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Abstract

In some countries, including France, patients can choose between consulting a physician working in the regulated sector where, in general, fees are fully covered by health insurance (whether public, private or mixed), or a physician working in the unregulated sector, where a balance billing scheme operates. In the latter, fees might not be fully covered by health insurance, and patients must make out-of-pocket payments. The paper analyses the signalling properties of this mechanism in a context where patients are heterogenous with respect to their propensity to adhere to the prescribed treatment. The model reveals that a small extra fee allows to obtain a separating equilibrium in which only patients with a high propensity to adhere to the treatment will opt for the unregulated sector and benefit of a higher care effort on behalf of their physician. We also analyse the other equilibria of the game and comment on their welfare properties.

Keywords: Balance billing, Treatment adherence, Signalling game, Health care systems.
JEL Classification: I11, D82.

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1 Introduction

In general, health authorities in the developed world regulate the market for outpatient care by setting the fees that physicians can charge. These regulated fees are almost always fully reimbursed by national health insurance schemes. However, in many countries, all or some categories of physicians are allowed to charge patients more than the regulated fee, a mechanism referred to as balance billing, bulk-billing or extra-billing. In this case, patients decide whether to make out-of-pocket (OOP) payments for the difference not covered.

As an example, in France specialist physicians can opt to work either in the Sector 1 framework, whereby they agree to provide medical services at a regulated fee which is fully covered by a combination of public and private (i.e., complementary) insurance schemes,[1] or in the Sector 2 framework, whereby they can charge an extra fee on top of the regulated fee. In 2017, 46% of specialized physicians in France were registered in Sector 2 (DREES, 2018). The level of cover provided by complementary insurance schemes for these extra expenses depends on the contract; some provide much more extensive cover than others. It is important to note however that the level of extra cover they can provide is capped by law. Accordingly, patients may be faced with high OOP payments (see Clerc et al., 2012; Coudin et al., 2015, Dormont and Peron, 2016; Calcoen and Van den Ven, 2019). The DREES 2018 report indicated that expenses not covered totalled 2 billion euros in France in 2017. Based on survey data from 2012, Dormont and Peron (2016) estimated sector 2 OOP payments at 439 euros per patient per year.

Other countries where balance billing is found include Belgium (Lecluyse et al., 2009; Calcoen and Van den Ven, 2019), Australia and the US. With respect to the latter, before 1984, a substantial proportion of physicians applied balance billing to beneficiaries of national health insurance for the 65+ year old patient population (US Medicare). However, between 1984 and 1990, a wave of directives prompted physicians to gradually abandon the balance billing system. Whereas in 1984, balance billing in the USA amounted to 27% of the total OOP payments charged to Medicare beneficiaries, by 1990 these directives stipulated that additional charges had to be

[1] Except for a one euro co-payment, introduced in 2005.

limited to a maximum of 10% of the regulated fee set by Medicare (McKnight, 2007; Kifmann and Scheuer, 2011).[2]

The primary criticism against balance billing systems is the high charges for patients, which limit access to care for those who are less wealthy. High balance billing fees also contribute to increased healthcare expenses, and put additional stress on private insurance companies, even if they only partly cover them. The primary benefit of balance billing systems is a higher income, as required to attract talent to the physician occupation, without any additional financial burden on public spending.

Our study suggests an additional benefit associated with balance billing systems. Under our assumptions, a well-designed balance billing system might provide a useful mechanism to identify patients according to their propensity to adhere to prescribed treatment. The model analyses the functioning of a hypothetical dual payment system for primary health care, which comprises a regulated sector where care is free of any supplementary charge, and an unregulated sector, where physicians are entitled to charge the patient an extra fee.

In the classical signalling model (Spence, 1973; 2002) an employee's education level can, depending on the parameters of the problem, signal their productivity to their employer. Our setting presents an additional layer of complexity given that the patient strategy includes two choices, both the sector choice and the choice of effort in adhering to the treatment. To our knowledge, no other theoretical analysis of the balance billing mechanism to date has shown under which conditions such a system can help the physician screen patients according to their propensity to adhere to a treatment.

A large body of literature in social sciences and medicine has been dedicated to the analysis of the patient-physician interaction, and how this interaction impacts real and patient-perceived quality of treatment (inter alia: Parson, 1951; Buller and Stone, 1992; Charles et al., 1997; Heritage and Maynard, 2006). One essential factor contributing to the success of prescribed treatment is patient adherence; in other words, the extent to which taking medication, following recommended diets and changing one's lifestyle all coincide with the associated medical advice

[2] See also Epp et al. (2000) for the presentation of balance billing in Canada.

received from a physician (inter alia, Davis, 1968; Haynes, 1979; Vermeire et al., 2001; DiMateo et al., 2002; DiMateo, 2004; Simpson et al., 2006; Iuga and McGuire, 2014). However, studies show that treatment adherence is a major problem. In the US it was reported that seventy-five percent of Americans had trouble taking their medicine as directed and that non-adherence to treatments accounted for an estimated 125,000 deaths annually as well as at least 10 percent of hospitalizations (Benjamin, 2012). In accordance with the literature on adherence to treatment, we assume heterogeneity in patients' adherence to prescribed treatment (Giuffrida and Gravelle, 1998; Lamiraud and Geoffard, 2007). To keep the analysis simple, we assume that there are only two types of patient: those with a low marginal cost of adhering to treatment and those with a high one.

We also assume that the physician's investment in their relationship with patients plays an important role in treatment success.[3] In our model, we follow Balsa and McGuire (2003) and Fichera et al. (2018), who assumed that the health production function positively depends on both the patient's effort to adhere to treatment and the physician's effort in terms of the amount of attention, interest and time they dedicate to the patient. Indeed, using observations from a large sample of interactions between English doctors and patients with cardiovascular diseases in 2004-2006, Fichera et al. (2018) verified this hypothesis.

It is commonly accepted that physicians also care about the health of their patients (Arrow, 1963; Ellis and McGuire, 1986; Balsa and McGuire, 2003).[4] Using a simple utility maximization framework we show that the optimal effort of a physician aligns with the level of treatment adherence effort by the patient, as perceived by the physician. While the effort of the patient cannot be observed, the physician will use information provided by the patient's payment strategy to revise their beliefs about the type and level of effort of the patient.

The most interesting outcome of this game is a separating equilibrium in which patients with a high propensity to adhere to treatment ("high adherence" type) use the balance billing system,

[3] Many studies in the psychology of healthcare emphasize the role of a physician's empathy with the patient (e.g., Derksen et al., 2013; Kelm et al., 2014).

[4] Recent experimental studies corroborate the assumption that physicians are altruistic (e.g., Godager and Wiesen, 2013; Kesternich et al. 2016).

while patients with a low propensity to adhere to treatment ("low adherence" type) use the regulated system (i.e., they do not make any OOP payment). In this separating equilibrium, the high adherence patient chooses the high effort level, while the low adherence one chooses the low effort level. Furthermore, in this model, physicians are able to perfectly identify patient types in terms of adherence to treatment and adapt their own level of effort to them. The separating equilibrium is not the only equilibrium of this game. If the balance billing fee is too high, the model presents a pooling equilibrium in which nobody makes an OOP payment, and physicians cannot infer the type of patient from the patient's billing strategy (i.e., choice to make OOP payment or not).

The reasoning behind our main result is also seen in Balsa and McGuire (2003) who explained how stereotypic beliefs can be part of an equilibrium with healthcare discrimination. More specifically, they found that because physicians believed that black patients were less compliant than white patients, it might be optimal for white (and respectively, black) patients to comply (respectively, not to comply). Our analysis enriches the literature in this respect, as it involves two decisions (whether to pay to signal willingness to adhere to treatment or not, and the effort level of each patient type in terms of treatment adherence/compliance). While in Balsa and McGuire (2003) the patient type is directly observable (color of the skin), this is not the case in our present study. Indeed, in our model, patients can decide to signal their patient type or not to the physician and adapt their level of effort accordingly.

As a related literature, a large number of existing studies in industrial organization of the health care sector analyse balance billing through the prism of price discrimination. Early models represented the physician as a monopolist providing a service of homogenous quality who could price discriminate between patients who had different levels of willingness to make OOP healthcare payments (Mitchell and Cromwell, 1982; Zuckerman and Holahan, 1991; Savage and Jones, 2004). In those models, balance billing could only increase the income of physicians at the expense of patients. Feldman and Sloan (1988) argued that if a monopolist physician is subjected to balance billing constraints (i.e., capping of extra fees), the quality of the service they provided would deteriorate. Glazer and McGuire (1993) analysed monopolistic competition between two physicians who engage in price and quality differentiation. They revealed the existence of a positive fee that maximizes social welfare, and showed that restrictions on balance billing introduced in the US in the late 1980s would reduce the quality of care for all patients. Kifmann and Scheuer (2011) used the same model to show that a mixed system with balance billing and regulated fee only patients could increase patient welfare if the administrative costs of Medicare were sufficiently low. This relatively optimistic conclusion on the ability of balance billing to improve patient welfare was recently challenged by Jelovac (2015) who showed that if physicians have imperfect information about their patients' willingness to pay and must charge uniform fees, then balance billing can increase inequalities in access to care and ultimately reduce social welfare. Gravelle et al. (2016) developed a n-player differentiation model à la Salop with price and quality differentiation, applying it to the Australian health care market, where balance billing is generalized.[5] They highlighted risks related to the documented increasing market concentration which could possibly lead to higher fees.[6]

Our paper may also be considered in terms of the analysis of the 'dual practice' system prevailing in many countries (e.g. the UK), where physicians can offer their services both in the public sector and in the private sector, the latter at a higher fee (see Eggleston and Bir, 2006; Barros and Siciliani, 2011; Socha and Bech, 2011). For instance, Kuhn and Nuscheler (2020) study how a monopolist physician sets tariffs and service quality (in terms of patient waiting time) when they have the choice between offering a basic service at a low regulated fee (public sector) and a higher quality service (i.e., shorter waiting time) at the higher fee in a private setting. To increase willingness to pay for private treatment, the monopolist physician shifts waiting time costs onto public patients. Kuhn and Nuscheler's main result is that the consequent positive network effect leads to an over-provision of private care if time costs are too high.

Our paper is organized as follows. Section 2 presents the game between patients and physicians. Section 3 defines and analyses the equilibria of this game. Section 4 extends the analysis of the

[5] In Australia patients pay a fee for each General Practitioner (GP) consultation. Physicians choose their fees freely. The national, tax-financed, healthcare insurance system (Medicare) provides a subsidy for the cost of a consultation (the Medicare rebate). The patient pays the excess between the physician fee and the Medicare rebate. These OOP co-payments by patients cannot be covered by complementary insurance.

[6] Mu et al. (2018) bring empirical evidence showing that patients do not perceive quality to be different between low-price and high-price medical services in Australia.

separating equilibrium to the case of wealth-constrained patients. Section 5 is our conclusion.

2 Model

We study the strategic interaction between a patient and a physician in the joint production of a healthcare service. In our model, patients differ in their propensity to adhere to prescribed treatment. The level of adherence is private information to them, and cannot be disclosed directly. In the first stage of the game, the patient chooses whether to pay an extra fee for or not. Depending on the equilibrium, the physician can infer from this choice of payment some information about the patient's propensity to adhere to their treatment. In the second stage, physicians and patients choose their optimal effort levels conditional on the first stage choices. To keep the analysis simple, we assume that the allocation of physicians to the sectors is exogenously given.[7]

The mass of patients is normalized to one. We assume that all patients have access to the regulated sector, in which the cost of the medical service is fully covered by public and private health insurance. Patients can also choose to consult a physician working in the unregulated sector under a balance billing scheme. In the latter, physician fees exceed fees in the regulated sector; let c denote the part of physician fees not covered by public and private insurance schemes under balance billing, with $c > 0$. This fee is assumed to be exogenous. The implicit assumption is that the National Health Authorities can control the size of this fee (or at least can set an upper limit on it, as indicated in Calcoen and Van den Ven, 2019). Accordingly, a patient's payment strategy is $S \in \{0, c\}$, depending on whether they opt for the balance billing system (goes to sector 2 and pays the extra fee $S = c$) or the regulated system (goes to sector 1 and pays no extra fee, $S = 0$).

We consider an elementary health production function with two inputs. In general, the probability that the treatment will be successful depends on both the patient's effort in adhering to treatment, and the physician's level of effort in the physician-patient relationship (that is to say the level of attention, time, and interest they dedicate to the patient). Let H_{ij} be the amount of health care delivered by the interaction between a physician j and a patient i, e_i the patient's effort and e_j the physician's effort. The health production function can take the standard Cobb-Douglas

[7] We analyze a physician's choice of sector in Besancenot, Lamiraud and Vranceanu (2020), using a price and quality differentiation model.

specification as suggested in Balsa and McGuire (2003):

$$H_{ij} = Ae_i e_j. \tag{1}$$

where A is a positive parameter that captures the productive efficiency of the patient-physician interaction. Since $\frac{\partial^2 H_{ij}}{\partial e_i \partial e_j} > 0$, this function features effort complementarity, as revealed in the empirical analysis by Fichera et al. (2018). Patients have the choice between two effort levels (Balsa and McGuire, 2003; Lamiraud and Geoffard, 2007), a high effort level $e^h = 1$ and a low effort level, $e^l = 0$. The {0;1} restriction on effort levels is imposed by the complexity of the subsequent calculations; a more realistic model would consider strictly positive effort levels for both types of patients. Due to this simplification, the choice of the low effort mechanically leads to treatment failure, which is essentially equivalent to no treatment at all. However, this extremely simple model suffices to describe the signalling mechanism, which should also be at work in a more realistic model.

A patient cost associated with adherence to treatment is assumed to be quadratic in the effort level; for an individual patient i, the adherence cost is $k_i \times (e_i)^2$, with $k_i > 0$. We assume that there are only two types of patients: type 1, or "high adherence" patients have the cost coefficient k_1 and type 2 or "low adherence" patients have the cost coefficient k_2, with $k_2 > k_1$.

The utility of the type i patient is therefore:

$$U_i = Ae_i e_j - k_i(e_i)^2 - S, \text{ with } i \in \{1, 2\} \text{ and } S \in \{0, c\}. \tag{2}$$

In line with literature, in our model the physician cares non only about their own benefit, but also about their patient's health (Ellis and McGuire, 1986; Balsa and McGuire, 2003). We assume that the physician $j's$ utility function has the additively separable form:

$$V_j = \varphi f + (1 - \varphi)Ae_i e_j - \beta(e_j)^2, \tag{3}$$

where $f > 0$ is the (constant) consultation fee (which may be sector specific), $Ae_i e_j$ is the amount of health care as defined before (Eq.1), φ and $(1 - \varphi)$ are the weights of the materialistic and respectively altruistic goal in the payoff of the physician and $\beta \times (e_j)^2$ is a quadratic cost of effort for the physician.

However, since the effort of the patient is private information and therefore unobservable, the physician uses their own expectations about their patient's effort as a guide to choose their own effort level in terms of investment in the professional interaction with the patient. Let $E_j\left[e_i|S\right]$ denote these expectations, conditional on the patient's observed payment strategy (i.e., making OOP payments or not) which, unlike the patient effort, is observable to the physician. The expected utility is:

$$EV_j[S] = \varphi f + (1-\varphi)AE_j\left[e_i|S\right]e_j - \beta\left(e_j\right)^2. \tag{4}$$

Then the first order condition for utility maximization determines the optimal effort of the physician simply as:

$$e_j = \frac{(1-\varphi)A}{2\beta}E_j\left[e_i|S\right], \tag{5}$$

where $\left[(1-\varphi)A\right]/(2\beta) \leq 1$; this restriction on parameters ensures that a physician's effort is also defined in the interval $[0,1]$.

Denoting $\gamma = \frac{(1-\varphi)A^2}{2\beta}$, the physician's utility for a given patient's effort can be written:

$$V_j[S,e_i] = \varphi f + (1-\varphi)\gamma\left[e_iE_j\left[e_i|S\right] - 0.5\left(E_j\left[e_i|S\right]\right)^2\right]. \tag{6}$$

In the following calculations, to avoid excessive notational complexity, we drop the index j from the conditional expectations of the physician.

The physicians' beliefs are represented by the conditional probabilities Pr[type $1|S$] and Pr[type $2|S$] where S is the observed billing strategy $S \in \{0,c\}$.

Let e_1 denote the effort of the type 1 patient, and e_2 the effort of the type 2 patient, with $e_{1,2} \in \{0,1\}$. With these notations, a physician's expectations about the patient's effort are:

$$E\left[e|S\right] = \Pr[\text{type } 1|S]e_1(S) + \Pr[\text{type } 2|S]e_2(S). \tag{7}$$

In equilibrium, e_1 and e_2 are the optimal effort levels of both types of patients.

Under these assumptions, the type i patient's utility (Eq.2) becomes:

$$U_i = \gamma e_iE\left[e_i|S\right] - k_i(e_i)^2 - S, \text{ with } i \in \{1,2\} \text{ and } S \in \{0,c\} \tag{8}$$

We will consider hereafter only the non-trivial case in which the two cost coefficients (k_1 and k_2) lie below and above γ. Therefore, the "high adherence" type 1 has $k_1 < \gamma$ and the "low adherence" type 2 has $k_2 > \gamma$. According to its definition, the threshold γ increases with physicians's altruism $(1-\varphi)$ and the technical efficiency of the care A; it decreases with the marginal cost of effort of the physician β.

Let μ be the frequency of type 1 patients in the total patient population; $(1-\mu)$ is the frequency of type 2 patients.

The *sequence of decision* is the following: At the outset of the game, Nature decides on patients' types (i.e., type 1 (high adherence) or type 2 (low adherence)). Then, in what we refer to as the first stage of the game, patients chose their best billing strategy (i.e., regulated fee or balance billing). In the second and last stage of the game, the physician observes the billing strategy, forms their beliefs about the type of patient (and their chosen effort) and finally decides about their own level of effort. At the same time, given the physician's beliefs, the patient chooses their optimal effort level.[8]

3 Equilibria of the game

An equilibrium of this game is defined as a situation in which patients chose their optimal billing and effort strategy given physicians' beliefs about their type of patient (high or low adherence type), and physicians' beliefs about the type of patients are correct given patients' optimal strategy.

Specific to this model, a physician's expectations about their patient's effort depend on the payment strategy implemented by each type of patient and on their optimal effort. In turn, one type's optimal effort depends on the optimal effort of the other type by the intermediation of the physician's expectations. As a consequence, the optimal effort of each patient type is equilibrium dependent.

Below, we present the two pure strategy equilibria of the game, namely a separating equilibrium, and a pooling equilibrium in which no patient opts for the balance billing system. We show in the Appendix A.1 that the opposite pooling equilibrium in which all patients pay the fee $c > 0$ does not exist. Appendix A.2 analyses the special case of a zero effort pooling equilibrium. Mixed

[8] Patients and physicians effort decisions are taken simultaneously (Balsa and McGuire, 2003). This analytical framework is the most meaningful for a one-shot patient-physician interaction. In the case of chronic diseases, characterized by a long-term relationship, a sequential approach including learning and reputation building would be more appropriate (McGuire, 2001).

strategy equilibria are analyzed in Appendix A.3 and A.4.

3.1 The separating equilibrium

We analyze a separating equilibrium in which all type 1 patients (those with a low marginal cost of treatment adherence) choose the balance billing system ($S = c$), and all type 2 patients (with a high marginal adherence cost) choose the system fully covered by public and private health insurance ($S = 0$).[9] In this case, the physician's beliefs are:

$$\Pr[\text{type } 1|S] = \begin{cases} 1 \text{ if } S = c \\ 0 \text{ if } S = 0 \end{cases}. \tag{9}$$

Because the choice of the balance billing system signals unambiguously the type of patient in this equilibrium, according to Eq. (7), a physician's expectations about a patient's effort level contingent of the latter's billing strategy can be written as: $E[e|S = c] = e_1$ and $E[e|S = 0] = e_2$.

Using a standard backward resolution method, we first determine *the optimal effort for each patient according to their type* as chosen at the last stage of the game. Then, we analyze the first stage choice of sector (i.e., payment strategy S), given the second stage optimal efforts. Note that the steps used to analyze this equilibrium can be used to study all equilibria of this game.

Optimal efforts (second stage)

The utility of the type 1 patient who pays the extra fee c is:

$$U_1(e_1, S = c) = \gamma e_1 E\left[e|S = c\right] - k_1 \left(e_1\right)^2 - c = \left(e_1\right)^2 \left(\gamma - k_1\right) - c$$

Because $(\gamma - k_1) > 0$, the optimal effort strategy for type 1 patients is $e_1 = 1$. This strategy is preferred to the zero effort strategy irrespective of the choice of effort level by type 2 patients.[10] With this optimal effort, the utility of a type 1 patient is:

$$U_1(e_1 = 1, S = c) = (\gamma - k_1) - c. \tag{10}$$

[9] The polar case, in which type 2 patients pay the extra fee, and type 1 do not, cannot be an equilibrium. Indeed, in this situation, the type 2 patient has all the incentive to deviate (i.e. move to a regulated fee physician), as they will save money by not paying the extra fee, and will be considered a high adherence (high effort) patient.

[10] The optimal effort of the other type does not appear in the expression of the physician's expectations since in this equilibrium the billing strategy signals to the physician the patient's type. This is not the case in other equilibria.

Turning to type 2 patients, we know that in this equilibrium, they do not pay c. The utility of a type 2 patient is therefore:

$$U_2(e, S=0) = \gamma e_2 E\left[e|S=0\right] - k_2\left(e_2\right)^2 = \left(\gamma - k_2\right)\left(e_2\right)^2 \tag{11}$$

We assumed that $k_2 > \gamma$: the optimal effort of the type 2 patient is $e_2 = 0$. For this optimal effort, their utility is**:**

$$U_2(e_2 = 0, S = 0) = 0. \tag{12}$$

Payment strategy (first stage)

In the second step, we study the choice of payment strategy by the patient, contingent on their type, and given their optimal effort strategy as reveled before.

If a type 1 patient deviates from the balance billing sector and chooses the regulated sector, physicians will believe that they are of the type 2, and, accordingly, that their optimal effort is 0. Formally, $E\left[e|S=0\right] = 0$. The utility of the type 1 patient who deviates from their equilibrium strategy is:

$$U_1(e_1, S=0) = e_1 E\left[e|S=0\right] - k_1\left(e_1\right)^2 = -k_1\left(e_1\right)^2.$$

Obviously, their optimal effort is $e_1 = 0$ and their utility is $U^1(e_1 = 0, S = 0) = 0$.

Thus the type 1 patient has no incentive to deviate from the balance billing strategy if:

$$U_1(e_1 = 1, S = c) = (\gamma - k_1) - c > 0 = U_1(e_1 = 0, S = 0). \tag{13}$$

This leads to the (separating) equilibrium existence condition:

$$c < c_1 = \left(\gamma - k_1\right). \tag{14}$$

If a type 2 patient decides to deviate and pays c (which is the optimal strategy of the type 1 patients), physicians will believe that they are of the type 1 and makes the high effort: $E\left[e|S=c\right] = 1$. Their utility would be:

$$U_2(e, S=c) = \gamma e_2 - k_2\left(e_2\right)^2 - c \tag{15}$$

This patient has the choice between making an effort $e_2 = 0$ or $e_2 = 1$. Because $(\gamma - k_2) < 0$, the optimal effort level is $e_2 = 0$ leading to a utility $U_2(e_2 = 0, S = c) = -c$. However, $U_2(e_2 = 0, S =$

$c) < U_2(e_2 = 0, S = c) = 0$. Therefore, the type 2 patient has no incentive to deviate from the $S = 0$ strategy.

Given all the above, *the only condition required* to guarantee the existence of this separating equilibrium is (14), $c < (\gamma - k_1)$. The coefficient γ captures characteristics that explain a stronger positive effect on a patient utility, as associated to the two high effort levels. For instance, altruism is fostering the effort provided by the physician in their bilateral relationship with their patient, while the marginal cost β is containing this effort. The higher the benefit for the type 1 patient from providing the high effort in conjunction with a high effort by the physician, the wider the range for the fee c that ensures the existence of the separating equilibrium (patient 1 has a positive utility) is.

Summary. In this equilibrium, high adherence patients (type 1) will choose the balance billing strategy, and pay c. This allows the physician to identify their type, and consequently provide the highest effort in their relationship with these patients. Patients of type 1 also provide the high effort level, resulting in the highest level of patient-physician health care production. Instead, low adherence patients will choose the low effort level (normalized to zero). For these patients paying the fee c is not worthwhile. The physician observes this lack of payment, deems the patient provides a low effort level, and consequently decides that their own effort level (in the physician-patient relationship) will be low.

Certainly, from the perspective of the type 1 patients, a small but positive extra fee c is to be preferred to a larger fee, as the low fee would achieve the desired separation effect at the lowest cost for them. Physicians would instead prefer a higher fee, which would maximize their revenue.

3.2 Pooling equilibrium $S = 0$

The game also presents pooling equilibria in which no patient pays the extra fee.

If, for whatever reason, a physician always expect a patient to exert the zero effort level, then physicians will never exert a positive effort. Patients correctly anticipates this and will, consequently choose to exert no effort, confirming the physicians' beliefs. This zero-effort equilibrium exists for all parameter values. The proof of existence of this equilibrium is provided in Appendix

A.2.[11]

There is another pooling equilibrium where no patient resorts to balance billing to signal their type, albeit, in contrast to the above-mentioned equilibrium, type 1 patients do provide a positive effort. If no patient pays the extra fee, physicians consider that the likelihood that a patient is of a given type is equal to the frequency of that type in the overall population of patients. However, should one patient in the whole population deviate and decide to pay the extra fee c, in line with the insight provided by the separating equilibrium above (where only type 1 patients pay the fee), we assume that physicians will consider that the patient who deviates is type 1 (i.e., the patient with the high propensity to adhere to the treatment).[12] Therefore the physician's beliefs are:

$$\Pr[\text{type } 1|S] = \begin{cases} \mu \text{ if } S = 0 \\ 1 \text{ if } S = c \end{cases} . \tag{16}$$

Following the same resolution steps as before, we first determine the equilibrium optimal effort of each patient type. In contrast with the previous case, because now physician's expectations (Eq. 7) include the optimal effort of both types, this optimal effort of one type depends on the optimal effort of the other type.

Optimal efforts (second stage)

We study first the effort strategy of type 2 patients, assuming that the effort strategy of the type 1 patients is given.

(a) Let us first assume that type 1 patients make a high effort level, $e_1 = 1$. The utility of type 2 patients is then:

$$\begin{aligned} U_2(e_2, S &= 0|e_1 = 1) = \gamma e_2 E\left[e|S=0\right] - k_2\left(e_2\right)^2 \\ &= e_2\left[\gamma\mu + \gamma(1-\mu-k_2)e_2\right]. \end{aligned} \tag{17}$$

The utility of the type 2 patient, contingent on their effort is: $U_2(e_2, S = 0) = 0$ if $e_2 = 0$ and $U_2(e_2, S = 0) = 0$ if $e_2 = 1$. Because $k_2 > \gamma$, the optimal effort is $e_2 = 0$, leading to optimal

[11] Since only a type 1 patient would benefit from paying the extra fee, the Cho and Kreps (1987) refinement might eliminate this zero-effort pooling equilibrium.

[12] The opposite system of beliefs (probably less meaningful), where physicians assume that a patient who decides to pay the fee is of the non-adherent type, also entails a $S = 0$ pooling equilibrium, not very different from the equilibrium analyzed in this text. The proof of existence can be provided on request.

utility:

$$U_2(e_2, S = 0) = 0. \tag{18}$$

(b) Let us now assume that type 1 patients make an optimal effort $e_1 = 0$. The utility of type 2 patients becomes:

$$\begin{aligned} U_2(e_2, S &= 0|e_1 = 0) = \gamma e_2 E\left[e|S = 0\right] - k_2 \left(e_2\right)^2 \\ &= \gamma e_2 \left[(1-\mu)e_2\right] - k_2 \left(e_2\right)^2. \end{aligned} \tag{19}$$

Depending on whether the patient implements the high or low effort level, the utility is respectively: $U_2(e_2, S = 0) = 0$ if $e_2 = 0$ or $U_2(e_2, S = 0) = \gamma(1-\mu) - k_2$ if $e_2 = 1$. Because $k_2 > \gamma$, the optimal effort is $e_2 = 0$, leading to the equilibrium utility:

$$U_2(e_2 = 0, S = 0) = 0. \tag{20}$$

From (a) and (b), we infer that $e_2 = 0$ is the optimal effort strategy of type 2 patient in the $S = 0$ pooling equilibrium, irrespective of type 1 patients' effort level.

We study now the optimal effort of the type 1 patients. Their utility is:

$$\begin{aligned} U_1(e_1, S &= 0) = \gamma e_1 E\left[e|S = 0\right] - k_1 \left(e_1\right)^2 \\ &= \gamma e_1 \left[\mu e_1 + (1-\mu)e_2\right] - k_1 e_1. \end{aligned} \tag{21}$$

We have shown that $e_2 = 0$ is the optimal strategy for type 2 patients irrespective of e_1, therefore the type 1 patient's utility is:

$$U_1(e_1, S = 0) = \left(e_1\right)^2 \left(\mu\gamma - k_1\right). \tag{22}$$

Two cases can be distinguished depending on the value of the marginal cost of adherence k_1 relative to $\gamma\mu$.

(i). The "efficient" case: $k_1 < \mu\gamma$

According to condition (22), if $k_1 < \mu\gamma$ (compliant patients have a relatively high propensity to adhere to the treatment), then the optimal effort of the type 1 patient is $e_1 = 1$, leading to equilibrium utility

$$U_1(e_1 = 1, S = 0) = \left(\mu\gamma - k_1\right) \tag{23}$$

Payment strategy (first stage)

Given these optimal efforts, we can study the necessary conditions for $S = 0$ to be the (generalized) equilibrium strategy.

According to the system of beliefs (16), a patient who deviates from the $S = 0$ strategy and pays the extra fee c will be perceived by physicians as a type 1 patient, thus: $E[e|c] = e_1 = 1$. When would the type 1 deviate from $S = 0$ and pay c? The utility of such a patient is:

$$\begin{aligned} U_1(e_1, S &= c) = \gamma e_1 E[e|S=c] - k_1 (e_1)^2 - c \\ &= (e_1)^2 (\gamma - k_1) - c. \end{aligned} \tag{24}$$

Because $k_1 < \gamma$, the optimal effort level is $e_1 = 1$, leading to:

$$U_1(e_1 = 1, S = c) = (\gamma - k_1) - c. \tag{25}$$

Accordingly, a type 1 patient has no incentive to deviate from $S = 0$ if:

$$U_1(e_1 = 1, S = 0) > U_1(e_1 = 1, S = c) \tag{26}$$

$$(\gamma\mu - k_1) > (\gamma - k_1) - c \tag{27}$$

$$c > c_2 = \gamma(1 - \mu) \tag{28}$$

When would a type 2 patient deviate from $S = 0$ and pay c? The utility of such a patient is:

$$\begin{aligned} U_2(e_2, c) &= \gamma e_2 E[e|c] - k_2 (e_2)^2 - c \\ &= \gamma e_2 e_1 - k_2 (e_2)^2 - c. \end{aligned} \tag{29}$$

Because the equilibrium effort of a type 1 patient is $e_1 = 1$, and $\gamma < k_2$ the optimal "deviating effort" level is $e_2 = 0$, leading to the deviating utility:

$$U_2(e_2 = 0, S = c) = -c. \tag{30}$$

This utility is lower then the equilibrium utility of the type 2 patient (equal to zero); the latter has no reason to deviate from the $S = 0$ strategy.

Thus, for $k_1 < \gamma\mu$, the necessary condition for this "efficient" pooling equilibrium ($S = 0; e_1 = 1, e_2 = 0$) to exist is just condition (28).

In this equilibrium, no patient pays the extra fee c, yet each type is implementing the same effort, just as in the perfect information case (see: separating equilibrium above). However, physicians form imprecise expectations about the patient's type and implement an average effort level that penalizes type 1 patients when compared to the separating equilibrium situation.

(ii). The "inefficient" case: $\mu\gamma < k_1 < \gamma$

According to condition (22), if $\mu\gamma < k_1$, then the optimal effort of the type 1 patient is $e_1 = 0$. In this case, patients' equilibrium utility is $U_i(e_i = 0, S = 0) = 0$ irrespective of patient type.

What are the necessary conditions for $S = 0$ to be the equilibrium strategy in this particular case?

Payment strategy (first stage)

If a type 1 patient deviates from the equilibrium strategy and pays the extra fee c they will be clearly identified as a type 1 patient and physician's expectations are $E[e|c] = e_1$. The patient's utility is:

$$\begin{aligned} U_1(e_1, S &= c) = \gamma e_1 E[e|c] - k_1 (e_1)^2 - c \\ &= -k_1 (e_1)^2 - c. \end{aligned} \tag{31}$$

Their optimal effort when deviating from the no balance billing strategy is $e_1 = 0$, leading to utility $U_1(e_1 = 0, S = c) = -c$. They have no incentive to deviate from $S = 0$.

If the type 2 patient deviates and pays c, they will be identified as a type 1 patient and, because $E[e|c] = e_1 = 0$, their utility would be:

$$U_2(e_2, S = c) = -k_2 (e_2)^2 - c \tag{32}$$

The optimal effort of a type 2 patient who deviates and pays c is $e_2 = 0$. We can check that the deviating utility $U_2(e_2 = 0, S = c) = -c$ is lower than the equilibrium utility.

If compliant patients are not compliant enough ($\mu\gamma < k_1$), irrespective of c, there is an "inefficient" pooling equilibrium in which nobody pays the extra fee, and both agents implement the low effort level: $(S = S = 0; e_1 = 0; e_2 = 0)$. This equilibrium has the same characteristics as the zero effort equilibrium as defined at the beginning of this section.

3.3 Equilibria: regioning and welfare analysis

The game between physicians and patients presents two pure strategy equilibria: a separating equilibrium in which type 1 patients pay the extra fee and type 2 do not, and a pooling equilibrium in which no patient pays the extra fee. In the Appendix A.3, we show that the game also presents an unstable hybrid equilibrium in which no type 2 patients pay the extra fee, while the type 1 patients are indifferent about paying the extra fee (and therefore signalling themselves) or not.[13]

Table 1 summarizes the properties of the various pure strategy equilibria, and highlights the range of parameters k_1 and c in which they can exist. Figure 1 provides a graphical representation of the regions of existence of the equilibria.

Equilibrium	Condition on c	Additional condition	Optimal efforts
Separating	$c < (\gamma - k_1)$	–	$(e_1 = 1, e_2 = 0)$
Pooling $S = 0$ efficient	$c > c_2 = \gamma(1-\mu)$	$k_1 < \mu\gamma$	$(e_1 = 1, e_2 = 0)$
Pooling $S = 0$ inefficient	$c > 0$	$\mu\gamma < k_1 < \gamma$	$(e_1 = 0, e_2 = 0)$

Table 1: Pure Strategy Equilibria of the Patient-Physician Game

As we can see,

- For $k_1 < \mu\gamma$ and $c < \gamma(1-\mu)$, the separating equilibrium is unique.

- For $k_1 < \mu\gamma$ and $\gamma(1-\mu) < \gamma(1-\mu) < c$, the efficient pooling equilibrium is unique.

- For $k_1 < \mu\gamma$ and $\gamma(1-\mu) < c < (\gamma - k_1)$, the efficient pooling equilibrium and the separating equilibrium overlap.

- For $k_1 > \mu\gamma$ and $c < \gamma(1-\mu)$, the inefficient pooling equilibrium and the separating equilibrium overlap.

- For $k_1 > \mu\gamma$ and $c > \gamma(1-\mu)$, the inefficient pooling equilibrium is unique.

These equilibria have different welfare properties. We recall the ex-ante utilities of a patient (Equation 8) and of a physician (Equation 6):

$$U_i = \gamma e_i E[e_i|S] - k_i(e_i)^2 - S, \text{ with } i \in \{1,2\} \text{ and } S = \{0,c\} \quad (33)$$

$$V_j = \varphi f_j + (1-\varphi)\gamma \left[e_i E[e_i|S] - 0.5\,(E[e_i|S])^2\right] \quad (34)$$

[13] In Appendix A.4 we show that a hybrid equilibrium where all type 1 patients pay the fee and the type 2 patients are indifferent about paying it or not, does not exist.

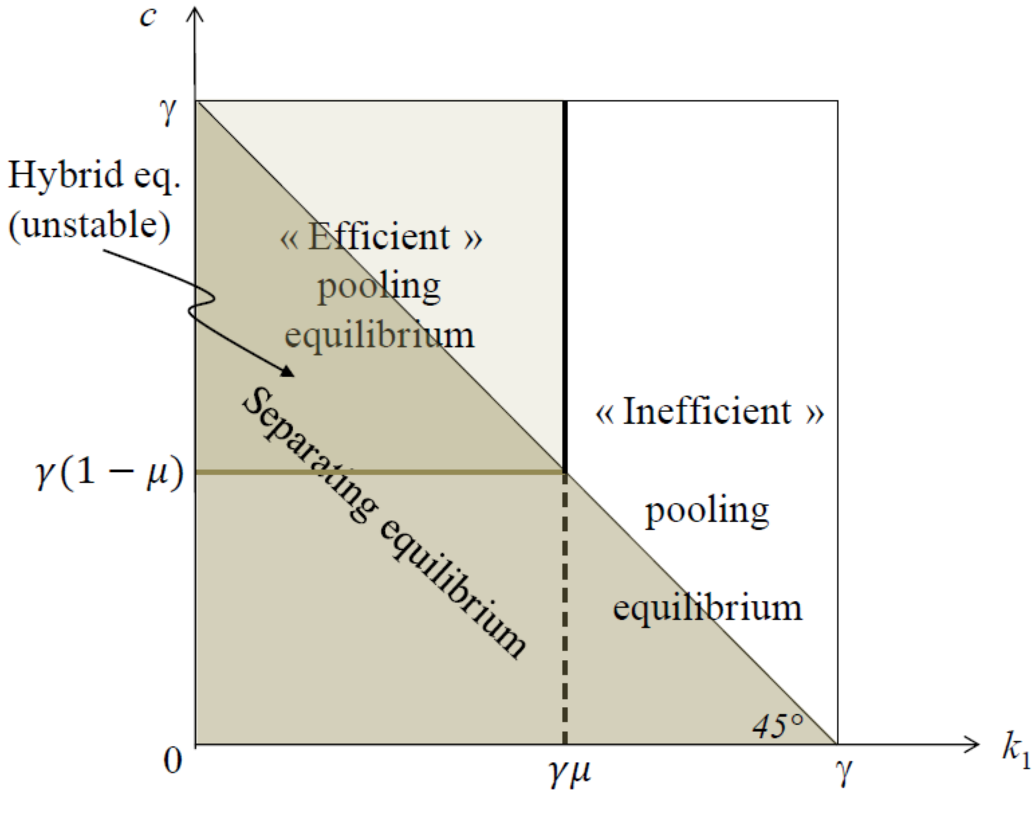

Figure 1: Regions of equilibria

To perform this analysis we make the additional assumption that physicians in sector 2 charge the extra fee c on top of the sector 1 fee and do not charge anything more. More precisely, if the fee in the regulated sector is p, then $f_1 = p$ and $f_2 = p + c$. This assumption probably underestimates the benefits of the physicians working in the sector 2, because the actual fee in sector 2 can exceed $p + c$ by an amount normally covered by private insurance schemes.

In the separating equilibrium, $E\left[e_i|S = c\right] = 1$ and $E\left[e_i|S = 0\right] = 0$. In the efficient pooling equilibrium, type 2 patients do not exert any effort while type 1 exert the high effort; physician's beliefs are $E[e|S = 0] = \mu$. A welfare analysis built on this assumption should be considered with extreme caution, given the simplified representation of the efforts. Because we normalized to zero the low effort level, the utility of type 2 patients is zero irrespective of the equilibrium. If the low effort level were positive, the utility of the type 2 patients would be higher in the pooling equilibrium, given that physicians exert a higher effort in the relationship with them compared to the separating equilibrium.

Table 2 presents the ex-post utility of one representative patient depending on their type and choice of sector, and the ex-post utility of a representative physician, depending on the sector where they carries out their practice, in the two positive effort equilibria.

Separating equilibrium $c < (\gamma - k_1)$	Pooling $S = 0$ efficient ($c > \gamma(1-\mu)$ and $k_1 < \mu\gamma$)
$U_1^{sep}(S = c; e_1 = 1) = \gamma - k_1 - c$	$U_1^{pool}(S = 0; e_1 = 1) = \gamma\mu - k_1$
$U_2^{sep}(S = 0; e_1 = 0) = 0$	$U_2^{pool}(S = 0; e_1 = 0) = 0$
$V_{Sector1}^{sep} = \varphi p$ $V_{Sector2}^{sep} = \varphi(p + c) + 0.5\gamma(1-\varphi)$	$V_{Sector1}^{pool} = \begin{cases} \varphi p + (1-\varphi)\gamma\left(\mu - 0.5\mu^2\right), \text{ if matched with type 1} \\ \varphi p - 0.5\gamma(1-\varphi)\mu^2, \text{ if matched with type 2} \end{cases}$

Table 2: Individual utility (patient) and profit (physician): Separating and pooling equilibrium

Depending on the parameters, either the separating equilibrium alone or several equilibria can exist.

A/ For a small fee $0 < c < \gamma(1-\mu)$ (and a low adherence cost $k_1 < \mu\gamma$), the separating equilibrium is unique. The utilities of a representative patient and representative physician are presented in the first column of Table 2. Obviously an increase in c is beneficial to physicians working in sector 2, but is detrimental to patients paying the extra fee. The highest collective utility (summing patients' utility and physicians' profits) is obtained for a small, positive c. We note that in absence of the signalling mechanism ($c = 0$), the zero-effort equilibrium should prevail.[14]

For a larger extra fee $\gamma(1-\mu) < c < (\gamma - k_1)$ (and a low adherence cost $k_1 < \mu\gamma$), the efficient pooling equilibrium and the separating equilibrium can both exist. Which one actually prevails depends on the evolution of the health care system and the beliefs of the agents over time.

In this high extra fee context, the utility of a type 1 patient is higher in the pooling equilibrium than in the separating equilibrium:

$$U_1^{pool}(S = 0; e_1 = 1) = \gamma\mu - k_1 \quad > \quad \gamma - k_1 - c = U_1^{sep}(S = c; e_1 = 1) \tag{35}$$

$$\Leftrightarrow \quad c > \gamma(1-\mu) \tag{36}$$

From comparison between $V_{Sector1}^{sep}$ and $V_{Sector1}^{pool}$ we note that a physician working for sector 1

[14] The efficient pooling equilibrium does not exist for $c \to 0$.

(regulated) is better off in the pooling equilibrium than in the separating equilibrium only if they are matched with a high effort patient (in the pooling case). Irrespective of c, an individual physician is better-off working for the sector 2 (in the separating equilibrium) than in sector 1 in the pooling equilibrium even if being matched with a high adherence patient. Indeed, we can check that $\varphi(p+c) + 0.5(1-\varphi)\gamma > \varphi p + (1-\varphi)\gamma\left(\mu - 0.5\mu^2\right), \forall c$. This might explain why physicians in sector 2 might be reluctant to push the extra fee above the threshold that ensures unicity of the separating equilibrium.[15]

To sum up, the separating equilibrium Pareto dominates the generalized zero-effort equilibrium; compared to the no-signal case, both the group of physicians and the group of patients are better-off if the balance billing system is implemented, although physicians would prefer a high fee and patients as small a fee as possible one. For a large extra fee, the game presents multiple equilibria: physicians are better off in the separating equilibrium, yet patients would be better off in the (efficient) pooling case. If physicians seek to rule out a zero profit pooling equilibrium, they would not call for sector 2 extra fees above $(\gamma - k_1)$.

4 An extension: not everyone can afford to pay c

In our analysis to this point, we have assumed that all patients can afford to pay the OOP medical expense. However, in real life a patient's wealth can be a constraint on their ability to pay an extra fee. This section extends the analysis of the separating equilibrium, which has the most appealing signalling properties, to address this additional source of heterogeneity. The most interesting case corresponds to a situation where a highly compliant patient (type 1) cannot afford to pay sector 2's extra fee (c). Accordingly, the group of patients in the regulated sector 1 include both the low adherence patients and what we refer to as the "poor" type 1 patients. On the other hand, "rich" type 1 patients can afford to pay c, and moreover, they want to pay this extra fee to signal their type to a physician.

Let us recall the former notations: there are μ type 1 patients (high adherence, $k_1 < \gamma$) and

[15] From a utilitarian perspective, we can sum physicians' individual profits and compare their collective utility between the separating and the pooling equilibrium. It turns out that, in the large extra fee case, the separating equilibrium generates a higher (collective) profit for the medical profession.

$(1-\mu)$ type 2 patients (low adherence, $k_2 > \gamma$). We further assume that a proportion σ of the type 1 patients cannot pay the OOP extra fee because of wealth constraints. The proportion of rich type 1 patients in the total patient population is $\mu(1-\sigma)$ and $\mu\sigma$ is the proportion of poor type 1 patients in the total population.

We analyze a special hybrid equilibrium in which rich type 1 patients always pay the fee c, while poor type 1 and type 2 patients never pay it.

Using Bayes' rule, the physician's beliefs are:

$$\Pr[\text{type } 1|S] = \begin{cases} 1 \text{ if } S = c \\ \dfrac{\sigma\mu}{\sigma\mu + (1-\mu)} \text{ if } S = 0 \end{cases} \tag{37}$$

Following the same steps as before, we first determine the (last stage) optimal efforts contingent upon the type of patient, then study the (first stage) optimal choice of sector (payment strategy).

Optimal efforts (second stage)

The optimal efforts of each type, and the effort expectations of the physician depend on the patient's chosen payment strategy. Let e_1^R be the equilibrium effort provided by the *rich* type 1 patient, and e_1^P the equilibrium effort provided by the *poor* type 1 patient. A physician's effort expectations can be written:

$$E[e|S=c] = e_1^R(S=c) \tag{38}$$

$$E[e|S=0] = \frac{\sigma\mu}{\sigma\mu + (1-\mu)} e_1^P(S=0) + \frac{(1-\mu)}{\sigma\mu + (1-\mu)} e_2(S=0) \tag{39}$$

A. We first study the optimal effort choice of type 2 patients.

Their utility can be written as:

$$U_2(e_2, S = 0) = \gamma e_2 E[e|S=0] - k_2 (e_2)^2 \tag{40}$$

$$= \gamma e_2 \left[\frac{\sigma\mu}{\sigma\mu + (1-\mu)} e_1^P(S=0) + \frac{(1-\mu)}{\sigma\mu + (1-\mu)} e_2(S=0) \right] - k_2 (e_2)^2 \tag{41}$$

Just as any patient, poor type 1 patients can choose as an effort level $e_1^P \in \{0; 1\}$.

(a) Let us first assume that type 1 patients make a high effort, $e_1^P = 1$. The utility of type 2 patients is:

$$U_2(e_2, S = 0|e_1^P = 1) = \gamma e_2 \left[\frac{\sigma\mu}{\sigma\mu + (1-\mu)} + \frac{(1-\mu)}{\sigma\mu + (1-\mu)} e_2 \right] - k_2 (e_2)^2 .$$

The utility of the type 2 agent – which is contingent on their own effort – is:

$$U_2(e_2, S = 0|e_1^P = 1) = \begin{cases} 0 & \text{if } e_2 = 0 \\ \gamma - k_2 < 0 & \text{if } e_2 = 1 \end{cases}. \tag{42}$$

Because $k_2 > \gamma$, their best choice is to have $e_2 = 0$.

(b) Let us assume that type 1 patients make the low effort, $e_1 = 0$. The utility of type 2 patients is:

$$\begin{aligned} U_2(e_2, S &= 0|e_1 = 1) = \gamma e_2 \left[\frac{(1-\mu)}{\sigma\mu + (1-\mu)} e_2\right] - k_2 (e_2)^2 \\ &= (e_2)^2 \left[\gamma \frac{(1-\mu)}{\sigma\mu + (1-\mu)} - k_2\right] \end{aligned} \tag{43}$$

Because $k_2 > \gamma$, $k_2 > \gamma \frac{(1-\mu)}{\sigma\mu + (1-\mu)}$, the best effort strategy is $e_2 = 0$.

We thus prove that, just as in the case of the separating equilibrium case, type 2 patients have a dominant zero effort strategy, $e_2 = 0$ (irrespective of choices of poor type 1 patients in terms of effort level), leading to equilibrium utility:

$$U_2(e_2 = 0, S = 0) = 0, \forall e_1 \in \{0, 1\}. \tag{44}$$

B/ The only feasible payment strategy of the poor type 1 patients is not to pay the extra fee c. To determine their optimal effort, we study their utility defined as:

$$U_P^1(e_1, S = 0|e_2) = \gamma e_1 \left[\frac{\sigma\mu}{\sigma\mu + (1-\mu)} e_1^P + \frac{(1-\mu)}{\sigma\mu + (1-\mu)} e_2\right] - k_1 (e_1)^2 \tag{45}$$

Because $e_2 = 0$, this expression boils down to:

$$U_P^1(e_1, S = 0| = 0) = \left(e_1^P\right)^2 \left[\gamma \frac{\sigma\mu}{\sigma\mu + (1-\mu)} - k_1\right] \tag{46}$$

The sign of $\left[\gamma \frac{\sigma\mu}{\sigma\mu + (1-\mu)} - k_1\right]$ depends on the proportion of poor patients in the total population of type 1 patients:

$$\gamma \frac{\sigma\mu}{\sigma\mu + (1-\mu\gamma)} \gtrless k_1 \Leftrightarrow \sigma \gtrless \sigma_0 = \frac{k_1}{\gamma - k_1} \frac{(1-\mu\gamma)}{\mu} \tag{47}$$

Therefore the optimal effort strategy of the poor type 1 patients is:

$$e_1^P = \begin{cases} 1, \text{ if } \sigma > \sigma_0 \\ 0, \text{ if } \sigma < \sigma_0 \end{cases}. \tag{48}$$

C/ Finally, we analyze the optimal effort strategy of the "rich" type 1 patients.

If they pay c, they are recognized as rich by the physician and their utility is:

$$U_1^R(e,c) = \gamma e_1^R E[e|c] - k_1 \left(e_1^R\right)^2 - c \tag{49}$$

$$= (\gamma - k_1)\left(e_1^R\right)^2 - c \tag{50}$$

Because $k_1 < \gamma$ the best effort strategy is (for the rich) $e_1^R = 1$, and the utility is:

$$U_1^R(e_1^R = 1, c) = (\gamma - k_1) - c. \tag{51}$$

If they do not pay c the physician believes that they are either type 2 or poor type 1. Their utility is:

$$U_1^R(e_1, S = 0|e_2) = \gamma e_1 \left[\frac{\sigma\mu}{\sigma\mu + (1-\mu)} e_1^P + \frac{(1-\mu)}{\sigma\mu + (1-\mu)} e_2\right] - k_1 (e_1)^2 \tag{52}$$

We know that the dominant strategy of the player 2 is zero effort, and the effort strategy of the poor type 1 depends on σ. Accordingly, the utility of the rich type 1 patient is:

$$U_1^R(e_1, S = 0|e_2 = 0; e_1^P) = e_1 e_1^P \left[\gamma \frac{\sigma\mu}{\sigma\mu + (1-\mu)}\right] - k_1 (e_1)^2 \tag{53}$$

If $\sigma < \sigma_0$, then $e_1^P = 0$, and the best effort is: $e_1^R = 0$, leading to:

$$U_1^R(e_1^R = 0, S = 0|e_2 = 0; e_1^P = 0) = 0. \tag{54}$$

If $\sigma > \sigma_0$, then $e_1^P = 1$, leading to:

$$U_1^R(e_1, S = 0|e_2 = 0; e_1^P = 1) = \gamma e_1 \frac{\sigma\mu}{\sigma\mu + (1-\mu)} - k_1 (e_1)^2 \tag{55}$$

Because for $\sigma > \sigma_0$ we have $\gamma \frac{\sigma\mu}{\sigma\mu + (1-\mu)} > k_1$, the optimal effort is $e_1^R = 1$, leading to:

$$U_1^R(e_1^R = 1, S = 0|e_2 = 0; e_1^P = 0) = \gamma \frac{\sigma\mu}{\sigma\mu + (1-\mu)} - k_1. \tag{56}$$

Payment strategy (first stage)

A/ If the proportion of poor type 1 patients is relatively small, $\sigma < \sigma_0$, then the "rich" type 1 makes the high effort and pays the extra fee c in sector 2 if:

$$U_1^R(e_1^R = 1, c) = (\gamma - k_1) - c > U_1^R(e_1^R = 0, S = 0|e_2 = 0; e_1^P = 0) = 0 \Leftrightarrow c < (\gamma - k_1) \tag{57}$$

This is exactly the same condition as condition (14) defining the former separating equilibrium. However, in this case the poor type 1 patients do not make the high effort.

B/ If the proportion of poor type 1 patients is relatively high, $\sigma > \sigma_0$, these patients cannot afford to pay c, but will deliver the high effort level. Rich type 1 patient pay the extra fee c as assumed for this equilibrium only if:

$$U_1^R(e_1^R = 1, S = c) > U_1^R(e_1^R = 1, S = 0 | e_2 = 0; e_1^P = 0) \quad (58)$$

$$(\gamma - k_1) - c > \gamma \frac{\sigma\mu}{\sigma\mu + (1-\mu)} - k_1 \quad (59)$$

$$c < \gamma \frac{(1-\mu)}{\sigma\mu + (1-\mu)} \quad (60)$$

This condition is stricter than the condition of existence of the elementary separating equilibrium, because $\sigma > \sigma_0 \Leftrightarrow \gamma \frac{\sigma\mu}{\sigma\mu + (1-\mu)} > k_1 \Leftrightarrow \gamma \frac{(1-\mu)}{\sigma\mu + (1-\mu)} < (\gamma - k_1)$.

Table 3 summarizes the conditions of existence of this special hybrid equilibrium.

		$\sigma < \sigma_0$ $c < (\gamma - k_1)$	$\sigma > \sigma_0 = \frac{k_1}{\gamma - k_1} \frac{(1-\mu\gamma)}{\mu}$ $c < \gamma \frac{(1-\mu)}{\sigma\mu + (1-\mu)}$
	Payment strategy	Optimal effort	Optimal effort
Type 2	$S = 0$	$e_2 = 0$	$e_2 = 0$
Poor type 1	$S = 0$ (imposed)	$e_1^P = 0$	$e_1^P = 1$
Rich type 1	$S = c$	$e_1^R = 1$	$e_1^R = 1$

Table 3: The Wealth-constrained Hybrid Equilibrium

Summary. Introducing the wealth constraint allowed us to improve the realism of the analysis. This more realistic setting corroborates the main finding of the simpler model: a small extra fee suffices to bring about the interesting separating equilibrium that allows the physician to identify the type of patient. In addition to the elementary model, we show that if the proportion of wealth constrained patients is low, they behave as type 2 patients. If the proportion of wealth constrained type 1 patients is large, they will implement the high effort level even if they cannot use the extra fee to signal themselves. For fees larger than the fees indicated in Table 3, the system switches to a pooling equilibrium in which the fee no longer allows to signal that the patient has a high adherence to the treatment.

5 Conclusion

The use of balance billing in healthcare is controversial. Some scholars argue that the system supports price discrimination between patients with different willingness to pay, and might provide for an efficient allocation of resources if both the sector's profit and patients' welfare are taken into account. On the other hand, other studies call attention on the fact that balance billing might deteriorate patients' overall welfare. In a more macroeconomic perspective, advocates of balance billing argue that the system would help increase physicians income and attract more talent to the profession without an additional burden on taxpayers. Critics argue that balance billing creates a dual market for medical services that excludes poorer patients from important healthcare services.

This paper contributes to the literature on balance billing by emphasizing the potential signalling properties of this mechanism, in a model that emphasizes differences in patient propensity to adhere to treatment. More specifically, by paying a supplementary fee (for a sector 2 physician), patients might signal to a physician their willingness to adhere to prescribed treatment. In the present analysis, we assumed that patient propensity to adhere to treatment is private information to them. Accordingly, patients must decide both on their billing strategy (which is observable to the physician) and their adherence effort strategy (unobservable). We built on a joint patient-physician healthcare production function to argue why physicians' own optimal level of effort in the patient-physician relationship depended on their beliefs about their patient's adherence to treatment. As a limitation, this paper does not provide an analysis of the supply side of the market; in other words, physicians' choice of sector of activity (regulated vs. unregulated) and the extra fee under the balance billing system are both exogenously given.

Our analysis of the various equilibria revealed that a mixed payment system (where some physicians charge regulated fees while others use balance billing), may signal patient propensity to adhere to treatment. We show that a small positive fee charged under the balance billing system is sufficient to achieve the separation of patient types: those with low propensity to adhere to treatment will choose the regulated, free-of-charge sector, while those with a high propensity to adhere will opt for the balance billing system. In this separating equilibrium, patients choose their optimal effort level, and physicians can identify both patient type and level of patient effort without error. In this situation, patients are better off than in the zero effort equilibrium that would prevail if the signalling mechanism were not available.

We were also able to analytically determine the critical fee above which a pooling equilibrium - where no patient pays the fee and where physicians no longer can identify patient type - can emerge. In this equilibrium, physicians are individually (and collectively) worse off than in the separating equilibrium, and so are those patients with a high propensity to adhere to treatment, since the physicians can no longer identify their patient type, and will make a lower effort level (i.e., they will invest less in the doctor-patient relationship).

To provide additional intuition about the model's predictions, we report on the results of a survey designed by the ESSEC Chair of Innovation and Health to elicit patient preferences for sector 1 and sector 2 specialist visits.[16] In line with the predictions of the model, the percentage of (self-reported) highly adherent patients was 63.52% in the group of respondents who declared to prefer sector 2 specialist consultation, a lager proportion than the 53.09% highly adherent patients in the group that reported to prefer the sector 1 (p-value$<$0.01). Notably, this pattern persists after controlling for income levels. Further empirical research could use census and field data to examine to what extent treatment adherence differs across sectors. This would enable researchers to test for the existence of a separating equilibrium in countries where balance billing is in place.

In our analysis, we assumed that patients have no OOP payments in the regulated sector. This might not be the case in real life. For instance, after 2005 in France, the National Health Insurance imposed a one-euro 'co-payment fee' for patients in the regulated sector, with the goal of setting an incentive for patients to avoid unnecessary consultations (i.e., to oppose moral hazard). Co-payments with a more complex structure are also applied in Belgium, which also has a mixed payment system. Because the co-payments are made by all patients - irrespective of the choice of sector - they have no consequence on the extra-fee thresholds defining equilibrium switches. However, compulsory out-of-pocket payments set a positive lower bound for the extra fee. A

[16] A computer assisted questionnaire was administered by the Paris-based survey institute *OpinionWay* on a representative sample of the French adult population (1050 persons) on January 4, 2021.

higher co-payment, as required by some experts, would only narrow the range of existence of the separating equilibrium.

In 2016, concerned about the continued increase in the fees which physicians in sector 2 could freely set, as well as the risk of excluding least wealthy patients from healthcare, French authorities imposed new rules on private supplementary insurers, capping their reimbursement in balance billing arrangements. In our model, if physicians cut their fees by the same amount, then this new measure would reach its goal without harming the signalling effect (as c is constant). However, if sector 2 physicians do not reduce their consultation fees by an identical amount, the reform could actually lead to higher out-of-pocket payments for patients for medical services (c), in turn increasing the probability that the medical system switches from the separating to the pooling equilibrium.

It is of course difficult to infer strong policy recommendations from our stylized model, and our conclusions should be evaluated with prudence. Nevertheless, our game theory framework allowed us to emphasize the signalling virtues of the balance billing mechanism in healthcare production. The approach we describe here may explain why sometimes small changes in policy related parameters can trigger sharp changes in expectations and behaviours.

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A Online Appendix

A.1 Appendix 1. Non-existence of the pooling equilibrium $S = c$

We prove the non-existence of an equilibrium in which all patients pay the fee c. Physicians' beliefs are:[17]

$$\Pr[\text{type } 1|\text{S}] = \begin{cases} \mu \text{ if } S = c \\ 0 \text{ if } S = 0 \end{cases} \tag{61}$$

Let us start by studying a patients' optimal effort. The utility of type 1 patient is:

$$\begin{aligned} U_1(e_1, S &= c) = \gamma e_1 E\left[e|S = c\right] - k_1\left(e_1\right)^2 - c \\ &= \gamma e_1\left[\mu e_1 + (1-\mu)e_2\right] - k_1\left(e_1\right)^2 - c. \end{aligned} \tag{A.62}$$

Assume first that the optimal effort of the type 2 patient is $e_2 = 1$. Compare the utility of type 1 for each of the two feasible levels: $U_1(e_1, S = c) = (\gamma - k_1) - c$ if $e_1 = 1$ and $U_1(e_1, S = c) = -c$ if $e_1 = 0$. When the type 2 patient chooses effort $e_2 = 1$, the optimal effort of a type 1 patient is also $e_1 = 1$.

[17] Note that with the alternative out-of-equilibrium beliefs, $\Pr[\text{type } 1|S = 0] = 1$, a type 1 patient would always find optimal to deviate. Because the strategy $S = 0$ would reveal his/her type, playing it allows not only to avoid the out-of-pocket payment c but also to benefit from the high physician effort.

Let us now assume that the optimal effort of the type 2 patient is $e_2 = 0$. The utility of the type 1 patient is then:

$$U_1(e_1, S = c) = (e_1)^2 (\mu\gamma - k_1) - c$$

Depending on the relative values of $\mu\gamma$ and k_1, the optimal effort of the type 1 can be either 0 or 1. If $k_1 < \mu\gamma$ (respectively $k_1 > \mu\gamma$) the optimal effort of type 1 patient is $e_1 = 1$ (respectively $e_1 = 0$).

Case 1. $k_1 < \mu\gamma$

In this case, the optimal effort strategy for type 1 patient is $e_1 = 1$ irrespective of e_2. Consider then the type 2 patient: their utility is:

$$\begin{aligned} U_2(e_2, S &= c) = \gamma e_2 E\left[e|S = c\right] - k_1 \left(e_2\right)^2 - c \\ &= \gamma e_2 \left[\mu + (1-\mu)e_2\right] - k_2 \left(e_2\right)^2 - c \end{aligned} \tag{A.63}$$

A type 2 patient has a utility level $U_2(e_2 = 1, S = c) = (\gamma - k_2) - c$ if they choose a high effort level ($e_2 = 1$), and utility $U^2(e_2 = 0, S = c) = -c$ if $e_2 = 0$. Because $k_2 > \gamma$, in the pooling 1 equilibrium, the optimal effort of type 2 patient is $e_2 = 0$ leading to utility:

$$U_2(e_2 = 0, S = c) = -c. \tag{64}$$

However, if a type 2 patient deviates and does not pay c, physicians acknowledge that they are a type 2. Their utility is:

$$U_2(e_2, S = 0) = (e_2)^2 (\gamma - k_2).$$

Because $(\gamma - k_2) < 0$, their optimal effort is $e_2 = 0$, leading to a "deviation" utility $U_2(e_2 = 0, S = 0) = 0$. Obviously, it is always optimal for type 2 to deviate:

$$U_2(e_2 = 0, S = c) = -c < 0 < U_2(e_2 = 0, S = 0) \tag{65}$$

This equilibrium is impossible in the case $k_1 < \mu\gamma$.

Case 2. $k_1 > \mu\gamma$

In this case, when a type 2 patient's effort is $e_2 = 0$ (resp. $e_2 = 1$), the optimal effort of a type 1 patient is also $e_1 = 0$ (resp. $e_2 = 1$).

(a) Let us assume that the optimal effort of a type 1 patient is $e_1 = 0$. If a type 2 patient agrees to pay c, their utility is $U_2(e_2, S = c)$:

$$U_2(e_2, S = c) = \gamma e_2 \left[(1-\mu)e_2\right] - k_2 \left(e_2\right)^2 - c = \left(e_2\right)^2 \left[\gamma(1-\mu) - k_2\right] - c$$

Because $[\gamma(1-\mu) - k_2] < 0$, the optimal effort for the type 2 patient is $e_2 = 0$ and it is therefore optimal for a type 1 patient to choose $e_1 = 0$.

In this case, $e_1 = e_2 = 0$ implies $E\left[e|S = c\right] = 0$ and, in equilibrium, both types of patients reach the same utility level, $U_i(e_i = 0, S = c) = -c$ for $i = 1$ or 2.

It is straightforward to see that, as for case 1 above, deviating from their initial strategy and refusing to pay c is the optimal strategy for a type 2 patient. Given the equilibrium beliefs, if a type 2 patient does not pay the supplementary fee, physicians acknowledge that they are type 2. The utility of a type 2 patient is :

$$U_2(e_2, S = c) = \gamma e_2 E\left[e|S = c\right] - k_1 \left(e_2\right)^2 = \left(e_2\right)^2 \left[\gamma - k_2\right]$$

Their optimal effort is $e_2 = 0$, leading to utility $U_2(e_2 = 0, S = 0) = 0$ which is higher than the equilibrium utility $U_2(e_2, S = c) = -c$. The equilibrium is therefore impossible.

(b) Let us assume now that the optimal effort of the type 1 patient is $e_1 = 1$, then a type 2 patient who pays c has the utility:

$$U_2(e_2, S = c) = \gamma e_2 \left[\mu + (1-\mu)e_2\right] - k_2 \left(e_2\right)^2 - c$$

According to their effort level, a type 2 patient obtains utility:

$$\begin{cases} U_2(e_2, S = c) = (\gamma - k_2) - c & \text{if } e_2 = 1 \\ U_2(e_2, S = c) = -c & \text{if } e_2 = 0 \end{cases} \tag{66}$$

The optimal effort is thus $e_2 = 0$ which also implies an optimal effort $e_1 = 0$ for a type 1 patient, which is inconsistent with the initial assumption. In this case, the equilibrium is impossible.

In both cases 1 and 2 the equilibrium beliefs are inconsistent with the generalized adoption of the balance billing system, the pooling $S = c$ equilibrium is impossible.

A.2 Appendix 2. Pooling $S = 0$ with predetermined zero effort

The model includes a special zero effort pooling equilibrium in which patients of both types choose the zero effort strategy irrespective of the payment strategy, and physicians, in response to their action, choose not to exert a positive effort either.

In this equilibrium, the patients' effort strategy is:

$$e_1(S) = e_2(S) = 0, \forall S \in \{0, c\}. \tag{67}$$

In the most general form, a physician's beliefs can be written as:

$$\Pr[type\_1|S] = \begin{cases} x \text{ if } S = 0 \\ \\ y \text{ if } S = c \end{cases}, \text{with } x \in [0,1] \text{ and } y \in [0,1]. \tag{68}$$

Because we assumed that optimal efforts are independent of the payment strategy, physicians should expect zero effort by the patient irrespective of S:

$$\begin{aligned} E\left[e|S=0\right] &= \Pr[type\_1|S=0]e_1(S=0) + \Pr[type\_2|S=0]e_2(S=0) = 0 && \text{(A.69)} \\ E\left[e|S=c\right] &= \Pr[type\_1|S=c]e_1(S=c) + \Pr[type\_2|S=c]e_2(S=c) = 0 && \text{(A.70)} \end{aligned}$$

Given that: $e_j = \frac{(1-\varphi)A}{2\beta} E\left[e|S\right] = 0$, the optimal effort of the physician j is also zero.

The utility of the type i patient (with $i \in \{1, 2\}$), is:

$$\begin{aligned} U_i(S) &= \gamma e_i E\left[e_i|S\right] - k_i(e_i)^2 - S && \text{(A.71)} \\ &= -k_i(e_i)^2 - S && \text{(A.72)} \end{aligned}$$

Obviously the optimal effort of a patient is $e_i = 0$, $\forall i \in \{1, 2\}$. At the equilibrium, the beliefs of the physician are consistent with the optimal effort strategies.

This equilibrium exists irrespective of the values of the parameters. Closer examination of this expression shows that a patient who anticipates that the physician will make a zero effort has no incentive to pay the extra fee S. Therefore, the zero effort equilibrium involves patients' pooling on the $S = 0$ payment strategy.

A.3 Appendix 3. Hybrid equilibrium A

We analyze the equilibrium in which no type 2 patient pays the extra fee c, while type 1 patients are indifferent between paying it or not.[18]

Let us denote by $(1-\nu)$ the proportion of patients 1 who pay the extra fee (v do *not* pay it). Physician's beliefs are:

$$\Pr[\text{type } 1|\text{S}] = \begin{cases} 1 \text{ if } S = c \\ \frac{\nu\mu}{\nu\mu+(1-\mu)} \text{ if } S = 0 \end{cases} \tag{73}$$

and:

$$E\left[e|S=c\right] = e_1 \tag{A.74}$$

$$E\left[e|S=0\right] = \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}e_1 + \frac{(1-\mu)}{\nu\mu+(1-\mu)}e_2\right] \tag{A.75}$$

Optimal effort (second stage)

Let us first consider the type 2 patient. In equilibrium, this patient does not pay ($S = 0$) and their utility is:

$$U_2(e_2, S = 0) = \gamma e_2 E\left[e|S=0\right] - k_2\left(e_2\right)^2 \tag{A.76}$$

$$= \gamma e_2\left[\frac{\nu\mu}{\nu\mu+(1-\mu)}e_1 + \frac{(1-\mu)}{\nu\mu+(1-\mu)}e_2\right] - k_2\left(e_2\right)^2. \tag{A.77}$$

If $e_1 = 0$, the type 2 patient utility is

$$U_2(e_2, S=0) = \left(e_2\right)^2\left(\gamma\left[\frac{(1-\mu)}{\nu\mu+(1-\mu)}\right] - k_2\right)$$

and, because $\gamma\frac{(1-\mu)}{\nu\mu+(1-\mu)} < \gamma < k_2$, the optimal effort is $e_2 = 0$.

If $e_1 = 1$, the type 2 patient's utility is:

$$U_2(e_2, S=0) = \gamma e_2\left[\frac{\nu\mu}{\nu\mu+(1-\mu)} + \frac{(1-\mu)}{\nu\mu+(1-\mu)}e_2\right] - k_2\left(e_2\right)^2$$

taking the values:

$$U_2(e_2, S=0) = \begin{cases} 0 & \text{if } e_2 = 0 \\ (\gamma - k_2) < 0 & \text{if } e_2 = 1 \end{cases} \tag{78}$$

In this case too, the optimal effort for a type 2 patient is $e_2 = 0$.

[18] We assume here that all type 1 patients can afford to pay the extra fee.

We conclude that, in this equilibrium, the type 2 patient must play the $e_2 = 0$ effort strategy. Their equilibrium utility is $U_2(e_2 = 0, S = 0) = 0$.

We turn now to analyzing the optimal choice of type 1 patients. In this mixed strategy situation, they must be indifferent about paying or not the extra fee c.

If they pays c, their type is revealed and their utility is $U_1(e_1, S = c) = (\gamma - k_1)(e_1)^2 - c$; the optimal effort level is $e_1 = 1$ leading to effective utility $U_1(e_1 = 1, S = c) = (\gamma - k_1) - c$.

If they do not pay ($S = 0$), their utility is (recall that $e_2 = 0$):

$$\begin{aligned} U_1(e_1, S &= 0) = \gamma e_1 E\left[e|S=0\right] - k_1 (e_1)^2 \\ &= (e_1)^2 \left(\gamma \left[\frac{\nu\mu}{\nu\mu + (1-\mu)}\right] - k_1\right) \end{aligned} \tag{A.79}$$

The optimal effort level is therefore:

$$e_1 = \begin{cases} 1 & \text{if } \left(\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] - k_1\right) > 0 \\ 0 & \text{if } \left(\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] - k_1\right) < 0 \end{cases} \tag{80}$$

The resulting utilities are:

$$\begin{cases} \left(\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] - k_1\right) > 0 \Leftrightarrow U_1(e_1 = 1, S = 0) = \left(\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] - k_1\right) \\ \left(\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] - k_1\right) < 0 \Leftrightarrow U_1(e_1 = 0, S = 0) = 0 \end{cases} \tag{81}$$

Payment strategy (first stage) (necessary existence condition):

- Case $\left(\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] - k_1\right) < 0$ or $\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] < k_1 < \gamma$.

In this case, $e_1 = 0$. The type 1 patient must be indifferent about paying or not. We have the utilities $U_1(e_1 = 0, S = 0) = 0$ and $U_1(e_1 = 1, S = c) = (\gamma - k_1) - c$. For $c = (\gamma - k_1)$, any value of $\nu \in [0, 1]$ is an equilibrium. This is a very specific (and probably not very interesting) situation.

- Case $\left(\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] - k_1\right) > 0$ ou $k_1 < \gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right]$.

In this case, the optimal effort is $e_1 = 1$ and the equilibrium utility is $U_1(e_1 = 1, S = 0) = \left(\gamma \left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right] - k_1\right) > 0$.

First, we note that type 2 patients have no incentive to deviate from their initial strategy. If a patient pays c and is seen as a type 1 patient doing the high effort 1, their utility is :

$$U_2(e_2, S = c) = \gamma e_2 - k_2 (e_2)^2 - c. \tag{82}$$

This utility is equal to $-c$ if $e_2 = 0$ and takes value $(\gamma - k_2 - c) < -c$ if $e_2 = 1$. The optimal effort is then $e_2 = 0$ and the utility $U_2(e_2 = 0, S = c) = -c < 0 = U_2(e_2 = 0, S = 0)$. Paying c is suboptimal.

Turning back to type 1 patients, as already mentioned, in this equilibrium they must be indifferent about paying or not the extra fee:

$$U_1(e_1 = 1, S = 0) = U_1(e_1 = 1, S = c) \tag{A.83}$$

$$\left(\gamma \left[\frac{\nu\mu}{\nu\mu + (1-\mu)}\right] - k_1\right) = (\gamma - k_1) - c \tag{A.84}$$

$$\gamma \left[\frac{\nu\mu}{\nu\mu + (1-\mu)}\right] = \gamma - c \tag{A.85}$$

This condition implicitly defines ν depending on the parameters:

$$\nu = \frac{(1-\mu)}{\mu}\frac{\gamma - c}{c}. \tag{86}$$

which is a monontonic decreasing function in c. We examine the conditions for which $\nu \in [0, 1]$.

$$\frac{(1-\mu)}{\mu}\frac{\gamma - c}{c} > 0 \Leftrightarrow c < \gamma \tag{A.87}$$

$$\frac{(1-\mu)}{\mu}\frac{\gamma - c}{c} < 1 \Leftrightarrow c > (1-\mu)\,\gamma \tag{A.88}$$

We also ensure that condition $k_1 < \gamma\left[\frac{\nu\mu}{\nu\mu+(1-\mu)}\right]$ is fulfilled. Indeed, from Eq. (83), the condition is equivalent to $k_1 < (\gamma - c) \Leftrightarrow c < (\gamma - k_1)$.

The equilibrium is feasible for an out-of-pocket extra fee c in the range $[(1-\mu)\,\gamma, \gamma]$ for $c < (\gamma - k_1)$ (see Figure 1 in the main text).

We remind that ν is the frequency of the patients who refuse to pay c, $(1-v)$ is the proportion who pay. Eq. (86) defines a decreasing relationship between ν and c, and, implicitly, an increasing relationship between c and the frequency of people who accept to pay the fee. This is specific to an unstable equilibrium.

A.4 Appendix 4. Non-existence of the hybrid equilibrium B

A hybrid equilibrium in which all of the type 1 patients pay c, while the type 2 patients are indifferent between paying or not, is impossible under our assumptions.

Let us denote the proportion of type 2 patients who decide to pay the extra fee by ρ. The physicians' beliefs are:

$$\Pr[\text{type } 1|\text{S}] = \begin{cases} 0 \text{ if } S = 0 \\ \\ \frac{\mu}{\mu+(1-\mu)\rho} \text{ if } S = c \end{cases} \tag{89}$$

Let us consider type 2 patients' behavior. A patient who plays $S = 0$ reveals their type. Their utility is:

$$U_2(e_2, S = 0) = \gamma e_2 E\left[e|S = 0\right] - k_2\left(e_2\right)^2 = \left(e_2\right)^2\left(\gamma - k_2\right)$$

Obviously the optimal effort is $e_2 = 0$ (recall that $k_2 > \gamma$), thus the utility is $U_2(e_2 = 0, S = 0) = 0$.

If a type 2 patient plays $S = c$, their utility is:

$$U_2(e_2, S \quad = \quad c) = \gamma e_2\left[\frac{\mu}{\mu + (1-\mu)\rho}e_1 + \frac{(1-\mu)\rho}{\mu + (1-\mu)\rho}e_2\right] - k_2\left(e_2\right)^2 - c \tag{A.90}$$

$$= \begin{cases} -c & \text{if } e_2 = 0 \\ \\ \gamma\left[\frac{\mu}{\mu+(1-\mu)\rho}e_1 + \frac{(1-\mu)\rho}{\mu+(1-\mu)\rho}\right] - k_2 - c & \text{if } e_2 = 1 \end{cases}. \tag{A.91}$$

Because $\gamma\left[\frac{\mu}{\mu+(1-\mu)\rho}e_1 + \frac{(1-\mu)\rho}{\mu+(1-\mu)\rho}\right] - k_2 < 0$ irrespective of e_1, the optimal strategy for type 2 patients is again $e_2 = 0$. However, in this hybrid equilibrium, type 2 must be indifferent about choosing between the two billing strategies. Because $e_2 = 0$ is optimal irrespective of e_1, $U_2(e_2 = 0, S = c) = -c$ while $U_2(e_2 = 0, S = 0) = 0$. The indifference condition cannot be fulfilled; the equilibrium is impossible.

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