

Should Physicians' Dual Practice Be Limited? An Incentive Approach*

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Abstract

We develop a principal-agent model to analyze how the behavior of a physician in the public sector is affected by his activities in the private sector. We show that the physician will have incentives to over-provide medical services when he uses his public activity as a way of increasing his prestige as a private doctor. The health authority only benefits from the physician's dual practice when it is interested in ensuring a very accurate treatment for the patient. Our analysis provides a theoretical framework in which some actual policies implemented to regulate physicians' dual practice can be addressed. In particular, we focus on the possibility that the health authority offers exclusive contracts to physicians and on the implications of limiting physicians' private earnings.

JEL classification: I11, I18, L51, H51.

Keywords: public-private health services, physician's incentives, moral hazard, exclusive contracts.

*I am very grateful to Carmen Herrero, Javier López-Cuñat and Nicolás Porteiro for their invaluable help and support. I also would like to thank Pedro Pita Barros, Tor Iversen, Izabela Jelovac, Inés Macho-Stadler, Pau Olivella, Lise Rochaix and the participants at the ASSET 2002 conference (Paphos), at the 3rd Health Economics Workshop (Marseille) and at the XXVII Simposio de Análisis Económico (Salamanca) for their helpful comments. Financial support from the Generalitat Valenciana Project GV01-371 and from Fundación Pedro Barrié de la Maza is gratefully acknowledged. The usual disclaimers apply.

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1 Introduction

It is quite common in countries where there are both public and private health care systems that many doctors work in both sectors at the same time. There are very few studies, however, that analyze the complex relationships that exist between the two sectors and, therefore, the conflicting interests that arise from the doctors' dual activity.

In this article we examine the specific implications that such dual activity has for public health authorities. Our main objective is to analyze the circumstances under which the health authorities benefit from the doctors' dual practice and those under which they lose. Our analysis thus provides a theoretical bench-mark for the evaluation of the optimality of some existing regulatory frameworks in the field. We will concentrate on two kinds of measures: First, the possibility of offering exclusive contracts (no private practice) to doctors who work in the public health sector. Under such contracts, the doctor agrees to forego his private practice in exchange for a mutually agreed amount of financial compensation. Secondly, the decision taken by some health authorities of limiting private earnings to public physicians.

The actual situation in some European mixed health care systems is as follows. In Spain, the Law of Professional Incompatibilities that governs the employment of civil servants (Law No. 53/1984), does not prohibit doctors from having private practices. The specific legislation for medical professionals, however, offers those who choose not to do so a fixed monthly bonus in addition to their basic salaries. In the UK, physicians who are employed in the public sector are allowed to operate in the private sector under their NHS contracts. NHS part-time consultants are not limited in their private practice, whereas for full-time consultants their private practice is limited to 10% of their NHS salary. Indeed, most private medical services are provided by physicians whose main commitment is to their NHS duties. A report by the Competition Commission (1994), estimated that 61% of NHS physicians in the UK have significant private work. In addition to this, and according to Yates (1995), a NHS specialist, on average, undertakes two operations a week in the private sector. In France, public hospitals employ both full-time and part-time physicians who can also accept private patients with the restriction that income from private fees is limited to no more than 30% of the physician's total income. Similar arrangements apply in the majority of the European countries which, although characterized as public health care systems, also allow private health care (Johnson, 1995; US Congress, 1995).

The conflicting interests that arise between the doctor's public and private practices can affect both services in many different dimensions. The standard approach in the principal-agent literature considers that while an agent's external tasks (i.e., private) might provide him with some extra revenue, they also reduce his level of effort in his contracted tasks. In the particular

case of doctors, however, we believe that there is another important dimension that has not been addressed by hardly any of the researches of the topic. There are many well-respected doctors whose service in public hospitals have won them the reputation of being “good doctors” and such prestige obviously has a positive influence on their private practice. Whilst they receive a fixed salary in the public service, regardless of the volume of patients they treat, in their private practice their income depends directly on the demand they receive from the patient population. A physician that is perceived by the population as a “good doctor”, therefore, will obviously increase his private revenue.¹

We formalize these ideas in a model with one patient, one specialist, and the health authority. The patient suffers from an illness whose severity is unclear and requires medical attention. In attending to the patient, the doctor is charged with two basic tasks: (a) to diagnose the ailment and its severity, and (b) to provide the required treatment. The doctor’s performance is affected by his condition of dual supplier in the following way: If he can cure the patient in a single treatment, it improves his “professional prestige”, which then reflects positively on his private practice and thus increases his private income.

The task of the health authority is to draw up the contract that minimizes the social costs. In this regard, there is a general consensus in the literature on the conviction that the doctor usually has access to privileged information compared with the insurers (see Gaynor, 1994). We therefore suppose that neither his diagnostic process nor the treatment he prescribes could be either verifiable or contractible. This general set-up with double moral hazard provides us an appropriate framework to study the role of the physician as dual supplier. Studying such a role disregarding any of these agency problems would lead to biased results due to the loss of important effects. The incentives included in the doctor’s contract will be therefore key factors in determining the sort of behavior he has with regard to his work.

It is within this framework of the doctor’s role as a dual supplier that we study the implications that such a situation has for the health authority. It allows us to verify whether it is to the health authority’s benefit to either avoid (by offering an exclusive contract to the physician) or limit the doctor’s private practice.

On characterizing the doctor’s behavior we find that his double role provides certain important strategic effects. On the one hand, his keen interest in curing the patient (and gaining prestige) leads him to over-provide services. In other words, he tends to prescribe stronger (and more expensive) treatments systematically, as a way of ensuring a higher level of successful treat-

¹Dranove (1988) studies the role of the reputation as a way of restricting the physicians’ incentives to perform demand inducement.

ments. He is therefore more likely to divert from the treatment recommended for the diagnosis that was done. This perverse incentive, however, has its positive aspect. If the health authority manages (through the contract) to force the doctor to apply the treatment indicated by the diagnosis, this interest shown in curing the patient generates a beneficial effect. The doctor will have an incentive to carry out a very precise diagnosis, thus avoiding, or at least minimizing, the chances of his providing a wrong treatment. In such a case, the doctor's dual practice can, indeed, be positive for the health authority.

We prove that the overall impact of the doctor's dual practice on the health authority's costs, depends basically on the treatment strategy that the health authority decides to follow. If it chooses a plan in which cost-savings prevail over the health losses of the patients, the doctor's dual activity will be negative, causing an increase in the social costs.

On the other hand, if the health authority decides to follow the strategy of sticking to the treatment that the diagnosis suggests, and if the cost associated with a wrong diagnosis is high enough, the effect of the doctor's private practice is positive for the health authority. In such a case, the extra payment that the health authority has to make to induce the doctor to follow the strategy is compensated by the doctor's interest in sticking to a very precise diagnosis.

We apply the analysis to the study of some actual regulatory policies regarding physicians' dual practice. First, we show that even in cases where the doctor's dual practice is socially detrimental, it is still not optimal for the government to offer him an exclusive contract. The reason for this is that, in designing the incentive contract, the health authority partially mitigates the increase in costs. The saving made from the doctor's exclusive contract is never enough to compensate what has to be paid to him for his losses from not having a private practice.

This result varies if we consider payment structures that are more similar to the ones currently used by several health authorities to contract specialists. Their systems of remuneration are not usually based on incentives, but rather, on the payment of a flat salary. When we repeat our analysis considering this form of payment, we observe situations in which it is better for the health authority to offer an exclusive contract to ensure that the doctor does not have a private practice. Such results may well explain the very existence of exclusive contracts, which must be considered a "second best" choice.

Secondly, for the case of a regulation based on limiting the physician's private earnings, we find that this measure can be useful to mitigate the physician's tendency to over-provide services. However, we also show that in those cases in which the health authority is highly concerned about the accuracy of the diagnosis the physician performs, this kind of regulation can be socially detrimental.

The literature has analyzed the physician's response to the form of contract quite extensively. Ellis and McGuire (1986, 1990), Selden (1990) and Blomqvist (1991), like ourselves, have studied how the different refund rules can lead the doctor to either over-provide or under-provide services. Ma (1994) emphasizes the interaction of cost and quality incentives under prospective payment and cost reimbursement systems. In all their analyses, however, none of them has considered the possibility that the doctor might be supplying to two different sectors simultaneously.

The possibility of over-treating a patient, in the sense of providing him with an excessively aggressive treatment appears in Gal-Or (1999), although in a framework completely different from ours. In her model, the physicians have incentives to practice "defensive medicine" in order to avoid paying malpractice costs, as a more aggressive treatment increases the probability of healing the patient.

The sequential modelling of the doctor's decisions (since diagnosis precedes treatment), follows Jelovac (2001) and García-Mariñoso and Jelovac (2002). In these studies, optimal contracts are designed respectively for a specialist and a GP in a context with double moral hazard. In these papers, however, the doctor's behavior is not affected by his external activities, as occurs in ours.

An interest has recently arisen, in the literature, in analyzing the implications of the doctor's dual activity. Rickman and McGuire (1999) study the system of optimal refund in the public sector for a doctor who also works in the private sector. Contrary to our analysis, theirs is not carried out in a principal-agent framework and furthermore, they concentrate on the implications of the fact that the doctor can offer both public and private services to the same patient. A companion paper, González (2002), studies the consequences of carrying out a policy of transferring patients from the public to the private sector. In this paper it is shown that if the doctors are dual providers, only the less serious patients will be transferred, generating an increase in the cost of implementing the policy.

This article is also related to the analysis of Holmstrom and Milgrom (1991), on the optimality of limiting access to external activities for the employees of a company. Although our model is quite different from theirs, it shares a common characteristic. In both, what determines whether these "outside activities" should be allowed, are not their intrinsic characteristics, but rather their impact on the agent's incentives in their "inside activities".

The rest of the paper is organized as follows: In the following section, we present the model. Section 3 analyzes the physician's behavior. In Section 4 we derive the health authority's optimal contract. Section 5 studies some alternative regulatory frameworks currently used to deal with physicians' dual practice. Finally, in Section 6, we present our conclusions.

2 The Model

There are three agents in this economy: a patient, a physician and the regulator or health authority.

The patient suffers from a specific type of illness. The severity of the illness is measured by a random variable s . We assume that s can only take two values: \underline{s} and \bar{s} , which indicate whether the patient suffers from either a low or a high severity of the illness. For the sake of simplicity, we assume that both types of illnesses are equally likely. The patient is perfectly aware that he is ill but does not know just how serious his illness is. He therefore seeks health care from the medical provider. The patient's utility is defined in terms of his expected health loss.

In our model, the patient can be given two different types of treatment: a "mild treatment" (\underline{T}), which can only cure a patient suffering from a low severity, or a "strong treatment" (\bar{T}), which can cure both levels of severity. The strong treatment, however, causes a health loss L in the patient when he is suffering from a low level of severity. This health loss can be interpreted as the result of an over-treatment.

The physician is supposed to provide the appropriate treatment to cure the patient. To do so, he exerts a level of effort $e \in [0, 1]$, in performing the diagnosis, which yields a signal (s^e) about the severity of the patient's condition. The accuracy of this signal depends positively on the level of effort exerted by the doctor in carrying out the diagnosis. We consider a probability of receiving a correct signal defined by the following function:

$$\Pr(s^e = \bar{s}|\bar{s}) = \Pr(s^e = \underline{s}|\underline{s}) = \frac{1+e}{2}.$$

In exerting the lowest level of effort ($e = 0$), the physician does not obtain any further information about the severity of the patient's condition except the common knowledge that either severity is possible with a probability of one-half. By exerting a greater effort, the physician would get a more accurate diagnosis of the severity of the patient. When $e = 1$, the signal is perfectly accurate.

In performing the diagnosis, the physician incurs in some disutility due to the effort he exerts. We denote it by $V(e) = k\frac{e^2}{2}$, where $k > 0$ is a measure of how the physician's marginal cost increases with his level of effort. This effort in diagnosing is not contractible and, as such, he will not be directly reimbursed for it.

Using the information he receives from the diagnosis, the physician decides on which treatment he will provide to the patient: either the mild treatment or the strong one. If the patient recovers his health with the first treatment prescribed the game ends. Otherwise, the patient receives a new round of treatment. Since we have restricted the analysis to a two-severity illness,

the patient is eventually cured after the second treatment. We measure the health loss borne by the patient from receiving a delayed cure for his illness by l .

To summarize, the patient only suffers from a health loss if the appropriate treatment is not provided to him: he either loses L if he is over-treated, or l if he is treated twice.

As already mentioned in the Introduction, we are interested in analyzing the implications for the public authority of allowing the physician to offer his services as a private provider. From all the possible dimensions that can be affected by the physician's dual practice we concentrate on a specific one: the physician uses his public performance as a way of improving his prestige as a medical provider. We model this by introducing a parameter $\mu > 0$ that measures the impact of the physician's activity in the public sector on his private revenue. We assume that the prestige of the physician increases (and hence he receives extra earnings of value μ) when he cures the patient with just one treatment in his activity in the public sector.² Therefore, μ does not reflect the physician's real private income, but rather, it is a proxy for how such revenue is affected by his activities within the public sector.³

The third agent involved in the model is the health authority. It pays the cost of the treatment provided to the patient, and the payments made to the physician. Concerning the costs of treatment, \bar{c} denotes the cost of the strong treatment, while \underline{c} is the cost of the mild one. We assume that $\bar{c} > \underline{c}$.

The health authority designs the physician's payment contract, which consists of three non-negative components: $(\bar{w}, \underline{w}, B)$. \bar{w} is the amount of money that the physician receives if the strong treatment is provided and \underline{w} if he recommends the mild treatment. Furthermore, in the latter case, we consider that the physician receives a bonus B if the patient is cured with just one round of treatment and no further payment if a second round of treatment is needed. This bonus can be interpreted as a premium for cost-containment, since the mild treatment is cheaper than the strong one.⁴ Moreover, as will be shown later on, B will be an important instrument for offering incentives to the physician.

²An alternative construction would be to consider losses in reputation when two treatments are required for the patient to recover from his illness.

³With this formulation we try to capture, in a stylized manner, the relationship between the physician's public and private activities. This will allow us to focus on the physician's public performance under double moral hazard, without explicitly modelling the private sector. We refer the reader to the Concluding Remarks for a more general discussion on this issue.

⁴This structure with no payment to the physician in a second round of treatment has been chosen for the sake of expositional clarity. However, it can be easily shown that this construction is equivalent to one with a positive payment if the patient requires a second treatment, provided the bonus for cost-containment strictly exceeds the second visit payment.

The health authority designs the contract in such a way that the expected social costs are minimized. Such costs, denoted by C , are the sum of the financial costs (i.e., expected treatment costs and payoffs to the physician) and the patient's disutility (which is measured by his expected health loss).

The timing of the game consists of the following stages. First, the health authority fixes the physician's payment contract, which he can either accept or reject (in which case the game ends). Secondly, the severity of the patient's illness is realized. He seeks health care from the physician, who exerts some level of effort while doing the diagnosis. This provides him with a signal about the patient's severity. Third, after observing the signal, the physician decides on a treatment. If the patient does not recover after the first treatment, the physician provides a new treatment. Once the patient has recovered his health, the game ends.

3 The Physician's Behavior

3.1 The Physician's Treatment Choice

In our model, the doctor faces a population of patients that can suffer from either a high severity or a low severity illness, with the same probability. Once the doctor has carried out his effort in the diagnosis, the information that he obtains will allow him to improve his prognosis on the patient's true situation.

The probability of having correctly diagnosed that the severity of the illness is high is as follows:⁵

$$\Pr(\bar{s}|s^e = \bar{s}) = \frac{\Pr(\bar{s}) \Pr(s^e = \bar{s}|\bar{s})}{\Pr(\bar{s}) \Pr(s^e = \bar{s}|\bar{s}) + \Pr(\underline{s}) \Pr(s^e = \bar{s}|\underline{s})} = \frac{1+e}{2}.$$

Similarly, the probability of having correctly diagnosed that the severity of the illness is low is given by:

$$\Pr(\underline{s}|s^e = \underline{s}) = \frac{1+e}{2}.$$

Hence:

$$\Pr(\underline{s}|s^e = \bar{s}) = \Pr(\bar{s}|s^e = \underline{s}) = \frac{1-e}{2}.$$

Once the physician has diagnosed the true severity of the condition, he then decides on the treatment that the patient should receive. Regardless of the severity of the illness, however, the doctor always has the choice between the two alternative treatments: the strong treatment or the mild one.

⁵Note that since $\Pr(\bar{s}) = \Pr(\underline{s})$, then $\Pr(\bar{s}|s^e = \bar{s}) = \Pr(s^e = \bar{s}|\bar{s})$.

When $s^e = \underline{s}$, if the doctor prescribes the mild treatment he receives a remuneration \underline{w} . Moreover, if the patient's condition is really mild (with a probability of $\Pr(\underline{s}|s^e = \underline{s})$), the physician also obtains B and, since the patient is cured with just one treatment, this has a positive impact on the doctor's private practice benefits, measured by μ . If, on the other hand, the patient's condition is severe (with $\Pr(\bar{s}|s^e = \underline{s})$) the physician obtains only \underline{w} . Finally, if he decides to prescribe the strong treatment, he earns \bar{w} and, furthermore, as the patient is cured, independently of the real severity of his condition, the doctor also receives μ .

Likewise, when $s^e = \bar{s}$, the doctor receives $\bar{w} + \mu$ if he prescribes treatment \bar{T} . If he prescribes treatment \underline{T} , his remuneration is \underline{w} if the diagnosis is correct. If the diagnosis is wrong (which occurs with a probability of $\Pr(\underline{s}|s^e = \bar{s})$) the doctor earns $\underline{w} + B + \mu$.

In comparing the different payments that the doctor receives from prescribing either of the two treatments, we can conclude that:

If $s^e = \underline{s}$, the doctor will prescribe \underline{T} whenever $e \geq \tilde{e} = \frac{2(\bar{w}-\underline{w})+\mu-B}{B+\mu}$ and \bar{T} otherwise.

If $s^e = \bar{s}$, the doctor prescribes \bar{T} whenever $e \geq \hat{e} = \frac{B-\mu-2(\bar{w}-\underline{w})}{B+\mu}$ and \underline{T} otherwise.

Keeping in mind that the doctor's level of effort is bounded, since $e \in [0, 1]$, we can summarize the doctor's decision on the type of treatment to be provided in the following lemma:

Lemma 1 *The treatment that the doctor prescribes is as follows:*

- If $2(\bar{w} - \underline{w}) + \mu - B \geq 0$:
 - If $B < \bar{w} - \underline{w}$, the doctor always prescribes \bar{T} , regardless of the signal of the severity of the condition.
 - If $B \geq \bar{w} - \underline{w}$, when $e \geq \tilde{e}$ the doctor prescribes the most appropriate treatment for the severity diagnosed. For $e \in [0, \tilde{e})$ the doctor always prescribes \bar{T} regardless of the signal.
- If $B - \mu - 2(\bar{w} - \underline{w}) \geq 0$:
 - If $\mu < \underline{w} - \bar{w}$, the doctor always prescribes \underline{T} , regardless of the signal of the severity of the condition.
 - If $\mu \geq \underline{w} - \bar{w}$, when $e \geq \hat{e}$ the doctor prescribes the most appropriate treatment for the severity diagnosed. For $e \in [0, \hat{e})$ the doctor always prescribes \underline{T} , regardless of the signal.

If the remuneration plan contracted with the physician is of the first type, he simply decides on either the strong treatment or the most appropriate one (since $\hat{e} < 0$). Moreover, the bonus

he receives would have to surpass a certain threshold for him to be encouraged to prescribe the most appropriate treatment. In contrast, when the doctor is employed under the other type of contract, it is generally the strong treatment that is dominated by one of the other two. With either type of contract, the effort that the doctor makes in the previous stage (i.e., the diagnosis), has to exceed a certain threshold for him to decide to prescribe the most appropriate treatment for the conditions revealed in the diagnosis. When his level of effort is low, the doctor will always prescribe a treatment that is independent of the one the diagnosis recommends but which depends, rather, on the sort of payment structure agreed to in his contract.

The repercussions that the doctor's behavior within the public health service has on his private practice, reflected by μ , affects his decision on what treatment to prescribe.

Remark 1 *The fact that the doctor also works in the private sector means that, in his contracted public health duties, he will always be more inclined to prescribe the strong treatment and less inclined to prescribe the mild one, regardless of the results of the diagnosis.*

It is quite easy to see that \tilde{e} is increasing in μ while \hat{e} is decreasing. In other words, the fact that the doctor's behavior in the public service affects his private income makes him more likely to be in the region where he always decides to prescribe the strong treatment, and less likely to be in the region where he decides to prescribe the mild one. The doctor with a private practice is interested in curing the patient with just one treatment, so that his reputation as "a good doctor" will benefit his private practice. This encourages him to prescribe the strong treatment. This gives us the first insight into the strategic effects of the physician's work in both sectors: it may encourage a tendency to over-provide services in the public health sector.

In our model, the doctor does not receive the signal of the patient's severity until Stage 3 of the game. Before exerting his effort in the diagnosis, therefore, the doctor anticipates the strategies that he will be able to follow once the signal has been received. In particular, the physician can follow any of the following strategies: (1) Prescribe the most appropriate treatment for the signal received; (2) Always prescribe the strong treatment; (3) Always prescribe the mild treatment.⁶

These three possible strategies do not only determine the doctor's expected utility (U) (and the effort he will exert in the diagnosis), but also the expected social costs (C).

The structure of the doctor's expected utility and of the health authority's expected costs, under each of the possible strategies are detailed in the Appendix 1.

⁶In fact, there is a fourth strategy the physician can follow: to prescribe the most inappropriate treatment for the signal received. However, this strategy is always dominated by one of the others, for any level of effort exerted.

The expected costs for the health authority are: \bar{C} if the doctor adopts the strong-treatment strategy, \underline{C} if he chooses the mild-treatment strategy, and C_* if he employs the most-appropriate-treatment strategy.

Likewise, the doctor's utility is: \bar{U} if he adopts the strong-treatment strategy, \underline{U} if he chooses the mild-treatment strategy, and U_* if he employs the most-appropriate-treatment strategy.

3.2 The Physician's Diagnosis Decision

In this subsection, we analyze the doctor's decision on the level of effort he exerts in the diagnosis, for each of the possible treatment strategies he adopts.

If he decides to adopt the most-appropriate-treatment strategy, he will choose the level of effort that maximizes U_* . Furthermore, this level of effort will necessarily overcome the thresholds defined in Lemma 1, for the strategy to be finally adopted.

We define:

$$\varepsilon \equiv \max \{\tilde{e}, \hat{e}\} = \frac{|2(\bar{w} - \underline{w}) + \mu - B|}{B + \mu}.$$

Only for those levels of effort in the diagnosis in which $e \geq \varepsilon$ it could be optimal for the doctor to adopt the strategy of providing the most appropriate treatment for the signal he receives.

The problem the doctor faces is as follows:

$$\begin{aligned} \max_e U_* &= \frac{1}{2} [\underline{w} + \bar{w} + \mu + \frac{1+e}{2}(B + \mu)] - k\frac{e^2}{2} \\ s.t \quad & e \in [\varepsilon, 1]. \end{aligned}$$

The solution to the problem is given by $e_* = \min \left\{ \max \left\{ \frac{B+\mu}{4k}, \varepsilon \right\}, 1 \right\}$.

When the doctor decides to adopt either of the other two treatment strategies, i.e., when he always provides the same treatment, independently of the signal received, (either \bar{T} or \underline{T}), the optimal level of effort in the diagnosis is the minimum. A positive level of effort does not have any effect on his payments (these are independent of the signal received and, therefore, of e) and only generates greater costs for him.

The following lemma summarizes all these possibilities.

Lemma 2 *The physician's optimal effort for each of the treatment strategies that he can adopt is as follows:*

- *If the doctor adopts the strong-treatment strategy, then $\bar{e} = 0$ and his expected utility is given by: $\bar{U} = \bar{w} + \mu$.*

- If the doctor adopts the mild-treatment strategy, then $\underline{e} = 0$ and his expected utility is given by: $\underline{U} = \underline{w} + \frac{1}{2}(\mu + B)$.
- If the doctor adopts the most-appropriate-treatment strategy to the signal, then $e_* = \min \left\{ \max \left\{ \frac{B+\mu}{4k}, \varepsilon \right\}, 1 \right\}$ and his expected utility is given by:

$$U_* = \frac{1}{2} \left[\underline{w} + \bar{w} + \mu + \frac{1+e_*}{2}(B+\mu) \right] - k \frac{e_*^2}{2}.$$

Once the doctor's expected utility has been computed under each strategy, we obtain a series of restrictions that determine when the doctor decides to adopt each of the possible treatment strategies. These restrictions are the ones that the health authority will include later on in his optimization program as incentive constraints. The doctor's decision is summarized in the following lemma.

Lemma 3 *The doctor's behavior concerning the strategy he will adopt is as follows:*

- To adopt the strong-treatment strategy is preferred by the doctor if:

$$e_* \left(\frac{B+\mu}{2} - ke_* \right) \leq \bar{w} - \underline{w} + \frac{\mu - B}{2}. \quad (\overline{IC})$$

- To adopt the mild-treatment strategy is preferred by the doctor if:

$$e_* \left(\frac{B+\mu}{2} - ke_* \right) \leq \underline{w} - \bar{w} + \frac{B - \mu}{2}. \quad (\underline{IC})$$

- To adopt the most-appropriate-treatment strategy to the signal is preferred by the doctor if:

$$e_* \left(\frac{B+\mu}{2} - ke_* \right) \geq \left| \bar{w} - \underline{w} + \frac{\mu - B}{2} \right|. \quad (IC_*)$$

With $e_* = \min \left\{ \frac{B+\mu}{4k}, 1 \right\}$.

The first result that is extracted from this lemma is that the only relevant region of effort is the one with $e > \varepsilon$. When $e = \varepsilon$, the doctor is ex-post indifferent to either adopting the optimal treatment strategy or one of the other two that are independent of the signal (see Lemma 1). Therefore, ex-ante, when the doctor includes the cost of his effort in the diagnosis in his decision, the most-appropriate-treatment strategy is trivially dominated by one of the other two.

When the effort under the optimal strategy is interior, its level is increasing in B and does not depend neither on \bar{w} nor on \underline{w} . This occurs because B is the only payment that is contingent

on healing the patient. In fact, it is a bonus for having diagnosed a low severity correctly, and the accuracy of the diagnosis increases with the effort exerted. Likewise, the effort also increases with μ , since the probability that the patient needs a second treatment (and the doctor does not gain any prestige) is smaller the more accurate the diagnosis is. Finally, k affects the decision on the level of effort negatively.

From the restrictions, it is easy to see that a higher \bar{w} induces the doctor to prescribe the strong treatment systematically, while a greater \underline{w} induces him to always provide the mild one. The effect of the bonus on the doctor's behavior is not so clear. For example, with a high value of B the doctor prefers the strategy of treatment contingent on the signal to giving the strong treatment always. However, if B is sufficiently high, it can result in the doctor's deciding to provide the mild treatment systematically.

The presence of μ has important implications in the choice of the strategy, which we summarize in the following remark.

Remark 2 *The fact that the doctor also works in the private sector implies that, in his public activity:*

- *He has fewer incentives to choose the mild-treatment strategy.*
- *If $e_* = \frac{B+\mu}{4k}$, he has a greater incentive to choose the strong-treatment strategy.*

This remark confirms the prediction made at the end of Subsection 3.1, that the doctor's quest for a good reputation discourages the under-provision of services in the public sector. Also, whenever the diagnosis process is not perfect ($e_* = \frac{B+\mu}{4k} < 1$) the doctor will have a higher tendency to over-provide services. If the diagnosis is perfect ($e_* = 1$), the decision to adopt either the most-appropriate-treatment strategy or the strong strategy is independent from μ , since with either the patient is always treated with just one treatment.

From the perspective of the health authority, the fact that the public and the private sectors are related through μ , has opposite effects. In particular, if the health authority wants to induce the doctor to adopt the most-appropriate-treatment strategy, the effect of μ over IC_* is ambiguous. On the one hand, it is less expensive to prevent the doctor from opting for the mild strategy but, on the other hand, the strong strategy becomes more attractive to him. To all this we must add that the effort the physician exerts, once he has opted for the most-appropriate-treatment strategy, is increasing in μ . Therefore, the possible rise in the government's costs to induce a positive effort in diagnosis, can be compensated by the fact that the level of effort finally exerted by the doctor, and thus, the accuracy of the diagnosis, is greater.

4 Contract Design

This section studies the optimal contracts that induce the physician to adopt each of the different treatment strategies presented in Section 3. From the perspective of the health authority, we put special emphasis on studying the repercussions that the doctor's strategic behavior as a result of his dual activity has on the design of the contract and on his treatment strategy choice.

We do the analysis within a framework with limited liability constraints for the doctor. That is to say, we impose that, under any circumstance, the doctor must receive a certain minimum payment. We denote this value by $M > 0$. Such a restriction, which is quite common in moral hazard models, reflects the existent limitations on the public liabilities that can be imposed on a doctor in the execution of his professional duties. Such limitations arise from the fact that the result of any medical treatment is, to a certain extent, unpredictable.⁷

We study two different scenarios. In the first one, we suppose that there is no agency problem and that the health authority can control the doctor's behavior perfectly, regarding both the effort he exerts in the diagnosis and his choice of treatment strategy. In the second scenario, we give the physician an informational advantage, assuming that neither of the two decisions that he can make are monitored by the health authority.

4.1 Contract with Symmetric Information

In this subsection, we characterize the optimal contract under symmetric information, i.e., considering that both the level of effort that the physician exerts in the diagnosis and the treatment strategy he chooses are verifiable and contractible. Depending on the treatment strategy that the health authority wishes to induce, the payments it offers to the physician and his level of effort will be the ones that minimize the government's expected cost. The health authority has to consider the fact that the doctor's expected utility, under any given strategy, cannot be lower than his reservation utility (PC) and that his liability constraints have to be fulfilled (LLC).

The problem the health authority faces when computing the optimal contract for each of the

⁷Moreover, from an analytical point of view, limited liability constraints introduce some kind of risk aversion in the physician's behavior. It avoids situations in which the principal can implement the first best allocation without incurring in extra costs.

treatment strategies presented is as follows:

$$\begin{aligned} & \min_{\bar{w}, \underline{w}, B, e} C \\ & s.t \quad \left\{ \begin{array}{l} U \geq M \quad (PC) \\ \bar{w} \geq M \\ \underline{w} \geq M \\ B \geq 0 \\ e \in [0, 1] \end{array} \right. \quad (LLC) \end{aligned} \quad (1)$$

With $(C, U) \in \{(\bar{C}, \bar{U}), (\underline{C}, \underline{U}), (C_*, U_*)\}$ depending on whether the health authority chooses the strong, the mild or the most-appropriate-treatment strategy.

We start by characterizing the optimal contract in those situations in which the health authority wants the physician to provide systematically one of the treatments.

Proposition 1 *The optimal contract $(\bar{w}^s, \underline{w}^s, B^s)$ under symmetric information is as follows:*

- *If the strong-treatment strategy is contracted, any contract such that $\bar{w}^s = M$ with $\bar{e}^s = 0$ is optimal. The associated costs are: $\bar{C}^s = M + \bar{c} + \frac{L}{2}$.*
- *If the mild-treatment strategy is contracted, any contract such that $\underline{w}^s = M$ and $B = 0$ with $\underline{e}^s = 0$ is optimal. The associated costs are: $\underline{C}^s = M + \underline{c} + \frac{(\bar{c}+l)}{2}$.*

Proof. See Appendix 2. ■

Under symmetric information, the level of effort that the health authority demands of the doctor in contracting either the strong-treatment strategy or the mild-treatment strategy, is null, i.e., $\bar{e}^s = \underline{e}^s = 0$. This occurs because in these cases treatment is decided regardless of the patient's diagnosis and, then, no effort in diagnosis is required. This decision by the health authority is consistent with the effort that the doctor would exert in the diagnosis if he had choice on this variable (see Lemma 2). The interaction between the doctor's public and private activities does not affect the social costs. The reason for this is that, although the presence of μ makes less expensive to induce a higher level of effort (since it relaxes the restriction *PC*), such effect does not really materialize, since, in equilibrium, the health authority will always choose $\bar{e}^s = \underline{e}^s = 0$.

The optimal contract under symmetric information, therefore, is partially undetermined, in the sense that multiple optimal contracts exist. In particular, a fixed salary, i.e. payments such that $\bar{w}^s = \underline{w}^s = M$ and $B^s = 0$ would be optimal in this context.

Before characterizing the optimal contract when the health authority decides to provide the most-appropriate-treatment strategy, we define a new term $\alpha \equiv L + l + \bar{c}$, which will be of use to us in presenting the rest of the results. α reflects the expected increase in the social cost due to an erroneous diagnosis.⁸ If this makes that the physician provides the strong treatment to the patient when he needed the mild one, the loss in health associated to the over-treatment is L and the health authority incurs an extra cost $\bar{c} - \underline{c}$. If, on the contrary, the physician provides the mild treatment to a patient that needs the strong one, to the loss in health (l) it is necessary to add the cost of uselessly prescribing the mild treatment (\underline{c}) in the first round. As we will see in the following proposition, α plays an important role in the determination of the optimal effort in diagnosis.

We restrict the value of the parameters under study by excluding some extreme situations. First, we rule out the cases where the social cost of an erroneous diagnosis is very low. Formally, we assume $\alpha > k$. Secondly, to avoid situations in which a perfect diagnosis will always be performed, we impose a sufficiently high cost on increasing the accuracy of the diagnosis ($k > \frac{\max\{\alpha, \mu\}}{4}$).

The following proposition characterizes the optimal contract under symmetric information when the most-appropriate-treatment strategy is contracted.

Proposition 2 *Under symmetric information, the optimal contract $(\bar{w}^s, \underline{w}^s, B^s)$ when the most-appropriate-treatment strategy is contracted, is as follows:*

- If $\mu \leq \frac{k}{2}$, any contract $\bar{w}^s \geq M$, $\underline{w}^s \geq M$, $B \geq 0$ such that $U_*^s = M$ is optimal, with:

$$e_*^s = \begin{cases} \min \left\{ \frac{\alpha + \mu}{4k}, 1 \right\} & \text{if } \varphi \left(\min \left\{ \frac{\alpha + \mu}{4k}, 1 \right\} \right) \geq \mu \\ \check{e} & \text{otherwise.} \end{cases}$$

With $\varphi(e) = \frac{2ke^2}{3+e}$ and $\check{e} \in \left(\frac{\alpha + \mu}{4k}, 1 \right]$ such that $\varphi(\check{e}) = \mu$.

The associated costs are:

$$C_*^s = M + \frac{1}{2}(\bar{c} + \underline{c}) + \frac{1}{2} \left[\frac{1 - e_*^s}{2} \alpha - \mu \left(1 + \frac{1 + e_*^s}{2} \right) + k (e_*^s)^2 \right].$$

- If $\mu > \frac{k}{2}$, the optimal contract is such that $\bar{w}^s = \underline{w}^s = M$, $B = 0$, with $e_*^s = 1$. The associated costs are: $C_*^s = M + \frac{1}{2}(\bar{c} + \underline{c})$.

Proof. See Appendix 2. ■

There are several insights in Proposition 2 that are worth mentioning. Firstly, if the health authority contracts the most appropriate strategy, the optimal level of effort that demands

⁸It is easy to see that the expected impact of a wrong diagnosis on the social costs is given by $\frac{1-e}{4}\alpha$.

of the doctor, when μ is relatively low, depends positively on both the costs associated with an erroneous diagnosis (reflected by α), and the value of μ . If the relationship between the doctor's activities in the two different sectors is sufficiently high ($\mu > \frac{k}{2}$), the principal will always contract a perfect diagnosis. The reason for this is that the doctor's level of effort in the diagnosis affects the government's costs through the participation constraint (PC). If $\mu \leq \frac{k}{2}$, this constraint is active and, therefore, the principal internalizes the higher expense that the higher level of effort implies. On the contrary, if μ exceeds this threshold, any contract that satisfies the limited liability constraints also fulfills (PC), independently of the level of effort required of the doctor. In other words, the doctor is willing to exert a higher level of effort since the cost he bears is compensated for an increase in his private income. This means that a more accurate diagnosis does not incur higher costs for the health authority and, therefore, it chooses $e_*^s = 1$.

Another interesting insight is that, as we saw in the case for the other two treatment strategies, a salary $\bar{w}^s = \underline{w}^s$ and $B^s = 0$ belongs to the set of optimal contracts in the absence of informational asymmetries.

Finally, we evaluate how the doctor's role as dual provider affects the social costs and, once again, the value of μ proves to be crucial to the results. If the relationship between the doctor's public and private activities is relatively low, the costs to the health authority (C_*^s) are decreasing in μ . This is because an increase in μ makes the participation constraint of the physician to be fulfilled for lower values of \underline{w} and \bar{w} . On the contrary, if the relationship between his public and private activities is high, the physician's participation constraint (PC) is not binding at the optimum ($U_*^s > M$). As a result, increases in μ would imply extra rents for the doctor (i.e., increases in U_*^s) and would have no effect on social costs.

The following remark summarizes the effects of the physician's dual practice on the expected social costs.

Remark 3 *The fact that the doctor works in both the public and the private sector, in the absence of informational asymmetries, has the following effects:*

- *It does not alter the social costs of adopting treatment strategies that are independent of the signal received in the diagnosis.*
- *When the treatment strategy employed is contingent on the diagnosis, the social costs are decreasing in μ provided μ does not exceed a certain threshold, beyond which they remain unaffected.*

4.2 Contract with Asymmetric Information

In this subsection we consider the case in which neither the level of effort that the doctor exerts in the diagnosis nor the treatment strategy he employs is observable.

The diagnosis of the severity of a patient's ailment and the choice of treatment that he should be given can only be done by a qualified physician. This implies that it may not be possible for the health authority to control the doctor's decisions in such activities. This scenario with asymmetric information will therefore be useful for reflecting the relationship between the physician and the health authority in real-life situations. We only study this double moral hazard situation, without analyzing intermediate scenarios. The reason is that it is precisely the interaction of these two dimensions what allows us to fully characterize the impact of the physician's dual activity.

Under asymmetric information, the problem the health authority faces is similar to the optimization program under symmetric information presented in (1). There are two fundamental differences. First, we must include the physician's incentive compatibility constraint with regard to the strategy that the principal wishes to induce (as defined in Lemma 3). That is to say: \overline{IC} if the health authority wants to induce the strong-treatment strategy, \underline{IC} if it wishes to implement the mild-treatment strategy and IC_* if it prefers the most-appropriate-treatment strategy. Secondly, as the doctor's effort in the diagnosis is no longer contractible, the principal has to take into account that the level of effort that the doctor would exert for each possible treatment strategy contracted is as given in Lemma 2.

The health authority's optimization program is as follows:

$$\begin{aligned} & \min_{\overline{w}, \underline{w}, B} C \\ & s.t \quad \left\{ \begin{array}{l} U \geq M \quad (PC) \\ \overline{w} \geq M \\ \underline{w} \geq M \quad (LLC) \\ B \geq 0 \\ IC \\ e^a = e \end{array} \right. \end{aligned} \quad (2)$$

With $(C, U, IC, e) \in \{(\overline{C}, \overline{U}, \overline{IC}, \overline{e}), (\underline{C}, \underline{U}, \underline{IC}, \underline{e}), (C_*, U_*, IC_*, e_*)\}$ depending on whether the health authority chooses the strong, the mild or the most-appropriate-treatment strategy.

The contract that the health authority will offer in each case is presented in the following proposition.

Proposition 3 *The optimal contract $(\overline{w}^a, \underline{w}^a, B^a)$ under asymmetric information is as follows:*

- If the strong-treatment strategy is considered: $\bar{w}^a = \underline{w}^a = M$ and $B^a = 0$, with $\bar{e}^a = 0$. The associated costs are: $\bar{C}^a = M + \bar{c} + \frac{l}{2}$.
- If the mild-treatment strategy is considered: $\bar{w}^a = M$, $\underline{w}^a = M + \frac{1}{2}\mu \left(1 + \frac{\mu}{8k}\right)$ and $B^a = 0$, with $\underline{e}^a = 0$. The associated costs are:

$$\underline{C}^a = M + \underline{c} + \frac{1}{2} \left[\bar{c} + l + \mu \left(1 + \frac{\mu}{8k}\right) \right].$$

- If the most appropriate strategy is considered: $\bar{w}^a = \underline{w}^a = M$ and:
 - If $\mu < 3k$, $B^a = 4\sqrt{k^2 + \mu k} - 4k - \mu$ with $e_*^a = \sqrt{1 + \frac{\mu}{k}} - 1 \in (0, 1)$.
 - If $\mu \geq 3k$, $B^a = k$ with $e_*^a = 1$.

The associated costs are:

$$C_*^a = M + \frac{1}{2}(\bar{c} + \underline{c}) + \frac{1}{2} \left[\frac{1 + e_*^a}{2} B + \frac{1 - e_*^a}{2} \alpha \right].$$

Proof. See Appendix 3. ■

To interpret this proposition, we study the results under each treatment strategy independently. If the government wants to induce the physician to provide the strong treatment systematically, the doctor's interest in building a good reputation for his private practice is, in principle, beneficial to the health authority, as it makes the incentive restriction more easily fulfilled. However, in equilibrium, the limited liability constraints prevent the government from taking advantage of this opportunity to reduce costs. As a result, the optimal contract would be a flat salary, and the social costs would be independent of μ , i.e., $\frac{\partial \bar{C}^a}{\partial \mu} = 0$.

If the principal prefers the mild-treatment strategy, the doctor's interest in curing the patients with just one treatment makes it more expensive to be induced $\left(\frac{\partial \underline{C}^a}{\partial \mu} > 0\right)$. The health authority would have to make an extra payment (increasing in μ) to prevent the doctor from opting for another treatment strategy that would ensure a greater positive impact on his private income.

If, however, the government wishes to implement the appropriate-treatment strategy, the doctor's condition of dual supplier has two opposite effects. On the one hand, his interest in improving his reputation makes him prefer the strong treatment systematically, since it cures all of the patients, which makes it more expensive for the government to induce this treatment strategy. On the other hand, if the doctor finally decides to follow the most-appropriate-treatment strategy, his interest in curing the patient induces him to exert a higher effort in the diagnosis, which is socially beneficial.⁹ The result of this trade-off, is presented in the following corollary.

⁹It can be shown that, despite this incentives to provide a more accurate diagnosis, the level of effort under asymmetric information is always sub-optimal (except when $e^a = 1$), with respect to the one with symmetric information.

Corollary 1 *When the health authority induces the doctor to provide the most-appropriate treatment strategy, the physician's dual practice generates:*

- *If $e_*^\alpha \in (0, 1)$:*
 - *An increase in the social costs if $\alpha < \hat{\alpha}(k, \mu)$.*
 - *A decrease in the social costs if $\alpha > \hat{\alpha}(k, \mu)$.*

With $\hat{\alpha}(k, \mu) = k \left(8\sqrt{1 + \frac{\mu}{k}} - \frac{3\mu}{k} - 6 \right) \in (2k, 2.3k) \forall \mu$.
- *If $e_*^\alpha = 1$ the social costs remain unaltered.*

The interpretation of Corollary 1 is quite clear, but two cases have to be distinguished. First, when the diagnosis is not perfect the value of α is crucial, since it reflects the expected social cost of an erroneous diagnosis. When α is relatively small, the health authority does not consider it optimal to induce the doctor to perform a very accurate diagnosis. The effect that really governs this case, therefore, is the higher cost involved in inducing the doctor to choose the most appropriate strategy. This makes the doctor's dual activity socially negative. In contrast, if α exceeds a certain threshold, the doctor's interest in performing a very accurate diagnosis is in line with that of the health authority's interests. As a result, although the government has to make an extra payment to ensure that the doctor chooses the most-appropriate-treatment strategy, it is compensated by the reduction in costs derived from the doctor's improved diagnosis. The final effect of the doctor's private practice, therefore, is positive for the health authority.

When the health authority induces the physician to exert the maximum level of effort in the diagnosis, i.e. $e_*^\alpha = 1$, his dual practice has no effect on social costs. The reason is that the health authority can not benefit from the physician's interest in gaining prestige, as he is already performing a fully accurate diagnosis.

The results of this analysis have their political implications as well. There are certain situations in which it would be in the health authority's interest to prohibit private practice by any doctor who works in the public health sector. This is the case when such dual activity by the doctor generates incentives for him to over-provide medical services. If the government prefers the physician to follow the mild-treatment strategy, or when it opts for a treatment in accordance with the signal received in the diagnosis, and, furthermore, the social costs of an incorrect diagnosis are not very high, the doctor's dual activity is negative from the social point of view. If the health authority has it within its power, it should prohibit the doctor from having a private practice whenever either of the two above-mentioned treatment strategies is chosen.

Labor legislation currently in force in many countries with mixed health care systems does not allow the health authorities to prohibit physicians' dual provision. In the next Section we will study, on the light of the analysis performed, two alternative ways in which this dual practice has been regulated.

5 Alternative Regulatory Measures

In the Introduction we presented alternative regulatory frameworks that exist in some countries with mixed health care systems: France, Spain and the U.K. They implement alternative regulations that can be categorized in two branches.

First, the Spanish system, based on exclusive contracts. In Spain, those doctors who work for the public sector are allowed to have their private practices if they wish to. If, however, they decide to forego this privilege, they receive a fixed monthly bonus in return for such exclusive contracting. The pertinent question here, therefore, is whether it is in the interest of the health authority to pay him a bonus to give up his private practice.

Secondly, the French and English systems, where the physicians' dual provision, although permitted, is restricted. In these countries, public physicians' private earnings cannot exceed a certain threshold. Such a threshold is computed in the UK on the basis of physicians' public revenues and in France on the basis of their total income.¹⁰

In the following subsections we will analyze the optimality of these alternative regulations.

5.1 Should an Exclusive Contract Be Offered?

In this subsection we study whether, in an initial stage of the game, it is in the interest of the health authority to offer the physician an exclusive contract with extra economic remuneration for him to forego his private practice. In the case of a contract being offered, the physician can either accept it (and work exclusively in the public sector) or reject it (and be a dual supplier).¹¹

In Subsection 4.1, we demonstrated that, under symmetric information, the physician's dual activity is never negative from the social point of view. The analysis that follows, therefore, only makes sense when asymmetric information exists between the doctor and the health authority.

The government should only decide to offer an exclusive contract if the savings obtained from the doctor's exclusive attention to the public health sector exceed the extra cost of paying him to give up his private practice.

¹⁰It is easy to see that these two regulations are analytically equivalent.

¹¹Note that the analytical difference between the subgames with and without physician's dual practice, is the presence or absence of the parameter μ .

So far, we have not really considered the doctor's private revenue in itself, but rather the effect that his performance in the public health sector has on it. In this section, however, the value of this revenue is crucial, since it also determines the extent of the sacrifice made by the physician when he is restricted to working exclusively in the public health sector.

We define the value of the doctor's private income, in absence of any relationship between public and private practices, by π . To this value we must add the increase in private income he obtains from his enhanced image and prestige as "a good doctor" (reflected by μ).¹²

We denote the quantity that the health authority offers to the doctor in exchange for his exclusive contract by $R \geq 0$. To analyze the government's behavior, we must determine the costs involved in both scenarios separately: C^E when there is an exclusive contract (equivalent to having $\mu = 0$), and C^{NE} when the doctor works in both sectors. We define:

$$\begin{aligned} C^E &= \min \{ \overline{C}^a(\mu = 0), \underline{C}^a(\mu = 0), C_*^a(\mu = 0) \} \text{ and} \\ C^{NE} &= \min \{ \overline{C}^a, \underline{C}^a, C_*^a \}. \end{aligned}$$

These two values determine the maximum that the government will be willing to pay for an exclusive contract (R_{\max}). Formally:

$$R_{\max} = \max \{ 0, C^{NE} - C^E \}.$$

The physician, on the other hand, will be interested in signing an exclusive contract if the remuneration he receives exceeds a certain threshold, R_{\min} , defined as:

$$R_{\min} = \pi + U^{NE} - U^E,$$

where U^{NE} is the doctor's expected utility when he works in both sectors, and U^E when he accepts an exclusive contract. $U^{NE} \in \{ \overline{U}^a, \underline{U}^a, U_*^a \}$, and $U^E \in \{ \overline{U}^a(\mu = 0), \underline{U}^a(\mu = 0), U_*^a(\mu = 0) \}$, having either value depending on the strategy chosen by the principal in each scenario.

Therefore, there will be room for exclusive contracts if there exist values of $\mu > 0$ and $\pi > 0$ such that $R_{\min} < R_{\max}$.

In the following proposition we analyze this possibility.

Proposition 4 *When the government offers an incentive contract to the doctor, it is never optimal for it to offer him an exclusive contract as well.*

¹²This sort of modelling implicitly assumes a linear relationship between the increase in the doctor's prestige as a result of his satisfactory performance in the public sector, and the increase in his private income.

Proof. See Appendix 4. ■

The government should only consider the option of an exclusive contract when the doctor's dual activity implies an increase in costs. It should also be noted that the treatment strategy chosen by the principal can vary, depending on whether the doctor is a dual supplier or not. From the previous analysis we know that there are two cases in which an exclusive contract is never desirable: Either when the government wants the doctor to systematically adopt the strong-treatment strategy, or when both, it prefers a treatment in accordance with the signal of the severity received and the social cost of an incorrect diagnosis is high.

Proposition 4 shows that even in cases where the doctor's dual practice is detrimental to the government, it will not offer exclusive contracts. The reason for this is that, through its incentive contract, the health authority partially mitigates the increase in costs. Therefore, the savings from the fact that the doctor is not a dual supplier are never enough to compensate the doctor for what he loses from not having a private practice.

These results seem to be difficult to reconcile with what actually happens in the real-economy, since in some "mixed" health systems, where doctors are dual suppliers, the health authorities do offer exclusive contracts. It must be remembered, however, that existing remuneration systems are not generally based on incentives.

The following proposition shows how the previous result changes radically if we focus our attention on remuneration systems based on a salary.

Proposition 5 *When the government pays the doctor a fixed salary, i.e., $\bar{w} = \underline{w} = M$ and $B = 0$, offering him an exclusive contract can be optimal if $\bar{c} > 2\underline{c} + l - L$.*

Proof. See Appendix 5. ■

Offering a salary to a physician who works in both sectors encourages him to prescribe the stronger treatment systematically, as a means of enhancing his image and reputation. This over-provision of services is not optimal if $\bar{c} > 2\underline{c} + l - L$ (i.e., if the strong treatment is sufficiently more expensive than the mild one). If this condition holds, therefore, there will be values of μ and π for which the government offering an exclusive contract and the doctor accepting it, is an equilibrium.

Our results provide a rationale for the existence of exclusive contracts, like the ones implemented by the Spanish Health Administration, as a second-best choice. If the health authority offers incentive contracts there is no reason for any exclusive contracts to be offered. If, however, the health authority chooses payment systems based on a flat salary, exclusive contracts can be a useful tool for helping to contain expenses within the public health sector. In this respect, if

we think of other dimensions of the physician’s activity with outputs difficult to measure, such as teaching or researching or even treating chronic illnesses, the health authority may not be interested in offering incentive contracts to physicians and, hence, exclusive contracts may be a powerful regulatory tool.¹³

5.2 Should we Limit Physicians’ Private Earnings?

In this subsection we study the consequences of a regulation that imposes an upper bound on the amount of public physicians’ private earnings, on the light of the analysis we have performed. As we already said, this sort of policy is currently in force in countries like France and the U.K.

Firstly, we can compare this regulation with the Spanish one, based on offering exclusive contracts to the physicians. With the Spanish regulation, the public authority has absolutely no power, as it cannot impose the physicians to sign the exclusive contract. In the French-English system, on the contrary, the public authority goes one step beyond. Even if its power is restricted, since it cannot forbid physicians’ dual practice, it can limit this dual provision by fixing an upper bound on the physicians’ private earnings. From this qualitative difference in the power of the public authority, it is clear that, when the physicians’ dual practice is welfare decreasing, its consequences will be less severe under the French-English type regulation.

We move now to a more specific analysis of the French-English system. To do so, we define by Π_{\max} the maximum amount of private earnings allowed by the health authority. In this analysis we consider that $\Pi_{\max} \in (\pi, \pi + \mu)$. With this restriction we ensure that, on the one hand, the physician is still concerned by his prestige in the private sector ($\Pi_{\max} > \pi$), but on the other hand, the regulation is active and imposes a restriction on the amount of private profits the physician can get ($\Pi_{\max} < \pi + \mu$).

Let us denote by μ' the difference in earnings between a physician with a “high” prestige, and one without it, i.e., $\mu' = \Pi_{\max} - \pi$. By construction, we have that $\mu' < \mu$. The direct implication of this sort of regulation is, therefore, a decrease in the physician’s incentives to gain prestige as a practitioner, as this has a lower impact on his earnings.

We proceed now to state how this affects the social costs borne by the health authority, depending on the treatment strategy chosen.

Corollary 2 *A regulation that limits physicians’ private earnings generates:*

- *If the mild-treatment strategy is chosen, a reduction in the social costs.*

¹³Holmstrom and Milgrom (1991) showed that in a principal-agent setting with multiple tasks, and if some of them are not observable, the optimal contract can be a fixed wage (no incentive provision).

- *If the strong-treatment strategy is chosen, no change in the social costs.*
- *If the most-appropriate-treatment strategy is chosen:*
 - *A reduction in the social costs, for low values of α .*
 - *An increase in the social costs, for high values of α .*

The interpretation of Corollary 2 is clear for the first two cases. When the health authority follows the mild-treatment strategy, physician's dual practice is detrimental as it generates an incentive to over-provide services. In this case, the regulation is beneficial precisely because it reduces such incentives. When the strong-treatment strategy is chosen, physician's private work has no effect on the social costs and, hence, the regulation has no impact.

However, when the health authority chooses the most-appropriate treatment strategy, the implications of the regulation are not so clear. They depend on whether the social cost of an erroneous diagnosis is high or not.¹⁴ When an incorrect diagnosis of the severity of the disease is socially not very harmful, the dual practice of the physician is cost-increasing. The regulation, therefore, helps to mitigate the increase in the costs. On the contrary, when the health authority is concerned about the accuracy of the diagnosis, the physician's interest in gaining prestige is a powerful tool, as it makes the physician increase his effort in the diagnosis. A regulation that limits the practitioner's private earnings, will reduce his incentives to perform a correct diagnosis and will be, therefore, welfare decreasing.

Therefore, our conclusion is that this sort of regulatory policy may be beneficial from a social point of view, although it can generate as a non-desired effect a reduction on the physicians' incentives to perform an accurate diagnosis.

6 Concluding Remarks

This paper studies, in a moral-hazard framework, the implications that the physician's dual activity has for public health authorities. As mentioned, the fact that many doctors work both in public and private sector at the same time is common in mixed health care systems.

From the different dimensions in which conflicting interests may arise between the doctor's public and private practices, we have focused on a particular one: The possibility that the physician uses his work in the public sector as a way of improving his professional prestige and, hence, increasing his private revenue. We derived optimal payment contracts for a physician in

¹⁴The threshold that determines the result is the one obtained in Corollary 1.

the public sector and we studied how his incentives are affected, under such contracts, when he is also a private provider.

We have found that the physician's dual practice has conflicting effects. On the one hand, his interest in curing patients and gaining prestige, generates an over-provision of health services. On the other hand, if the health authority is able to control these incentives to over-provide services, then it can benefit from the physician's increased interest in doing a more accurate diagnosis.

Regarding policy recommendations, our analysis suggests that the physician's dual practice can be either welfare improving or reducing, depending on the treatment policy that the health authority wants to implement. If the priority of the health authority is to contain costs, then the doctor's dual activity is negative. If the priority is to minimize patients' health losses, his dual practice affords the objective at a lower cost.

In several countries with mixed health care systems the labor legislation in force allows dual activity by the physicians. Despite this, different measures have been undertaken by the governments to regulate this issue. This work provides a theoretical framework in which the optimality of exclusive contracts and of limits on physicians' private incomes can be addressed. Considering the former, our analysis shows that if the remuneration policy of the health authority is based on a salary, then exclusive contracts can be useful for cost-containment. However, if we consider incentive payment contracts, it is never optimal to offer an exclusive contract to the physician.

Considering the latter type of regulation, and under an incentive contract, we show that limiting physicians's private income is beneficial from a social point of view, except in those cases in which the health authority is highly concerned about the accuracy of the diagnosis the physician performs. In such a case, this kind of regulation is socially harmful.

The assumption of equal probability for the two severities of the illness has been made for the sake of analytical tractability. In spite of this, some new effects of dealing with other probability structures can be spotted. First, the larger the proportion of patients suffering from a low severity is, the lower the physician's incentives to over-provide services will be. However, a second effect may overwhelm this positive one. Now, the over-provision of services becomes more costly, since it affects a larger proportion of the population. Therefore, the final effect over the health authority costs can not be unambiguously determined.

Risk neutrality has been assumed for both the physician and the health authority. This assumption has certainly been useful to deal with the computations of the model, but it should deserve a couple of quick comments. Firstly, concerning the physician's behavior, it can be

shown that neither his interest in over-providing medical services nor his willingness to perform a more accurate diagnosis, rely on his risk neutrality. Hence, they would be preserved in an environment with a risk averse physician. Secondly, dealing with a risk averse health authority would mainly alter its decision concerning which treatment strategy to induce the physician to follow. This is a dimension, however, that we have not addressed in this work.

We have imposed no restriction on the relationship between the two types of patients' health losses (l for an unsuccessful treatment and L for an over-treatment). If we had wanted to focus on which treatment policy is preferred by the health authority, the relationship between such parameters would have been crucial. In any case, our analysis suggests that the physician's dual activity will make the health authority more reluctant to implement the mild-treatment strategy, as it becomes more costly due to the physician's incentives to over-provide services.

Finally, it is worth mentioning that we have dealt with a static framework to analyze the interaction between physician's public and private activities, when a dynamic interaction would have probably been more appropriate. This simplification, however, has allowed us to study the effects of dual practice not only on the diagnosis decision but also on the physician's treatment choice. An interesting and ambitious task for further research would certainly be the study of physicians' dual practice in a fully dynamic setting. In particular, one may think of reputation as a stock that is enhanced with good results and depleted with bad results. This would provide us with interesting insights on the long-run implications of the physician's acquisition of reputation. One could expect to find, for instance, that older and well-reputed professionals would exert much less effort and prescribe less the strong treatment than younger ones. Performing such analysis, however, would certainly require to sacrifice some of the aspects considered in this work.

References

- [1] Blomqvist, Å. (1991) “The Doctor as a Double Agent: Information Asymmetry, Health Insurance, and Medical Care”. *Journal of Health Economics* 10, 411-432.
- [2] Competition Commission (1994) “Private Medical Services: a Report on the Agreements and Practices Relating to Charges for the Supply of Private Medical Services by NHS consultants”. London: HMSO
- [3] Dranove, D. (1988) “Demand Inducement and the Physician/Patient Relationship”. *Economic Inquiry* 26, 281-298.
- [4] Ellis, R.P. and McGuire, T.G. (1986) “Provider Behavior Under Prospective Reimbursement: Cost Sharing and Supply”. *Journal of Health Economics* 5, 129-152.
- [5] Ellis, R.P. and McGuire, T.G. (1990) “Optimal Payment Systems for Health Services”. *Journal of Health Economics* 9, 375-396.
- [6] Gal-Or, E. (1999) “Optimal Reimbursement and Malpractice Sharing Rules in Health Care Markets”. *Journal of Regulatory Economics* 16, 237-265.
- [7] Garcia-Mariñoso, B. and Jelovac, I. (2003) “GPs’ Payment Contracts and their Referral Practice”. Forthcoming: *Journal of Health Economics*.
- [8] Gaynor, M. (1994) “Issues in the Industrial Organization of the Market for Physician Services”. *Journal of Economics and Management Strategy* 3-1, 211-255.
- [9] González, P. (2002) “Policy Implications of Transferring Patients to Private Practice”. IVIE Working Papers WP-AD2002-12.
- [10] Holmstrom, B. and Milgrom, P. (1991) “Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design”. *The Journal of Law, Economics and Organization* 7, 24-52.
- [11] Jelovac, I. (2001) “Physicians’ Payment Contracts, Treatment Decisions and Diagnosis Accuracy”. *Health Economics* 10, 9-25.
- [12] Johnson, N. (1995) *Private Markets in Health and Welfare: An International Perspective*. Berg Publishers Ltd., Oxford.
- [13] Ma, C.-t.A. (1994). Health Care Payment Systems: Costs and Quality Incentives. *Journal of Economics and Management Strategy* 3-1, 93-112.

- [14] Rickman, N. and McGuire, A. (1999) "Regulating Providers' Reimbursement in a Mixed Market for Health Care". *Scottish Journal of Political Economy* 46-1, 53-71.
- [15] Selden, T.P. (1990) "A Model of Capitation". *Journal of Health Economics* 9, 397-410.
- [16] US Congress (1995) "Hospital Financing in Seven Different Countries". Office of Technology Assessment. Background Paper OTA-BP-H-148. Washington DC, US Government Printing Office.
- [17] Yates, J. (1995) "Private Eye, Heart and Hip: Surgical Consultants, the National Health Service and Private Medicine". London: Churchill Livingstone.

Appendix

Appendix 1. Physician's expected utility and health authority's expected costs under the alternative treatment strategies

1.- Under the strong-treatment strategy:

$$\bar{U} \equiv \bar{w} + \mu - V(e).$$

$$\bar{C} \equiv \bar{w} + \bar{c} + \frac{1}{2}L = \bar{U} - \mu + \bar{c} + \frac{1}{2}L + V(e).$$

2.- Under the mild-treatment strategy:

$$\underline{U} \equiv \underline{w} + \frac{1}{2}(\mu + B) - V(e).$$

$$\underline{C} \equiv \frac{1}{2}(\underline{w} + B + \underline{c}) + \frac{1}{2}(\underline{w} + \underline{c} + \bar{c}) + \frac{1}{2}l = \underline{U} - \frac{1}{2}\mu + \underline{c} + \frac{1}{2}(\bar{c} + l) + V(e).$$

3.- Under the most-appropriate treatment strategy:

$$\begin{aligned} U_* &\equiv \frac{1}{2} \left[\frac{1+\epsilon}{2} (\underline{w} + \mu + B) + \frac{1-\epsilon}{2} (\bar{w} + \mu) \right] + \frac{1}{2} \left[\frac{1+\epsilon}{2} (\bar{w} + \mu) + \frac{1-\epsilon}{2} (\underline{w}) \right] - V(e) = \\ &= \frac{1}{2} \left[\underline{w} + \bar{w} + \mu + \frac{1+\epsilon}{2} (B + \mu) \right] - V(e). \end{aligned}$$

$$\begin{aligned} C_* &\equiv \frac{1}{2} \left[\frac{1+\epsilon}{2} (\underline{w} + B + \underline{c}) + \frac{1-\epsilon}{2} (\bar{w} + \bar{c}) \right] + \frac{1}{2} \left[\frac{1+\epsilon}{2} (\bar{w} + \bar{c}) + \frac{1-\epsilon}{2} (\underline{w} + \underline{c} + \bar{c}) \right] + \\ &+ \frac{1-\epsilon}{2} \left[\frac{1}{2}L + \frac{1}{2}l \right] = \frac{1}{2} \left[\bar{c} + \underline{c} + \bar{w} + \underline{w} + \frac{1+\epsilon}{2}B + \frac{1-\epsilon}{2}(\bar{c} + l + L) \right] = \\ &= U_* - \frac{1}{2}\mu \left(1 + \frac{1+\epsilon}{2} \right) + \frac{1}{2} \left[\underline{c} + \bar{c} + \frac{1-\epsilon}{2}(L + l + \bar{c}) \right] + V(e). \end{aligned}$$

Appendix 2. Proof of Propositions 1 and 2

Under symmetric information, the optimal payment contract and the optimal level of effort under the different treatment strategies are the solution to the following program:

$$\begin{aligned} &\min_{\bar{w}, \underline{w}, B, e} C \\ &s.t \quad \left\{ \begin{array}{l} U \geq M \quad (PC) \\ \bar{w} \geq M \\ \underline{w} \geq M \\ B \geq 0 \\ e \in [0, 1] \end{array} \right. \quad (LLC) \end{aligned}$$

With $(C, U) \in \{(\bar{C}, \bar{U}), (\underline{C}, \underline{U}), (C_*, U_*)\}$ depending on whether the health authority chooses the strong, mild or the most-appropriate-treatment strategy.

If the health authority contracts both the mild or the strong treatment strategy, since the treatment decision is independent on the physician's diagnosis and inducing effort only increases the health authority costs, the health authority prefers the effort to be minimal, i.e., $\bar{e}^s = \underline{e}^s = 0$.

The *(LLC)* imply the *(PC)*. Therefore, the health authority chooses the cheapest contract compatible with the *(LLC)*. Then, when the health authority contracts the strong strategy any contract $(\bar{w}^s, \underline{w}^s, B^s)$ with $\bar{w}^s = M$ is optimal. Analogously, when the health authority contracts the mild strategy any contract $(\bar{w}^s, \underline{w}^s, B^s)$ with $\underline{w}^s = M$ and $B = 0$ is optimal.¹⁵

If the health authority contracts the most-appropriate-treatment strategy, the problem it faces is given by:

$$\begin{aligned} \min_{\bar{w}, \underline{w}, B, e} C_* &= \frac{1}{2} \left[\bar{c} + \underline{c} + \bar{w} + \underline{w} + \frac{1+e}{2}B + \frac{1-e}{2}\alpha \right] \\ &\quad \frac{1}{2} [\underline{w} + \bar{w} + \mu + \frac{1+e}{2}(B + \mu)] - k\frac{e^2}{2} \geq M \quad (PC) \\ s.t. \quad &\left. \begin{array}{l} \bar{w} \geq M \\ \underline{w} \geq M \\ B \geq 0 \end{array} \right| (LLC) \\ &e \in [0, 1] \end{aligned}$$

We will study independently two cases, depending on whether *(PC)* is binding or not at the optimum.

i) If *(PC)* is not binding at the optimum, then we can ignore it. Since the health authority's costs are increasing in the payments to the physician, we make the *(LLC)* binding. This immediately implies that $e_* = 1$. One can check that this solution will indeed fulfill that *(PC)* is not binding (as we have assumed) if and only if $\mu > \frac{k}{2}$.

ii) If *(PC)* is binding at the optimum, and the limited liability constraints *(LLC)* are fulfilled, then a necessary condition for the optimal level of effort is that $\varphi(e) = \frac{2ke^2}{3+e} \geq \mu$. $\varphi(e)$ is such that $\varphi'(e) > 0$, $\varphi(0) = 0$ and $\varphi(1) = \frac{k}{2}$.

Substituting *(PC)* into the objective function and optimizing with respect to e we find that $e_* = \min\{\frac{\alpha+\mu}{4k}, 1\}$. Note that e_* will only be the solution provided $\varphi(e_*) \geq \mu$.

When $\varphi(e_*) \geq \mu$, then the solution to the problem is $e_* = \min\{\frac{\alpha+\mu}{4k}, 1\}$.

When $\varphi(e_*) < \mu$, e_* cannot be the solution. Moreover, since $\varphi(e) \leq \frac{k}{2} \forall e$, then if $\mu > \frac{k}{2}$ there does not exist any $e \in [0, 1]$ such that $\varphi(e) \geq \mu$. We distinguish two situations:

¹⁵Note that under these payment structures, positive levels of effort can be sustained in equilibrium. However, this would not alter the social costs and only would reduce physician's utility.

If $e_* = 1$, then $\varphi(e_*) < \mu \Leftrightarrow \mu > \frac{k}{2}$, and we have already shown that in this region there is no solution with (PC) binding.

If $e_* = \frac{\alpha+\mu}{4k}$, and $\mu \leq \frac{k}{2}$ we have: $\varphi\left(\frac{\alpha+\mu}{4k}\right) < \mu$, $\varphi(1) = \frac{k}{2} \geq \mu$ and $\varphi'(e) > 0$. These imply that there exists a value $\check{e} \in \left(\frac{\alpha+\mu}{4k}, 1\right]$ such that $\varphi(\check{e}) = \mu$. This value \check{e} is the optimal level of effort in this region.

Therefore, we have characterized the solution for all the range of parameter values. The optimal contract under symmetric information is presented in Proposition 2.

Appendix 3. Proof of Proposition 3

When the health authority cannot contract either the physician's effort or the treatment strategy, then its optimization program is as follows:

$$\begin{array}{l} \min_{\bar{w}, \underline{w}, B} C \\ s.t \quad \left\{ \begin{array}{l} U \geq M \quad (PC) \\ \bar{w} \geq M \\ \underline{w} \geq M \\ B \geq 0 \\ IC \\ e^a = e \end{array} \right. \quad (LLC) \end{array}$$

With $(C, U, IC, e) \in \{(\bar{C}, \bar{U}, \bar{IC}, \bar{e}), (\underline{C}, \underline{U}, \underline{IC}, \underline{e}), (C_*, U_*, IC_*, e_*)\}$ depending on whether the health authority chooses the strong, the mild or the most-appropriate-treatment strategy.

First, note that the participation constraint (PC) is always implied by the limited liability constraints (LLC) when the health authority wants to induce either the strong or the mild treatment strategy. This, in turn, makes that when the most-appropriate treatment strategy is considered the participation constraint is implied by the incentive compatibility constraints.

The physician chooses the level of effort he will exert in diagnosis. When the strategy chosen is either the strong or the mild one, the physician always chooses to exert no effort (i.e., $\underline{e} = \bar{e} = 0$) since it has no effect on his revenue and only implies higher costs.

Hereinafter, we need to study the health authority's problem under the three alternative treatment strategies independently:

i) When the health authority chooses the strong-treatment strategy, its expected costs do not depend on B . Moreover, since B makes the constraint (\bar{IC}) tougher, the optimal B is the lowest one such that the constraints are satisfied. Therefore, the liability constraint associated

to B is binding at the optimum, i.e., $B = 0$. The same argument applies to \underline{w} and, then, at the optimum $\underline{w} = M$. It is easy to verify that, under $B = 0$ and $\underline{w} = M$, the liability constraint associated to \bar{w} is more demanding than the incentive compatibility constraint (\overline{IC}). Since the health authority's costs are increasing in \bar{w} , the liability constraint associated to \bar{w} also binds at the optimum.

Therefore, if the strong-treatment strategy is considered the optimal contract is such that:

$$\bar{w}^a = \underline{w}^a = M \text{ and } B^a = 0, \text{ with } \bar{e}^a = 0.$$

The associated costs are: $\bar{C}^a = M + \bar{c} + \frac{l}{2}$.

ii) When the health authority chooses the mild-treatment strategy, an analogous argument to the one used with \underline{w} in i) ensures that $\bar{w} = M$ in the optimum.

We can reduce the health authority's optimization problem as follows:

$$\begin{aligned} \min_{\underline{w}, B} \underline{C} &= \underline{w} + \underline{c} + \frac{1}{2}(B + \bar{c} + l) \\ \text{s.t.} &\begin{cases} \underline{w} \geq M \\ B \geq 0 \\ e_* \left(\frac{B + \mu}{2} - ke_* \right) \leq \underline{w} - M + \frac{B - \mu}{2} \end{cases} \quad \begin{array}{l} (LLC) \\ (IC) \end{array} \end{aligned}$$

with $e_* = \min \left\{ \frac{B + \mu}{4k}, 1 \right\}$.

Since \underline{C} is increasing in \underline{w} , $\underline{w} = \max \{M, M'\}$ in the optimum, with $M' = M + e_* \left(\frac{B + \mu}{2} - ke_* \right) - \frac{B - \mu}{2}$.

M' is decreasing in B for all $e_* < 1$ (i.e. $B < 4k - \mu$) and constant if $e_* = 1$. ($B \geq 4k - \mu$). Moreover, when M' is decreasing in B , its slope is greater than $-\frac{1}{2}$.

When $B = 0$, $M' = M + \frac{1}{2}\mu \left(1 + \frac{\mu}{8k} \right) > M$. Therefore, the only two candidates to solution (vertexes of the domain) are:

$$\begin{aligned} B &= 0 \text{ and } \underline{w} = M + \frac{1}{2}\mu \left(1 + \frac{\mu}{8k} \right), \\ B &> 0 \text{ and } \underline{w} = \max \{M, M + \mu - k\}. \end{aligned}$$

In order to choose between these two candidates, it is useful to know that the slope of the level-curves of the objective function is $\frac{d\underline{w}}{dB} = -\frac{1}{2}$, whereas $\frac{\partial M'}{\partial B} > -\frac{1}{2}$. This directly implies that, if the mild-treatment strategy is considered, the optimal contract is such that:

$$\bar{w}^a = M, \underline{w}^a = M + \frac{1}{2}\mu \left(1 + \frac{\mu}{8k} \right) \text{ and } B^a = 0, \text{ with } \underline{e}^a = 0.$$

The associated costs are:

$$\underline{C}^a = M + \underline{c} + \frac{1}{2} \left[\bar{c} + l + \mu \left(1 + \frac{\mu}{8k} \right) \right].$$

iii) When the health authority chooses the most-appropriate-treatment strategy, the optimal contract is the solution to:

$$\begin{aligned} \min_{\bar{w}, \underline{w}, B} C_* &= \frac{1}{2} \left[\bar{c} + \underline{c} + \bar{w} + \underline{w} + \frac{1+e_*}{2} B + \frac{1-e_*}{2} (\bar{c} + l + L) \right] \\ s.t \quad & \left\{ \begin{array}{l} \bar{w} \geq M \\ \underline{w} \geq M \\ B \geq 0 \end{array} \right. \quad (LLC) \\ & \left\{ \begin{array}{l} e_* \left(\frac{B+\mu}{2} - k e_* \right) \geq \left| \bar{w} - \underline{w} + \frac{\mu-B}{2} \right| \\ e_* = \min \left\{ \frac{B+\mu}{4k}, 1 \right\} \end{array} \right. \quad (IC_*) \end{aligned}$$

Consider first the case where $e_* = 1$ (or equivalently $\frac{B+\mu}{4k} \geq 1$). Then, the health authority's problem can be rewritten as:

$$\begin{aligned} \min_{\bar{w}, \underline{w}, B} C_* &= \frac{1}{2} [\bar{c} + \underline{c} + \bar{w} + \underline{w} + B] \\ s.t \quad & \left\{ \begin{array}{l} \bar{w} \geq M \\ \underline{w} \geq M \\ B \geq 0 \end{array} \right. \quad (LLC) \\ & \left\{ \begin{array}{l} \bar{w} \leq \underline{w} + B - k \\ \bar{w} \geq \underline{w} + k - \mu \\ \frac{B+\mu}{4k} \geq 1 \end{array} \right. \quad (IC_*) \end{aligned}$$

The problem above is one of linear programming. We want to minimize a function that is increasing in \bar{w} , \underline{w} and B , subject to a series of linear constraints. We find two solutions depending on the value of the parameters:

- If $\mu \leq k$, the optimal contract is such that:

$$\underline{w} = M, \bar{w} = M + k - \mu \text{ and } B = 4k - \mu$$

The associated costs are:

$$C_*^0 = M + \frac{1}{2} (\bar{c} + \underline{c} + 5k - 2\mu)$$

- If $\mu > k$, the optimal contract is such that:

$$\underline{w} = M, \bar{w} = M \text{ and } B = \max \{4k - \mu, k\}.$$

The associated costs are:

$$C_*^1 = M + \frac{1}{2} (\bar{c} + \underline{c} + \max \{4k - \mu, k\})$$

Consider now the case where $e_* = \frac{B+\mu}{4k} < 1$. Then, the health authority's problem can be rewritten as:

$$\begin{aligned} \min_{\bar{w}, \underline{w}, B} C_* &= \frac{1}{2} \left[\bar{c} + \underline{c} + \bar{w} + \underline{w} + \frac{1}{2}(B + \alpha) + \frac{B + \mu}{8k}(B - \alpha) \right] \\ \text{s.t.} \quad &\left\{ \begin{array}{l} \bar{w} \geq M \\ \underline{w} \geq M \\ B \geq 0 \end{array} \right. \quad (LLC) \\ &\left\{ \begin{array}{l} \frac{1}{2}(B - \mu) + \underline{w} - \bar{w} - \frac{(B+\mu)^2}{16k} \leq 0 \\ \bar{w} - \underline{w} - \frac{1}{2}(B - \mu) - \frac{(B+\mu)^2}{16k} \leq 0 \end{array} \right. \quad (IC_*) \\ &\frac{B+\mu}{4k} < 1 \end{aligned}$$

It is easy to see that C_* is convex and increasing in B for all $B \in [0, 4k - \mu]$.

We can re-write the (IC_*) as follows:

$$\frac{(B - \mu)}{2} - \frac{(B + \mu)^2}{16k} \leq \bar{w} - \underline{w} \leq \frac{(B + \mu)^2}{16k} + \frac{(B - \mu)}{2}.$$

Note that both the right-hand-side and the left-hand-side terms of the inequality are increasing in B . This restriction, together with $\bar{w} \geq M$ and $\underline{w} \geq M$, determine the restricted domain of the minimization program.

We analyze how this domain changes with B , taking into account that the optimal level of B is the lowest one such that the constraints are fulfilled. We obtain that the solution to the program has to be on the frontier of the right-hand-side restriction:

$$\bar{w} - \underline{w} = \frac{(B + \mu)^2}{16k} + \frac{(B - \mu)}{2}.$$

Moreover, we find that $\bar{w} = M$, and this implies: $\underline{w} = M - \frac{(B+\mu)^2}{16k} - \frac{(B-\mu)}{2}$. This will only be a feasible value of \underline{w} if it fulfills the initial restriction $\underline{w} \geq M$. It is easy to check that it holds only if $B \in [0, \tilde{B}]$ with $\tilde{B} = 4\sqrt{k^2 + \mu k} - 4k - \mu > 0$.

Substituting the above values of \bar{w} and \underline{w} in the objective function and minimizing with respect to B , we can see that the objective function is convex in B and attains a global minimum at $B = \alpha$.

It can be shown that $\alpha > \tilde{B}$. This implies, then, that the optimal level of B is $B_* = \tilde{B}$. This can be the solution provided $\tilde{B} < 4k - \mu$, i.e., if $\mu < 3k$. The value of e associated is $e = \sqrt{1 + \frac{\mu}{k}} - 1$.

Summarizing, the unique candidate to solution is a contract such that:

$$\begin{aligned} \bar{w} &= \underline{w} = M \text{ and } B = 4\sqrt{k^2 + \mu k} - 4k - \mu \\ \text{with } e &= \sqrt{1 + \frac{\mu}{k}} - 1 \in (0, 1) \text{ if and only if } \mu < 3k. \end{aligned}$$

The associated costs are:

$$C_*^2 = M + \frac{1}{2}(\bar{c} + \underline{c}) + \frac{1}{2} \left(\alpha + \frac{1}{2} \sqrt{1 + \frac{\mu}{k}} \left[4\sqrt{k^2 + \mu k} - 4k - \mu - \alpha \right] \right)$$

If $\mu \leq k$, comparing C_*^0 with C_*^2 we find that the solution with $e_* < 1$ always dominates. If $k \leq \mu < 3k$, comparing C_*^1 with C_*^2 we find that the solution with $e_* < 1$ always dominates.

Finally, if $\mu \geq 3k$ the solution is $e_* = 1$ with $\bar{w} = \underline{w} = M$ and $B = k$.

Therefore, the optimal contract under asymmetric information if the most-appropriate treatment strategy is considered, is as described in Proposition 3.

Appendix 4. Proof of Proposition 4

Several cases have to be studied independently:

i) If $C^E = \bar{C}^a(\mu = 0)$, with $C^{NE} = \min \{ \bar{C}^a, \underline{C}^a, C_*^a \}$.

This is the case in which the health authority wants to induce, when the physician signs an exclusive contract, the strong-treatment strategy. Since $\bar{C}^a(\mu = 0) = \bar{C}^a$, then $C^{NE} \leq \bar{C}^a(\mu = 0)$. Therefore, it is never optimal for the health authority to offer an exclusive contract to the physician.

ii) If $C^E = \underline{C}^a(\mu = 0)$ and $C^{NE} = \underline{C}^a$.

The maximum the health authority is willing to pay for an exclusive contract is:

$$R_{\max} = \max \{ 0, \underline{C}^a - \underline{C}^a(\mu = 0) \} = \frac{1}{2} \mu \left(1 + \frac{\mu}{8k} \right).$$

The physician will sign the exclusive contract if he receives at least:

$$R_{\min} = \pi + \underline{U}^a - \underline{U}^a(\mu = 0) = \pi + \frac{1}{2} \mu \left(1 + \frac{\mu}{8k} \right).$$

Both conditions are compatible (i.e., $R_{\max} \geq R_{\min}$) only if $\pi \leq 0$, which is a contradiction.

Therefore, in this case, an exclusive contract is never offered.

iii) If $C^E = \underline{C}^a(\mu = 0)$ and $C^{NE} = \bar{C}^a$.

Proceeding analogously, we find that an exclusive contract is offered if:

$$R_{\max} \geq R_{\min} \Leftrightarrow \pi + \mu \leq \frac{\bar{c}}{2} - \underline{c} + \frac{L-l}{2}.$$

Since $C^{NE} = \bar{C}^a$, this necessarily implies that $\bar{C}^a < \underline{C}^a$, and this is true if:

$$\frac{\bar{c}}{2} - \underline{c} + \frac{L-l}{2} < \frac{1}{2} \mu \left(1 + \frac{\mu}{8k} \right).$$

Both conditions are simultaneously fulfilled only in the extreme case when $\pi \rightarrow 0$, and provided $\mu > 8k$, which contradicts our assumption $k > \frac{\max\{\alpha, \mu\}}{4}$.

Therefore, R_{\max} does not exceed R_{\min} and an exclusive contract is never offered in this case.

iv) If $C^E = \underline{C}^a(\mu = 0)$ and $C^{NE} = C_*^a$.

Applying the same argument than in the cases above, we can check that an exclusive contract will be offered to the physician (i.e., $R_{\max} \geq R_{\min}$) if:

$$\frac{1}{4}(\bar{c} + L - l) - \frac{1}{2}\underline{c} - \frac{\alpha}{4} \left(\sqrt{1 + \frac{\mu}{k}} - 1 \right) - \frac{\mu}{2} \left(1 + \frac{\sqrt{1 + \frac{\mu}{k}}}{2} \right) + \frac{k}{2} \left(\sqrt{1 + \frac{\mu}{k}} - 1 \right)^2 \geq \pi.$$

Since $C^{NE} = C_*^a$, this necessarily implies that $C_*^a < \underline{C}^a$, and this is true if:

$$\frac{\alpha}{4} + \frac{\mu}{2} \left(1 + \frac{\mu}{8k} \right) - \frac{1}{2} \left[\alpha + \frac{1}{2} \sqrt{1 + \frac{\mu}{k}} \left(4\sqrt{k^2 + \mu k} - 4k - \mu - \alpha \right) \right] \geq \frac{1}{4}(\bar{c} + L - l) - \frac{1}{2}\underline{c}.$$

Both conditions are compatible if:

$$\frac{\mu}{4k} \left(\frac{\mu}{4k} - \sqrt{1 + \frac{\mu}{k}} \right) + \frac{1}{2} \left(\sqrt{1 + \frac{\mu}{k}} - 1 \right)^2 - \sqrt{1 + \frac{\mu}{k}} \left(\sqrt{1 + \frac{\mu}{k}} - 1 - \frac{\mu}{4k} \right) - \frac{\pi}{k} \geq 0.$$

This condition never holds, for any $k > 0$, $\pi > 0$ and $\mu \in (0, 4k)$. An exclusive contract, therefore, will never be offered.

Appendix 5. Proof of Proposition 5

Under asymmetric information, if the health authority pays the doctor a fixed salary such that $\bar{w} = \underline{w} = M$ and $B = 0$, the doctor will prescribe the strong treatment systematically. Then:

i) If the health authority wants to induce the strong-treatment strategy, an exclusive contract will never be offered.

ii) If the health authority wants to induce the mild-treatment strategy, it will be willing to offer an exclusive contract provided that:

$$R_{\max} \geq R_{\min} \Leftrightarrow \pi + \mu \leq \frac{\bar{c}}{2} - \underline{c} + \frac{(l - L)}{2}.$$

The right term of the inequality is always positive, since we are in the region in which the health authority chooses the mild-treatment strategy, i.e., in the region in which $\bar{c} + L > 2\underline{c} + l$.

Then, provided $\bar{c} > 2\underline{c} + l - L$ there exist values of $\mu > 0$ and $\pi > 0$ for which the health authority is interested in offering an exclusive contract that is acceptable by the physician.