect demand **on** the other side. The overall effect will involve a standard price effect combined with "network" (two-sided market) effects. Differentiating the demand functions and evaluating the derivatives at the symmetric equilibrium yields

$$\begin{aligned}
\frac{dn_1^P}{dK_1} &= \frac{-1}{4t_D t_P\,|B|}\left[\left(2t_D + \frac{4}{m}d_1 - \theta m g_D\right)\right], &(7)\\
\frac{dn_1^D}{dK_1} &= \frac{-1}{4t_D t_P\,|B|}\left[\left(\theta g_P + \frac{4}{m}d_1\right)\right], &(8)\\
\frac{dn_1^P}{dw_1} &= \frac{1}{4t_D t_P\,|B|}\left[m\left[\gamma g_D + 4c_1\zeta\right]\right], &(9)\\
\frac{dn_1^D}{dw_1} &= \frac{1}{4t_D t_P\,|B|}\left[2t_P - \left(\gamma g_P - 4mc_1\zeta\right)\right], &(10)\\
\frac{dn_1^P}{dc_1} &= \frac{m}{4t_P t_D\,|B|}\left[\zeta\left(2t_D - \left(\theta m g_D - 4\left(\frac{d_1}{m} + c_1^2\right)\right)\right) + c_1\gamma g_D\right], &(11)\\
\frac{dn_1^D}{dc_1} &= \frac{1}{4t_P t_D\,|B|}\left[\left(2t_P - \left[\gamma g_P - 4mc_1\zeta\right]\right)c_1 + \left(\theta g_P + \frac{4}{m}d_1\right)m\zeta\right], &(12)\\
\frac{dn_1^P}{dd_1} &= \frac{1}{4t_D t_P\,|B|}\left[\gamma g_D + 4c_1\zeta\right] = \frac{1}{m}\frac{dn_1^P}{dw_1}, &(13)\\
\frac{dn_1^D}{dd_1} &= \frac{1}{4mt_D t_P\,|B|}\left[2t_P - \left(\gamma g_P - 4mc_1\zeta\right)\right] = \frac{1}{m}\frac{dn_1^D}{dw_1}, &(14)
\end{aligned}$$

with

$$\begin{aligned}
|B| &= \frac{1}{4t_P t_D}\Big[4t_P t_D - 2t_P\theta m g_D - \gamma g_P 2t_D + \frac{4}{m}d_1\left(2t_P - \gamma\left(g_P + m g_D\right)\right)\\
&\qquad + 4mc_1\zeta\left[2t_D - \theta\left(m g_D + g_P\right)\right]\Big],
\end{aligned}$$

where subscripts are used for the derivatives of g, which are denoted g_P and g_D.

These expressions look rather tedious and uninformative. However, some inspection of their properties is useful for the interpretation of our results below. In particular, it is helpful to identify the effects of variation in the different fees and prices. For simplicity, we do this under the assumption that $g_P < 0$, *i.e.* the learning-by-doing is dominated by the congestion effect.

Let us start with the effect of K_1 on the demand functions. First, we examine the effect of K_1 on n_1^D (the indirect effect of the patient fee on the doctors' market) assuming $\partial n_1^P/\partial K_1 < 0$ (the direct effect has the expected sign). Expression (8) shows that an increase of K_1 generates conflicting effects on hospital 1's demand on the doctors' side. An increase of K_1 decreases the number of patients, and consequently increases the quality supplied by hospital 1 (and decreases the quality supplied by hospital 2). Consequently, hospital 1 becomes more attractive to doctors' (according to the weight θ). However, a contradictory effect occurs when hospitals use a case payment scheme, because less patients then means a lower remuneration for doctors (this is reflected by the term $4d_1/m$). Overall, the sign of $\partial n_1^D/\partial K_1$ then depends on the sign of $\theta g_P+4d_1/m$.

Now, let us turn to the effect of K_1 on n_1^P. When there are no case payments, no fee-for-service and no network effects, (7) reduces to $-1/(2t_P)$, which is the traditional Hotelling expression. Additionally to this Hotelling effect, the introduction of a case payment increases the (absolute value of the) slope of patients' demand function (with respect to K_1). Roughly speaking, the use of a case payment scheme increases the price responsiveness of patients' demand. Finally, as usual in the network economics literature, it is assumed that the transportation cost is high enough to ensure that $\partial n_1^P/\partial K_1 < 0$.[20]

Expressions (9) and (10) can be inspected in a similar way to explain the effects of w_1 on n_1^P and n_1^D. We can for instance look at its indirect effect on the patients' side, while assuming $\partial n_1^D/\partial w_1 > 0$ (standard direct effect). An increase in the number of doctors working for hospital 1 due to an increase of their salary marginally increases the quality supplied and thus patients' utility by γg_D. This increase in quality is enhanced under a fee-for-service scheme because of the induced effect on $(4\zeta c_1)$. On the doctors' side, in the absence of network externalities and fee-for-service/case payments, equation (10) reduces to the standard Hotelling term $1/(2t_D)$. We assume, once again, that t_P

[20] Otherwise, no duopoly equilibrium exists and the market would tend to be monopolistic.

is high enough to ensure that $\partial n_1^D/\partial w_1 < 0$. The remaining expressions which give the derivatives with respect to d_1 and c_1 can be interpreted along the same lines.

Finally, it follows directly from equations (13), (9), (14) and (10) that

$$\frac{dn_1^P}{dd_1} = \frac{1}{m}\frac{dn_1^P}{dw_1}, \qquad \frac{dn_1^D}{dd_1} = \frac{1}{m}\frac{dn_1^D}{dw_1}. \tag{15}$$

In words, salary and case payment affect demand *on both sides* in a similar way; the respective derivatives are simply proportional to each other.

3 Equilibrium analysis: general expressions

This patient-doctor equilibrium is essentially a "migration" equilibrium which is a competitive equilibrium in the sense that every single doctor or patient takes not only prices but also n_j^P and n_j^D as given. More precisely, the equilibrium is defined by three conditions (all taken simultaneously): *(i)* patients patronize their preferred hospital, *(ii)* doctors are affiliated with their preferred hospital and *(iii)* doctors' effort levels are optimal and given by (3).

Our main objective is to compare the implications of different remuneration and pricing schemes. To do so, we shall successively consider the different instruments in isolation or in various combinations. To avoid repetitions, we shall start by considering the general problem obtained when *all* instruments are available. Though somewhat lengthy and tedious the expressions so obtained are convenient to generate the special cases considered in the remainder of the paper.

Hospital j maximizes its profit functions with respect to K_j, c_j, d_j and w_j.[21] We determine the (symmetric) Nash equilibrium of this game. Without loss of generality, we concentrate on the program of hospital 1 which consists in maximizing Π_1 with

[21] We assume that hospitals compete in prices on both sides. However, the underlying two-sided market structure would be preserved if one side of the market were regulated. For instance, when patients face an administrated price the doctors' remuneration would continue to affect consumers' demand functions through the network externalities (quality).

respect to K_1 and T_1 where profit is defined by

$$\begin{aligned}
\Pi_1 &= n_1^P(K_1,K_2,T_1,T_2,\phi)(K_1-d_1-c_1e_1)-mw_1n_1^D(K_1,K_2,T_1,T_2,\phi), \\
&= n_1^P(K_1,K_2,T_1,T_2,\phi)[K_1-d_1]-mn_1^D(K_1,K_2,T_1,T_2,\phi)\left[c_1^2+w_1\right]. \quad (16)
\end{aligned}$$

Note for future reference that the case payment is proportional to the number of patients and does not depend on the number of doctors. Similarly, the total fee-for-service payment is simply proportional to the number of doctors; this is because a doctors *total* effort does not depend on the number of patients; see expression (4).

Differentiating with respect to the pricing parameters and setting $n_1^P = n_1^D = 1/2$ in the resulting expressions shows that the following conditions hold in a symmetric equilibrium

$$\frac{\partial \Pi_1}{\partial K_1} = \frac{1}{2} + \frac{\partial n_1^P}{\partial K_1}[K_1-d_1] - m\frac{\partial n_1^D}{\partial K_1}\left[c_1^2+w_1\right] = 0, \quad (17)$$

$$\frac{\partial \Pi_1}{\partial w_1} = [K_1-d_1]\frac{\partial n_1^P}{\partial w_1} - \frac{m}{2} - m\frac{\partial n_1^D}{\partial w_1}\left[c_1^2+w_1\right] = 0, \quad (18)$$

$$\frac{\partial \Pi_1}{\partial c_1} = \frac{\partial n_1^P}{\partial c_1}[K_1-d_1] - m\left[c_1^2+w_1\right]\frac{\partial n_1^D}{\partial c_1} - 2c_1\frac{m}{2} = 0, \quad (19)$$

$$\frac{\partial \Pi_1}{\partial d_1} = -\frac{1}{2} + \frac{dn_1^P}{dd_1}[K_1-d_1] - \left[c_1^2+w_1\right]m\frac{dn_1^D}{dd_1} = 0. \quad (20)$$

Expression (17) illustrates the implications of the two-sided market structure. Specifically, a variation in K_1 affects demand on both sides of the market (directly for patients and indirectly for doctors via the network effects).

Not surprisingly, it follows from (15) that

$$\frac{\partial \Pi_1}{\partial d_1} = \frac{1}{m}\frac{\partial \Pi_1}{\partial w_1}.$$

Consequently, if hospitals use both case payments and a salary scheme to remunerate doctors, there exists a continuum of symmetric equilibria.[22] In this paper, we refrain from dealing with the complexity of equilibria multiplicity. Instead, we concentrate

[22] A similar property appears in Armstrong (2006) when platforms use two-part tariffs.

on studying the equilibrium allocations obtained under different type of doctors' remuneration schemes. Our main focus will be on schemes that involve a fee-for-service, possibly in combination with case or salary payments. In a first step, we will report the equilibria under (pure) wage or case payments scheme which constitute interesting benchmarks. Observe that when there is only a fixed salary, but no case payment and no fee-for-service ($d = c = 0$) we have $e = 0$ and we return essentially to the setting of Bardey *et al.* (2010), who do already characterize the equilibria under wage schemes. To make this paper self-contained, we shall restate one of their results, as we need it for the comparisons; see Proposition 1.

4 Pure salary and case payment schemes

Assume first that the hospitals use a salary scheme for providers, combined with a fixed payment for patients.[23] The symmetric equilibrium is then obtained by solving (17) and (18) after setting $d_j = c_j = 0$ and using the expressions for the demand derivatives. It is described in the following proposition.

Proposition 1 *(Bardey et al., 2010) When hospitals use K_j and w_j as sole instruments the symmetric equilibrium is given by*

$$K_1^w = t_P - \frac{1}{2}(\gamma + m\theta) g_P, \tag{21}$$

$$w_1^w = -t_D + \frac{1}{2}(\gamma + m\theta) g_D, \tag{22}$$

and hospitals realize a profit of

$$\Pi^w = \frac{mt_D + t_P}{2} - \frac{(\gamma + \theta m)(g_P + mg_D)}{4}. \tag{23}$$

Observe that g_P and g_D are evaluated at $n_1^P = n_1^D = 1/2$, so that this proposition provides a closed form solution.

[23] Recall that with $c = e = 0$, a fee-for-service on the patients' side would be of no relevance.

Turning to the case where hospitals use K_j and d_j, solving (17) and (20) for $w_j = c_j = 0$ establishes the following proposition.

Proposition 2 *When hospitals use K_j and d_j as sole instruments the symmetric equilibrium is given by*

$$K_j^d = \frac{mt_D}{2} + t_P - \frac{1}{4}(\gamma + \theta m)(2g_P + mg_D), \tag{24}$$

$$d_j^d = -\frac{mt_D}{2} + \frac{1}{4}m(\gamma + \theta m)\, g_D. \tag{25}$$

and hospitals realize a profit of

$$\Pi^d = \frac{mt_D + t_P}{2} - \frac{(\gamma + \theta m)(g_P + mg_D)}{4}.$$

Notice that d_j^d is exactly equal to $mw_j^w/2$. In other words, the total remuneration received by providers $T_j^d = d_j^d/m$ is half of the remuneration achieved in the salary game, namely $T_j^w = w_j^w$. To understand why case payments lead to lower compensations, let us start from the equilibrium salary w^w. By definition, this salary level is such that no hospital can gain by decreasing its salary given the salary offered by the other hospital. Now, when the case payment level is the strategic variable, a decrease in a say d_1 induces (for a given level of d_2) a reduction in compensation offered by hospital 2 (because some doctors move to hospital 2). This implies that a reduction in d_1 (given d_2) is beneficial, even though a reduction in w_1 (given w_2) is not. Interestingly, the price level is also smaller with the case payment scheme. To see this, combine (21) and (24) to obtain $K_j^d = K_j^w - (m/2)w^w$. Intuitively, we can once again start from the equilibrium under salary schemes. By definition, hospital 1 cannot gain by decreasing its price given K_2 and w_2. Under the case payment regime, a reduction in K_1 brings about a reduction in the compensation (per doctor) paid by hospital 2 (because some patients move from hospital 2 to hospital 1). This in turn mitigates the negative effects of a decrease in the price and implies that a unilateral price decrease is beneficial when d_2 is held constant even though it was not beneficial when w_2 was constant.

The main features of the comparison between salary and case payment schemes are summarized in the following proposition.[24]

Proposition 3 *Comparing the equilibria achieved under salary and case payments shows that*

i) $e^w = e^d = 0$*: in both cases, doctors have no incentives to exert effort and set e at its minimum level.*

ii) $T_j^d < T_j^w$ *and* $K_j^d < K_j^w$*: patients pay a lower price and doctors earn a lower remuneration under a case payment than under a salary scheme.*

iii) $V^d > V^w$ *and* $U^d < U^w$*: patients are better off and doctors worse off under case payment than under wage schemes.*

iv) $\Pi_j^w = \Pi_j^d$*: hospitals' profits are the same under both remuneration schemes.*

The health economics literature has extensively dealt with the relative merits of payment schemes and specifically their incentive properties. A point that is often made is that flat payment schemes (as opposed to fee-for-service schemes) have the advantage of providing stronger incentives for cost reduction.[25] Our results are in line with this conventional wisdom albeit in a somewhat trivial way. Specifically, we find that both payment schemes provide the same incentives to limit the number of medical acts as much as possible. However and interestingly, in spite of similar properties in terms of effort incentives, we show that a switch from salary to case payment scheme contains strong implications in rents distribution between the two sides. When doctors are paid by a case payment scheme, *ceteris paribus*, it reinforces the hospitals' competition on the patients' side, as the number of patients intervenes in the doctors' payment. Consequently, a switch from salary to case payment decreases both patients' pay and doctors' remuneration. In other words, a case payment is more patients friendly.

[24] Items *i), ii)* and *iv)* follow directly from Propositions (1) and (2). Item *iii)* follows from *i)* and *ii)*, making use of (1) and (2), the specification of patients' and doctors' utilities.

[25] See, for instance, Gosden *et al.* (1999) for a review of the literature on the remuneration of health care providers.

Finally, the impact on hospitals' profits is *a priori* ambiguous. In our specific setting the two effects happen to perfectly cancel out each other so that profits are the same under the two schemes; we simply have a transfer of rents from doctors to patients. This result is due to the assumption that the market is fully covered on both sides which implies that hospitals compete in a "business stealing" model. Furthermore, when the quality is simply determined by the doctor/patient ratio, the term $g_P + mg_D$ is equal to 0 and hospitals' profits do not depend on the network externalities at play (see Bardey *et al.*, 2010). This is because the negative externality generated by patients and the positive one due to doctors exactly cancel each other out. In such a case, their profits are the same as in a Hotelling game without network externalities.

5 Pure fee-for-service schemes

We now turn to the case where hospitals use a fee-for-service rate on the doctors' side, while patients continue to pay a fixed fee. The hospital's relevant first-order conditions are now equations (17) and (19). The symmetric equilibrium achieved in the case is described in Proposition 4, which is established in Appendix A.

Proposition 4 *When hospitals only use K_j and c_j, the symmetric equilibrium is described by*

$$\begin{aligned} K_1^c &= t_P - \frac{1}{2}\left[(\gamma + 2m\theta)\, g_P - 4mc_1^c\zeta\right] + \frac{\theta g_P m\zeta}{2c_1^c}, \\ (c_1^c)^2 &= -2t_D + \frac{1}{2}\left[(\gamma + 2m\theta)\, g_D + 4c_1^c\zeta\right] + \frac{\zeta}{c_1^c}\left(t_D - \frac{\theta m g_D}{2}\right), \end{aligned}$$

and hospitals realize a profit of

$$\Pi^c = \frac{1}{2}\left[t_P + 2mt_D - \frac{1}{2}\left[(\gamma + 2m\theta)\,(g_P + mg_D)\right] - \frac{m\zeta}{c_1^c}\left(t_D - \frac{\theta\,(mg_D + g_P)}{2}\right)\right].$$

While we were able to obtain closed-form solutions under wage and case payment schemes, this is no longer possible with a pure fee-for-service scheme. Accordingly, the prices reported in Proposition 4 are implicitly defined as functions of c_1^c. This makes their interpretation more difficult. An observation that can easily be made at this point is that hospitals' profits increase with the fee-for-service rate. However, this is a relationship between two endogenous variables which has to be interpreted with care.

Closed form solutions continue to be available in the special case where $\zeta = 0$. In this situation, e can be interpreted as a pure induced demand effect. Indeed, with $c > 0$ and $\zeta = 0$, doctors exert a positive level of effort (increasing the number of services) to increase their remuneration, but this does not induce any benefits to patients. The equilibrium in this case is stated in the following corollary, which follows directly from Proposition 4.

Corollary 1 *Assume $\zeta = 0$. When hospitals use K_j and c_j as sole instruments the symmetric equilibrium is described by*

$$K_1^c = t_P - \frac{1}{2}(\gamma + 2m\theta)\, g_P, \tag{26}$$

$$(c_1^c)^2 = -2t_D + \frac{1}{2}(\gamma + 2m\theta)\, g_D, \tag{27}$$

and hospitals realize a profit of

$$\Pi^c = \frac{1}{2}\left[t_P + 2mt_D - \frac{1}{2}\left[(\gamma + 2m\theta)(g_P + mg_D)\right]\right].$$

On the patients' side, as usual, the price charged depends positively on the transportation cost t_P. Moreover, the negative externality generated by patients increases the price. Comparing K_1^c defined by (26) with K_1^w specified by (21) shows that this effect is stronger when doctors are remunerated via a fee-for-service than under a salary scheme. Consequently we have $K_1^c(\zeta = 0) > K_1^w$. Intuitively, the fee-for-service induces a higher level of e, which increases the hospitals' cost. This cost increase is shifted, at least to some degree, to patients. In the same way, on the doctors' side, hospitals take more advantage of the transportation cost t_D when they use a fee-for-service scheme due to the positive number of services provided by doctors. The positive externality generated by doctors favor them in comparison with a salary payment. Note that the equilibrium fee-for-service-rate is positive only if $4t_D \leq (\gamma + 2m\theta)\, g_D$. In words, the positive externality generated by doctors must be high enough to outweigh the transportation cost that reduces their remuneration.

We will now compare patients' and doctors' welfare and hospitals' profits achieved under fee-for-service and under the other remuneration schemes. We will concentrate on the comparison with the salary regime. The comparisons will make use of the following lemma which is established by substituting the equations provided in Propositions 1 and 4 into the definitions of V, U and Π and by rearranging the resulting expressions.

Lemma 1 *Welfare and profit variations between wage and fee-for-service regimes are given by*

$$\Delta V = V^c - V^w = \zeta m c_1^c - K_1^c - (0 - K_1^w) = m\left[-\zeta c_1^c + \frac{1}{2}\theta g_P \left(\frac{c_1^c - \zeta}{c_1^c}\right)\right], \quad (28)$$

$$\Delta U = U^c - U^w = (c_1^c)^2 \left(1 - \frac{m^2}{2}\right) - w_1^w \quad (29)$$

$$= -m c_1^c \left(\frac{m c_1^c - 4\zeta}{2}\right) - \left[t_D - \frac{\theta m g_D}{2}\right]\left(\frac{c_1^c - \zeta}{c_1^c}\right), \quad (30)$$

$$\Delta \Pi = \Pi^c - \Pi^w = \frac{m}{2}\left[t_D - \frac{\theta\,(m g_D + g_P)}{2}\right]\left(\frac{c_1^c - \zeta}{c_1^c}\right). \quad (31)$$

These expressions are rather complex. The only obvious result is that $\Delta V < 0$ for $\zeta = 0$. Intuitively, the fee-for-service increases the number of services provided (we have $e > 0$). As discussed above, this results in higher payments for patients but does not give them any extra benefits. The other expressions are ambiguous, even for $\zeta = 0$. When $t_D \leq \theta m g_D/2$, we have $\Delta U < 0$, so that providers are also better off with a salary scheme. This is because they receive a higher payment and do not incur any desutility of effort. However, when $t_D > \theta m g_D/2$ these two effects go in opposite directions. Regarding $\Delta\Pi$, we have an explicit expressions for $\zeta = 0$.[26] Consequently, some results

[26] The second factor on the RHS of (31) is then equal to 1.

can be obtained for that case. For instance, when the quality is determined by the doctor/patient ratio (a function homogeneous of degree 0, which implies $mg_D + g_P = 0$), $\Delta\Pi$ is necessarily positive. It appears that hospitals take advantage of the fee-for-service to charge twice the transportation cost on doctors, allowing them to increase their profit (compared to salary or case payment schemes).

When $\zeta > 0$, only few analytical results can be obtained. They make use of the following Lemma (established in Appendix B) which studies the comparative statics properties of c_1^c and K_1^c with respect to ζ.

Lemma 2 *The variations of c_1^c and K_1^c with respect to ζ satisfy the following properties.*

i) In the neighborhood of $\zeta = 0$, $\theta m g_D \geq 2t_D$ ensures that $dc_1^c/d\zeta \geq 1$ which in turn implies $c_1^c \geq \zeta$.

ii)

$$\frac{dK_1^c}{d\zeta} = m\left[4c_1 + \left(-2c_1 + \frac{\theta g_P}{2c_1}\right)(1-\varepsilon)\right],$$

where

$$\varepsilon = \frac{\zeta}{c_1}\frac{dc_1^c}{d\zeta}.$$

The variation of the total fee paid by patients with respect to ζ is ambiguous and mainly depends on the elasticity of the fee-for-service rate with respect to ζ. Situations in which this elasticity is higher than 1 can be interpreted as a kind of "induced demand effect". In this case, the fee-for-service rate paid to doctors increases faster than the patients' valuation of the number of medical acts. Then, the fixed price paid by patients increases faster than their valuation of the number of services. On the contrary, when this elasticity is smaller than 1, there are two conflicting effects and the overall impact is ambiguous.

In the neighborhood of $\zeta = 0$, we have $c_1^c \geq \zeta$ which, from (28) implies $\Delta V < 0$ so that patients are worse off when the doctors' remuneration is switched from wage to fee-for-service. Intuitively, the positive level of c implies that doctors exert some effort. However, the valuation of this effort is low and it is more than outweighed by the increase in the patients' payments.

Analytically, this result cannot be extended for level of ζ beyond the neighborhood of zero. For larger levels of ζ we have to resort to numerical simulations. This is done in Section 7 below which appear to confirm the negative impact of a fee-for-service scheme on the patients' welfare.

6 Mixed fee-for-service schemes

We now consider the case where the different types of remuneration can be combined (on the doctors' side). First, we study a scheme involving both a salary and a fee-for-service. Then, we consider a combination of case payment and fee-for-service. As to the patients, we continue to consider only fixed fees.

6.1 Fee-for-service and salary

The relevant first-order conditions are now (17), (19) and (18). The resulting equilibrium is stated in the following proposition, which is established in Appendix C.

Proposition 5 *When hospitals use a fixed fee K_j on the patients' side, while combining wage w_j and fee-for-service c_j on the doctors' side,*

(i) the symmetric equilibrium is given by

$$K_1^{wc} = t_P - \frac{1}{2}(\gamma + m\theta)\, g_P + 2m\zeta^2, \tag{32}$$

$$w_1^{wc} = -t_D + g_D \frac{1}{2}(\gamma + m\theta) + \zeta^2, \tag{33}$$

$$c_1^{wc} = \zeta, \tag{34}$$

and hospitals realize a profit of

$$\Pi^{wc} = \Pi^{w} = \Pi^{d} = \frac{1}{2}\left[t_P + mt_D - \frac{1}{2}(\gamma + m\theta)(g_P + mg_D)\right]. \tag{35}$$

(ii) the induced effort level $e_j^* = m\zeta$ is efficient (maximizes total surplus).

Interestingly, the mixed payment case turns out to be simpler to solve than the pure fee-for-service case and we obtain closed form solutions like in Section 4. The proposition shows that the introduction of a fee-for-service (on top of the salary) only makes a difference when $\zeta > 0$, *i.e.*, when effort is valued positively by patients. For $\zeta = 0$, the extra instrument is not used in equilibrium and both the patients' bill as well as the wage remain at the same levels as under a pure wage scheme (we have $K_1^{wc} = K_1^w$ and $w_1^{wc} = w_1^w$). Now, when $\zeta > 0$, hospitals use a positive fee-for-service, and it is just equal to ζ (the marginal benefit to patients).

The shifting pattern of this extra fee is quite interesting. One could have expected some kind of crowding out (or substitution) between remuneration schemes, but we find exactly the opposite result: salary but also prices increase such that patients loose and doctors win. This result is due to the role played by the effort and is not related to variations in the quality level. To understand this, consider a slightly different game in which the fee-for-service rate is *exogenously set* at its efficient level $c_1 = c_2 = \zeta$, while the effort per patient is *fixed* and given by $e = m\zeta$ (the level of effort implied by (3) when $c_1 = c_2 = \zeta$ and when $n_1^P = n_1^D = 1/2$).[27] In this game, when hospitals compete in price and salary as in Section 4, symmetric equilibrium, prices and salaries are equal to $K_1^w + m\zeta^2$ and w_1^w respectively (where K_1^w and w_1^w are defined by expressions (21) and (22) in Proposition 1). Now, let us continue to assume that the fee-for-service is given by $c_1 = c_2 = \zeta$, but that the effort per patient is determined by (3) which depends on the number of patients and doctors effectively affiliated with both hospitals. Further assume

[27] In this game, the demand functions for hospital 1 are given by

$$\begin{aligned} n_1^P &= \frac{1}{2} + \frac{1}{2t_P}\left(\gamma g\left(n_1^P, n_1^D\right) - [K_1 - K_2]\right), \\ n_1^D &= \frac{1}{2} + \frac{1}{2t_D}\left(\theta g\left(n_1^P, n_1^D\right) + [w_1 - w_2]\right). \end{aligned}$$

that prices and wages in hospital 2 are given by $K_2^w + m\zeta^2$ and w_2^w respectively.[28] An increase in the price or the wage in hospital 1 now brings about an increase in the effort per patient in hospital 1 (because some patients move from hospital 1 to hospital 2, while doctors move from hospital 2 to hospital 1). This in turn mitigates the negative effects of an increase in the price and the wage and implies that a unilateral price and wage increase is beneficial when w_2, K_2 and c_2 are held constant. This leads to higher prices and wages which, as shown by (32) and (33) are given by $K_1^w + 2m\zeta^2$ and $w_1^w + m\zeta^2$. To sum up, the introduction of the fee-for-service component along with a salary scheme leads to higher prices on the patients' side and higher wages on doctors' side. Observe, that this has no adverse effect on hospitals' profits; the extra compensation paid to doctors is exactly shifted to patients. A patient's bill increase by $2m\zeta^2$, which is equal to the sum of the fee-for-service ($mc_1^{wc}\zeta = m\zeta^2$) and the extra salary ($m\zeta^2$).

Welfare comparisons are also much simpler than in the pure fee-for-service case. With the closed form solutions reported in Propositions 1 and 5, it is straightforward to compare patients' and doctors' welfare.

Proposition 6 *When a fee-for-service component is introduced into a pure salary scheme, the welfare variations are:*

i) on the patients' side, $\Delta V = V^{wc} - V^w = -m\zeta^2 < 0$*;*

ii) on the doctors' side, $\Delta U = U^{wc} - U^w = (3/2)\,\zeta^2 > 0$*.*

To sum up, patients loose, doctors win and (as shown by 35) hospitals are indifferent. Patients do benefit from the increase in e (which they value when $\zeta > 0$), but this benefit is more than offset by the increase in fees.

[28] The demand system for hospital 1 becomes

$$\begin{aligned} n_1^P &= \frac{1}{2} + \frac{1}{2t_P}\left(\gamma g\left(n_1^P, n_1^D\right) + \zeta^2\left(\frac{mn_1^D}{n_1^P} - \frac{m\left(1-n_1^D\right)}{1-n_1^P}\right) - (K_1 - K_2)\right), \\ n_1^D &= \frac{1}{2} + \frac{1}{2t_D}\left(+\theta g\left(n_1^P, n_1^D\right) + [w_1 - w_2]\right). \end{aligned}$$

6.2 Fee-for-service and case payment

The relevant first-order conditions are now (17), (19) and (20). The solution is derived in Appendix D, and presented in the following proposition.

Proposition 7 *When hospitals use a fixed fee K_j as the sole instruments on the patients' side, while case payment d_j and fee-for-service c_j on the doctors' side,*

(i) the symmetric equilibrium is given by

$$\begin{aligned} d_1^{dc} &= -\frac{1}{2}mt_D + (\theta m + \gamma)\frac{mg_D}{4} + \frac{1}{2}m\zeta^2, \\ K_1^{dc} &= t_P + \frac{1}{2}mt_D - \frac{(\gamma + m\theta)(2g_P + mg_D)}{4} + \frac{3}{2}m\zeta^2, \\ c_1^{dc} &= \zeta, \end{aligned}$$

and hospitals realize a profit of

$$\Pi^{dc} = \Pi^{wc} = \Pi^{w} = \Pi^{d} = \frac{1}{2}\left[t_P + mt_D - \frac{1}{2}(\gamma + m\theta)(g_P + mg_D)\right],$$

(ii) the induced effort level $e_j^* = m\zeta$ is efficient (maximizes total surplus).

As in the previous case, for $\zeta = 0$, hospitals do not use a fee-for-service rate and consequently we obtain exactly the same equilibrium under a pure case payment. Now, when $\zeta > 0$, the fixed price paid by patients is increased. This rent paid by patients is totally transferred to doctors as hospitals' profit remain unchanged. The intuition is exactly the same as when the fee-for-service was combined with the salary. There is no crowding out between remuneration schemes, *i.e.,* the case payment received by doctors increases simultaneously with the fee-for-service rate. Consequently, prices and wages are increased because the effort per patient is increasing in the number of doctors and decreasing in the number of patients.

Proposition 8 *When a fee-for-service component is introduced into a pure case payment scheme, welfare variations are:*

i) on the patients' side, $\Delta V = V^{dc} - V^{d} = -m\zeta^2 / < 0$*;*

ii) on the providers' side, $\Delta U = U^{dc} - U^{d} = \zeta^2 > 0$.

The introduction of a fee-for-service component into a case payment scheme unambiguously decreases the patients' welfare and increases the doctors' utility. As in the previous case *i.e.* in the salary case, the fee-for-service introduction favors doctors while patients are worse off. However, the case payment scheme remains more "patient friendly" exactly like under pure (salary or case payment) remuneration schemes; see Proposition 3.

7 Numerical illustration

We now provide a numerical example which illustrates our analytical results and provides a basis of comparisons for the cases where analytical results are ambiguous. Table 1 reports the results for the following example: $g\left(N_j^P, N_j^D\right) = \left(N_j^D / N_j^P\right)$, $t_P = 4$, $t_D = 1$, $\gamma = 2$, $\theta = 1$, $m = 0.3$, $\overline{V} = 10$ and $\overline{U} = 0$. We consider different levels of ζ including 0 (the case for which we have a full set of analytical results). We use the simplest meaningful specification for quality which depends on the doctor-patient ratio.

For the most part this example simply illustrates the earlier results and there is no point reviewing them here. However, there are some extra features which supplement the analytical results. First, we find that a fee-for-service is bad for patients' welfare, even for levels of ζ beyond the neighborhood of $\zeta = 0$. As ζ increases, patients put a higher value on the doctors' effort and only a fee-for-service can induce this effort. This effect tends to make the fee-for-service remuneration attractive to patients. However, this comes at a price. As competition for doctors intensifies, their total compensation increases in a significant way and this extra cost is more than fully shifted to the patients. Overall, it turns out that the increase in fees more than outweighs the benefits patients derive from the higher effort.

ζ (Patient valuation of doctors effort)	0	0.5	1	2
T^w	3.6	3.6	3.6	3.6
T^d	1.8	1.8	1.8	1.8
T^c	3.2	5.66	9.49	22.22
T^{wc}	3.6	4.1	5.6	11.6
T^{dc}	1.8	2.15	3.21	7.44
K^w	5.38	5.38	5.38	5.38
K^d	4.84	4.84	4.84	4.84
K^c	5.56	6.23	7.35	11.14
K^{wc}	5.38	5.53	5.98	7.78
K^{dc}	4.84	4.95	5.29	6.64
Π^c	2.30	2.26	2.25	2.23
$\Pi^w = \Pi^c = \Pi^{wc} = \Pi^{dc}$	2.15	2.15	2.15	2.15
V^w	4.62	4.62	4.62	4.62
V^d	5.16	5.16	5.16	5.16
V^c	4.44	4.13	3.58	1.69
V^{wc}	4.62	4.55	4.32	3.42
V^{dc}	5.16	5.13	5.01	4.56
U^w	3.6	3.6	3.6	3.6
U^d	1.8	1.8	1.8	1.8
U^c	3.05	5.40	9.06	21.22
U^{wc}	3.6	4.08	5.55	11.42
U^{dc}	1.8	2.16	3.25	7.62

Table 1: Equilibrium under different remuneration schemes when $g(N_j^P, N_j^D) = (N_j^D/N_j^P)$, $t_P = 4$, $t_D = 1$, $\gamma = 2$, $\theta = 1$, $m = 0.3$, $\overline{V} = 10$, $\overline{U} = 0$ for different levels of ζ. Superscripts w, d and c respectively refer to the solutions under pure salary, case payment or fee-for-service schemes. Mixed schemes are denoted by a combination of the corresponding superscripts.

Turning to the mixed schemes, we know from the analytical part that patients' welfare decreases as a fee-for-service element is introduced along with a salary or case payment. The numerical example also shows what happens when a wage element is introduced into a fee-for-service scheme. For the considered parameter values, this leads to an increase in patients' welfare. More interestingly, it has an ambiguous effect on doctors' welfare. It increases when ζ is small, but decreases for larger levels of ζ. In other words, when ζ is sufficiently large, doctors would prefer a pure fee-for-service scheme.

8 Conclusion

This paper represents an attempt to study the interplay between hospitals' competition and doctors' remuneration schemes properties *via* a two-sided market approach. In a first step, we consider *pure* wage, case payment or fee-for-service payment schemes. We find that a doctor's effort is higher under a fee-for-service scheme than under other schemes. As a matter of fact, when doctors are remunerated solely *via* a salary or a case payment, they provide the minimum level of effort. Under salary and case payment schemes, hospitals obtain the same equilibrium profit. Patients pay a lower price and doctors receive less remuneration when under case payments than under salary schemes. In other words, a case payment scheme favors patients while doctors are better off under a salary scheme. Next, even though our set up can be considered as biased in favor of fee-for-service schemes, our results suggest that patients are worse off when doctors are paid *via* a fee-for-service rather than with a salary or a case payment scheme. We show this analytically for the case when the number of acts provides only small benefits to patients. For larger levels of benefits, numerical simulations appear to corroborate this result.

Second, we consider payment schemes mixing fee-for-service with either salary or case payments. We show that in either case, hospitals set the fee-for-service rate just equal to the patients' valuation of the number of consultations. Both types of mixed schemes yield the same profit for hospitals as under pure case fee or salary schemes. Moreover, the two mixed schemes imply the same overall welfare even though they differ in their implications for patients and doctors. Exactly like in the pure remuneration case, the presence of a case element favors patients, while a salary term favors doctors. Finally, our results show that the introduction of a fee-for-service component into a case or salary scheme always favor doctors, whereas patients are worse off, in spite of the increase in effort.

Our model could inspire empirical studies of the hospital sector in several directions. First, it would worth verifying through a structural approach if patients' welfare systematically decreases when doctors within hospitals are remunerated via a fee-for-service scheme. Second, our result suggests that there is no crowding out between doctors' remuneration scheme. It would be interesting to confront this result to empirical evidence to verify if *ceteris paribus*, a doctor who benefits from a mixed payment scheme (salary or case payment plus a fee-for-service) tends to receive a higher total payment than doctors who are remunerated through a pure salary/case payment.

Finally, this article can be extended in several directions. First, it would be interesting to consider situations where the market for patients is not completely covered. From a theoretical perspective this would actually simplify the model. However, it would make it more interesting from an applied policy perspective as access to health care is a major problem in practice. Second, both from a theoretical and from a practical perspective, it would be useful to study mixed oligopolies (with public or non-profit hospitals).

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Appendix

A Proof of Proposition 4

The demand functions properties are in this case:

$$\begin{aligned}
\frac{dn_1^P}{dK_1} &= \frac{-1}{4t_D t_P |B|}\left[(2t_D - \theta m g_D)\right], \\
\frac{dn_1^D}{dK_1} &= \frac{-1}{4t_D t_P |B|}\left[\theta g_P\right], \\
\frac{dn_1^P}{dc_1} &= \frac{m}{4t_P t_D |B|}\left[\zeta\left(2t_D - \left(\theta m g_D - 4(c_1)^2\right)\right) + c_1 \gamma g_D\right], \\
\frac{dn_1^D}{dc_1} &= \frac{1}{4t_P t_D |B|}\left[(2t_P - [\gamma g_P - 4mc_1\zeta])\, c_1 + \theta g_P m \zeta\right],
\end{aligned}$$

where

$$|B| = \frac{1}{4t_P t_D}\left[4t_P t_D - 2t_P \theta m g_D - \gamma g_P 2t_D + 4mc_1\zeta\left[2t_D - \theta\left(mg_D + g_P\right)\right]\right].$$

The first-order conditions reduce to

$$\begin{aligned}
\frac{\partial \Pi_1}{\partial K_1} &= \frac{1}{2} + \frac{\partial n_1^P}{\partial K_1} K_1 - mc_1^2 \frac{\partial n_1^D}{\partial K_1} = 0, \\
\frac{\partial \Pi_1}{\partial c_1} &= \frac{\partial n_1^P}{\partial c_1} K_1 - mc_1^2 \frac{\partial n_1^D}{\partial c_1} - mc_1 = 0.
\end{aligned}$$

From (17) and (19),[29] we have

$$\begin{aligned}
K_1 &= \frac{(2t_P - [(\gamma + 2m\theta)\, g_P - 4mc_1\zeta])\, c_1 + \theta g_P m \zeta}{2c_1}, \\
&= t_P - \frac{1}{2}\left[(\gamma + 2m\theta)\, g_P - 4mc_1\zeta\right] + \frac{\theta g_P m \zeta}{2c_1},
\end{aligned}$$

and,

$$c_1^2 = 2c_1\zeta - 2t_D + \frac{g_D}{2}(\gamma + 2m\theta) + \frac{\zeta}{c_1}\left(t_D - \frac{\theta m g_D}{2}\right).$$

[29] Intermediate computations are relegated to a technical addendum and are available upon requests.

Finally, evaluating hospitals' profits at this equilibrium yields

$$
\begin{aligned}
\Pi^c &= \frac{1}{2}\left[t_P - \frac{1}{2}\left[\left(\gamma + 2m\theta\right)g_P - 4mc_1\zeta\right] + \frac{\theta g_P m\zeta}{2c_1}\right. \\
&\qquad \left. -m\left(2c_1\zeta + \left(-2t_D - t_D\frac{\zeta}{c_1} + \frac{g_D}{2}\left[\left(\gamma + 2m\theta\right)\right] - g_D\frac{\theta m\zeta}{2c_1}\right)\right)\right], \\
&= \frac{1}{2}\left[t_P + 2mt_D - \frac{1}{2}\left[\left(\gamma + 2m\theta\right)\left(g_P + mg_D\right)\right] + \frac{m\zeta}{c_1}\left(t_D - \frac{\theta\left(g_P + mg_D\right)}{2}\right)\right].
\end{aligned}
$$

B Proof of Lemma 2

Prices in a symmetric equilibrium are given by:

$$
\begin{aligned}
K_1^{***} &= t_P - \frac{1}{2}\left[\left(\gamma + 2m\theta\right)g_P - 4mc_1\zeta\right] + \frac{\theta g_P m\zeta}{2c_1}, \\
\left(c_1^{***}\right)^2 &= -2t_D + \frac{1}{2}\left[\left(\gamma + 2m\theta\right)g_D + 4c_1\zeta\right] + \frac{\zeta}{c_1}\left(t_D - \frac{\theta m g_D}{2}\right).
\end{aligned}
$$

Differentiation with respect to ζ gives:

$$
\begin{pmatrix} 1 & -2m\zeta + \frac{\theta g_P m\zeta}{2c_1^2} \\ 0 & 2\left(c_1 - \zeta\right) + \frac{\zeta}{c_1^2}\left(t_D - \frac{\theta m g_D}{2}\right) \end{pmatrix}
\begin{pmatrix} dK_1 \\ dc_1 \end{pmatrix}
= -\begin{pmatrix} -2mc_1 - \frac{\theta m g_P}{2c_1} \\ -2c_1 - \frac{1}{c_1}\left(t_D - \frac{\theta m g_D}{2}\right) \end{pmatrix} d\zeta
$$

So, the Cramer's rule gives:

$$
\begin{aligned}
\frac{dc_1}{d\zeta} &= \frac{1}{|\Upsilon|}\begin{vmatrix} 1 & 2mc_1 + \frac{\theta m g_P}{2c_1} \\ 0 & 2c_1 + \frac{1}{c_1}\left(t_D - \frac{\theta m g_D}{2}\right) \end{vmatrix}, \\
&= \frac{1}{|\Upsilon|}\left[2c_1 + \frac{1}{c_1}\left(t_D - \frac{\theta m g_D}{2}\right)\right],
\end{aligned}
$$

with

$$
|\Upsilon| = 2\left(c_1 - \zeta\right) + \frac{\zeta}{c_1^2}\left(t_D - \frac{\theta m g_D}{2}\right).
$$

Moreover, we have

$$\begin{aligned}
\frac{dK_1}{d\zeta} &= \frac{1}{|\Upsilon|}\begin{vmatrix} 2mc_1 + \frac{\theta m g_P}{2c_1} & -2m\zeta + \frac{\theta g_P m\zeta}{2c_1^2} \\ 2c_1 + \frac{1}{c_1}\left(t_D - \frac{\theta m g_D}{2}\right) & 2\left(c_1 - \zeta\right) + \frac{\zeta}{c_1^2}\left(t_D - \frac{\theta m g_D}{2}\right) \end{vmatrix}, \\
&= \frac{1}{|\Upsilon|}\left[\left(2mc_1 + \frac{\theta m g_P}{2c_1}\right)\left(2\left(c_1 - \zeta\right) + \frac{\zeta}{c_1^2}\left(t_D - \frac{\theta m g_D}{2}\right)\right)\right. \\
&\qquad \left. - \left(2c_1 + \frac{1}{c_1}\left(t_D - \frac{\theta m g_D}{2}\right)\right)\left(-2m\zeta + \frac{\theta g_P m\zeta}{2c_1^2}\right)\right], \\
&= m\left[4c_1 + \left(-2c_1 + \frac{\theta g_P}{2c_1}\right)\left(1 - \epsilon\right)\right],
\end{aligned}$$

with

$$\epsilon = \frac{\zeta}{c_1}\frac{dc_1}{d\zeta}.$$

Finally, we have

$$\begin{aligned}
\frac{dc_1}{d\zeta} &\geq 1 \\
&\Leftrightarrow \\
2c_1 - \frac{1}{c_1}\left(t_D - \frac{\theta m g_D}{2}\right) &\geq 2\left(c_1 - \zeta\right) - \frac{\zeta}{c_1^2}\left(t_D - \frac{\theta m g_D}{2}\right).
\end{aligned}$$

A sufficient condition to ensure this last inequality is $\theta m g_D \geq 2t_D$.

C Proof of Proposition 5

The relevant first order conditions are now:

$$\begin{aligned}
\frac{\partial \Pi_1}{\partial K_1} &= \frac{1}{2} + \frac{\partial n_1^P}{\partial K_1}K_1 - m\left[c_1^2 + w_1\right]\frac{\partial n_1^D}{\partial K_1} = 0, \\
\frac{\partial \Pi_1}{\partial c_1} &= \frac{\partial n_1^P}{\partial c_1}K_1 - m\left[c_1^2 + w_1\right]\frac{\partial n_1^D}{\partial c_1} - mc_1 = 0, \\
\frac{\partial \Pi_1}{\partial w_1} &= K_1\frac{\partial n_1^P}{\partial w_1} - \frac{m}{2} - m\left[c_1^2 + w_1\right]\frac{\partial n_1^D}{\partial w_1} = 0,
\end{aligned}$$

while the demand functions properties become:

$$\begin{aligned}
\frac{dn_1^P}{dK_1} &= \frac{-1}{4t_D t_P |B|}\left[(2t_D - \theta m g_D)\right], \\
\frac{dn_1^D}{dK_1} &= \frac{-1}{4t_D t_P |B|}\left[\theta g_P\right], \\
\frac{dn_1^P}{dw_1} &= \frac{1}{4t_D t_P |B|}\left[m\left[\gamma g_D + 4c_1\zeta\right]\right], \\
\frac{dn_1^D}{dw_1} &= \frac{1}{4t_D t_P |B|}\left[2t_P - (\gamma g_P - 4mc_1\zeta)\right], \\
\frac{dn_1^P}{dc_1} &= \frac{m}{4t_P t_D |B|}\left[\zeta\left(2t_D - \left(\theta m g_D - 4c_1^2\right)\right) + c_1\gamma g_D\right], \\
\frac{dn_1^D}{dc_1} &= \frac{1}{4t_P t_D |B|}\left[(2t_P - \left[\gamma g_P - 4mc_1\zeta\right])c_1 + \theta g_P m\zeta\right],
\end{aligned}$$

where

$$|B| = \frac{1}{4t_P t_D}\left[4t_P t_D - 2t_P\theta m g_D - \gamma g_P 2t_D + 4mc_1\zeta\left[2t_D - \theta\left(mg_D + g_P\right)\right]\right].$$

It gives

$$c_1 = \zeta.$$

Moreover, patients' price becomes

$$\begin{aligned}
K_1 &= \frac{\frac{\partial n_1^D}{\partial w_1} + m\frac{\partial n_1^D}{\partial K_1}}{2\left(\frac{\partial n_1^D}{\partial K_1}\frac{\partial n_1^P}{\partial w_1} - \frac{\partial n_1^P}{\partial K_1}\frac{\partial n_1^D}{\partial w_1}\right)}, \\
&= t_P - \frac{1}{2}\left(\gamma + m\theta\right)g_P + 2m\zeta^2.
\end{aligned}$$

The salary is determined by

$$\begin{aligned}
mw_1 &= \frac{\frac{1}{2} + \frac{\partial n_1^P}{\partial K_1}K_1}{\frac{\partial n_1^D}{\partial K_1}} - mc_1^2, \\
&\iff \\
w_1 &= -t_D + \frac{g_D}{2}\left(\gamma + m\theta\right) + \zeta^2.
\end{aligned}$$

Hospitals' profit becomes:

$$\begin{aligned}
\Pi_1 &= \frac{1}{2}\left[\hat{K}_1 - m\left[\left(\hat{c}_1\right)^2 + \hat{w}_1\right]\right], \\
&= \frac{1}{2}\left[t_P + mt_D - \frac{1}{2}\left(\gamma + m\theta\right)\left(g_P + mg_D\right)\right].
\end{aligned}$$

D Proof of Proposition 7

From the set of relevant first order conditions, we have:

$$\begin{aligned}
\frac{1}{2}+\frac{\partial n_1^P}{\partial K_1}\left[K_1-d_1\right] &= mc_1^2\frac{\partial n_1^D}{\partial K_1},\\
\frac{\partial n_1^P}{\partial c_1}\left[K_1-d_1\right]-mc_1 &= mc_1^2\frac{\partial n_1^D}{\partial c_1},\\
-\frac{1}{2}+\frac{dn_1^P}{dd_1}\left[K_1-d_1\right] &= mc_1^2\frac{dn_1^D}{dd_1},
\end{aligned}$$

while the demand functions become:

$$\begin{aligned}
\frac{dn_1^P}{dK_1} &= \frac{-1}{4t_Dt_P\left|B\right|}\left[\left(2t_D-\left(\theta mg_D-\frac{4}{m}d_1\right)\right)\right],\\
\frac{dn_1^D}{dK_1} &= \frac{-1}{4t_Dt_P\left|B\right|}\left[\left(\theta g_P+\frac{4}{m}d_1\right)\right],\\
\frac{dn_1^P}{dc_1} &= \frac{m}{4t_Pt_D\left|B\right|}\left[\zeta\left(2t_D-\left(\theta mg_D-4\left(\frac{d_1}{m}+c_1^2\right)\right)\right)+c_1\gamma g_D\right],\\
\frac{dn_1^D}{dc_1} &= \frac{1}{4t_Pt_D\left|B\right|}\left[\left(2t_P-\left[\gamma g_P-4mc_1\zeta\right]\right)c_1+\left(\theta g_P+\frac{4}{m}d_1\right)m\zeta\right],\\
\frac{dn_1^P}{dd_1} &= \frac{1}{4t_Dt_P\left|B\right|}\left[\gamma g_D+4c_1\zeta\right],\\
\frac{dn_1^D}{dd_1} &= \frac{1}{4mt_Dt_P\left|B\right|}\left[2t_P-\left(\gamma g_P-4mc_1\zeta\right)\right].
\end{aligned}$$

We obtain:

$$\begin{aligned}
c_1 &= \zeta,\\
\tilde{d}_1 &= -\frac{1}{2}mt_D+\left(\theta m+\gamma\right)\frac{mg_D}{4}+m\zeta^2,\\
\tilde{K}_1 &= t_P+\frac{1}{2}mt_D-\frac{\left(\gamma+m\theta\right)\left(2g_P+mg_D\right)}{4}-\frac{1}{2}m\zeta^2.
\end{aligned}$$

At a symmetric equilibrium, hospitals' profit are:

$$\begin{aligned}
\tilde{\Pi}_1 &= \frac{1}{2}\left[\tilde{K}_1-\tilde{d}_1-mc_1^2\right]\\
&= \frac{1}{2}\left[t_P+mt_D-\frac{\left(\gamma+m\theta\right)\left(g_P+mg_D\right)}{2}\right]=\Pi_1^*=\Pi_1^{**}.
\end{aligned}$$