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INCENTIVE CONTRACTS FOR PUBLIC HEALTH CARE PROVISION UNDER ADVERSE SELECTION AND MORAL HAZARD[1]

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February 1, 2001

Abstract

Any health care system should provide treatment so as to maximise expected social welfare. Whether health care provision is public or private, the implementation of this outcome, through the way health care providers or hospitals are compensated for the cost of providing services, has been a policy issue for a long time in a number of countries. Many payment reforms are now based on a (high-powered) DRG-price system, so as to induce cost consciousness. In this paper we analyse this issue for a public health care system, where public hospitals offer treatment. Each hospital is privately informed about the true disease of any patient, while cost control cannot be verified, and offer treatment with a stochastic outcome. Ex post outcome and realised cost of treatment can be verified, with cost depending on treatment intensity, cost-reducing effort and the type of disease. With a disease-contingent transfer, the hospital is able to capture a socially costly rent, because of tax distortions and because rent has no (direct) weight in the welfare function.

When type of treatment can be verified, treatment should be less intensive than under complete information, if marginal cost of treatment is disease-dependent. However, rent extraction is accomplished not only by a less aggressive treatment (which has a negative impact on the likelihood for recovery), but also by offering a cost-reimbursement scheme, without any recovery-contingent bonus. When treatment is unverifiable, induced treatment should again be below the first-best level. This solution is implemented through a combination of a recovery-contingent bonus (declining in severity) and cost sharing (with the fraction of cost being reimbursed by the government being increasing in severity).

1. Introduction

One of the striking features of any modern society is the observation that health care expenditures, relative to GDP, have been increasing at a relatively high rate since the World War II. This growth pattern is observed in countries with institutional differences both in the organisation of health care provision and in the financing arrangements. (Figure 1 in Chalkley and Malcomson (2000) provides a nice illustration of the substantial (and a rather congruent) increase in public health expenditures relative to GDP in OECD-countries between 1960 and 1992. Norway seems to have one of the highest growth rates according to this survey.)

Because the international comparison shows a systematic time pattern among countries, one might think there are some common explanatory factors behind the growth in health expenditures, independent of the institutional arrangements of the health care industry. One conjecture is that changes in demographic variables (like declining age-specific mortality rates caused by improved standard of living and better medical conditions, as been observed in most OECD-countries since 1950) might attribute significantly to the rise in medical expenditures. However, empirical findings based on data from US, do not support this hypothesis, as reported by Newhouse (1992, p.6), "aging can only account directly for a tiny fraction of the increase in expenditure".

Another potential factor explaining the overall rise in health expenditures has been that health care is a typical service industry, with an inelastic demand and with a labour-intensive technology. It has been taken almost for granted that productivity growth is slower for services (in general, for all sectors defined as "non-progressive") than in other "progressive sectors". Baumol (1967) takes this view and predicts that relative costs for services will increase over time; hence the rise in health expenditures. However, even though health care is a typical service industry, it is probably not true, according to Newhouse (op.cit.) again, to call the health industry a "non-progressive" sector. The technological and scientific progress since 1945 seems to be so important than it is beyond any common sense to consider this sector as "non-progressive". We have experienced outstanding advances in science, chemistry, biochemistry, biotechnology and medicine, far beyond what one could imagine 50 years ago. These advances have produced new scientific and medical knowledge that is being diffused around the world by a highly global profession, having new and effective procedures, as well as medicines and technical equipment, so as to cope with an increased number

of illnesses. Accumulation of medical knowledge will induce more treatment, both from the demand side and from the supply side. Normally this expansion effect due to technological progress will require more resources allocated to the health care industry. Social benefit from having increased the capabilities of treating more people from more diseases should after all, be expected to exceed social cost. But, even though technological improvements and scientific advances are expected to raise welfare, one should also try to assess the additional costs caused by the incentive effects due to improved knowledge. As newly invented procedures for dealing with certain diseases become known to the public, it is expected that this new information will generate some additional demand. If the government feels that demand will be increased at a too high rate caused by new treatment procedures and expanded knowledge, some demand-side cost sharing may solve part of this problem. On the other hand, if the medical staff in the health-care industry, for some reason or another, has an incentive to provide high-tech and (too) expensive services for treating patients, then one should redesign the incentive system or reorganise the institutions, so as to reduce these costs. (In real life, many policy reforms aimed at correcting the use of resources in the health industry can be seen as attempts to reduce these indirect costs due to bad incentives and inefficient organisational structures.) On the other hand, the accumulation of knowledge or technological progress might as well lead to savings in required input use, without reducing the likelihood for successful treatment. This effect is obviously socially beneficial.

Because health care expenditures cannot grow forever at a higher rate than the rest of any economy, some reforms are needed, so as to protect the Welfare State. However, it seems politically infeasible to impose reforms so as to affect demographic factors, while at the same time technological progress is appreciated by most governments, as an engine for economic growth and higher economic welfare. Hence, to reduce medical expenditures, most reforms have attempted to alter the incentives, both on the demand side and the supply side. In the search for reducing health care expenditures, one cost category has become the main target for most policy reforms, the so-called "agency costs". As noted by Ellis and McGuire (1993) and Gaynor (1994), agency costs seem to have a major impact on the growth in health expenditures. Almost any relationship between any two actors in health care provision, like that between physician and patient, health care provider and sponsor/procurer (either private or public), hospital and regulator, or that between an insured person and an insurance

company, seem to be disturbed by a series of agency problems. Ellis and McGuire (op.cit.) discuss how demand-side cost sharing (due to health insurance or co-payment) and/or supply-side cost sharing (the way a health care provider is compensated for the treatment offered a patient) may alleviate agency problems. (The most important sources for these agency costs are related to asymmetric or private information, moral hazard, lack of commitment power and the inability to write complete contracts; see Laffont and Tirole (1993) for more on these agency problems within the context of regulation. The main insight from this brilliant study is how the power of incentive contracts will be affected by the various informational and institutional problems.)

In the present paper we focus only on supply-side incentives to reduce costs of treatment, within an institutional setting with publicly provided health care services, where patients do not make any direct out-of-pocket-payment to the health care provider, which is organised as a pure public firm (public ownership). This institutional setting is quite different from the one we find in US. Hence the reforms being initiated in US should be expected to differ from the reforms we have seen in countries with more public ownership in the health care industry.

In 1983 the federal government changed the payment system in US, roughly, by leaving a low-powered payment system in favour of a more high-powered compensation system, so as to provide better incentives for health care providers to reduce costs. (According to Ellis and McGuire (op.cit.) this reform seems to show a reduction in average cost per hospital discharge. Others have shown that a reform like the one being imposed in US, has some adverse (and unintended) effects on hospital behaviour and medical outcomes; see Cutler (1995) and McClellan (1997).)

Any reform within the health care industry should not be judged solely by its capability to implement cost reductions. One should also take into account how the reform affects the quality of treatment being provided by the health care supplier, as measured by the impact on the likelihood for recovery. (In the large literature analysing the reform in US, quality is used in a number of ways. One is related to how the change in payment system affects the hospitals' incentive to engage in quality competition, while others are concerned about the incentives to dump high-cost patients. Both issues seem to be important within a system with private health care providers, see for instance Rogerson (1994), Ma (1994), Ellis (1998) and Lewis and Sappington (1999).) One paper, which takes explicitly into the account the relationship between payment system and quality of treatment as measured by the likelihood for recovery, is Gal-Or (1999). The present

paper extends her model by assuming that we have a public health care system, like the one is Norway. The main issue is to analyse, within that system, the tension or trade-off between providing incentives for cost reductions and provision of appropriate treatment (quality), which affects the likelihood for recovery. Although the papers having analysed the US health care reform seem to be differ substantially with regard to modelling assumptions, one might be tempted to draw one common conclusion from these papers. The payment system should be more low-powered (or involve more cost sharing) than many of the payment systems (like the prospective payment system in the US Medicare program) that have been proposed. This conclusion is confirmed in the present paper. (See also Chalkley and Malcomson (1996) for a discussion about the experience with contracting under NHS in UK.)

In the Norwegian health care system, payments to hospitals (most of them under public ownership) have from the late 90's been a combination of block contracts and cost per case contracts (or a fixed DRG-price per patient treated). The payment system was introduced so as to achieve cost effectiveness. Despite the change in the payment system, the anticipated cost reductions have not been realised. Public hospitals in Norway are running with "large deficits" due to cost-overruns, according to the owner (local public government). To eliminate these cost-overruns, the owners (or local politicians) have required reductions in the volume of work, (inflating the waiting lists, closing wards or reduce the number of beds), or by undertaking necessary changes in the internal organisation of the hospital system. None of these attempts seem to motivate hospitals to provide higher quality. (These days the Ministry of Health has prepared a plan for an extensive reorganisation of the entire hospital system, by transferring ownership rights from local authorities (counties) to the state. This can be seen as a first step towards bringing national health care expenditures down, by eliminating too extensive and expensive duplication of activities and encourage more competition among the hospitals. But if the old system suffered from some incentive problems, the new one will obviously suffer from others.)

The goal of any payment mechanism for the health care industry should be to motivate any provider to choose appropriate treatment or quality of the services provided for any patient at the lowest possible cost. With complete contracting and complete information, there should in principle be possible to specify what treatment and what cost reductions any health care provider should undertake for any type of patient with some well-specified disease. In the real world, complete contracting is seldom feasible,

while the relationship between the government, the patients and the health care provider will suffer from private information, as well as moral hazard problems due to non-verifiable actions. In this paper we will consider a model, which is influenced by the approach taken by Gal-Or (op.cit.). We'll focus on the trade-off between cost effectiveness and quality as given by the mapping from the choice of treatment induced by the payment system into the likelihood for recovery when the hospital has private information about the true disease of any patient. In contrast to the approach taken by Gal-Or, we assume that the cost of treatment is disease-contingent, and increasing in severity. We will look at how the optimal solution can be implemented through the design of a payment scheme, which we restrict to be in a class of a modified DRG-system, with some disease-contingent transfer, a recovery-contingent bonus, and some cost sharing. Irrespective of what can be explicitly written into a contract, the provider will have an incentive to report a more severe disease than the true one, so as to capture a socially costly rent. (This type of "DRG creep" or "coding" matters also in the problem analysed by Lewis and Sappington (op.cit.).) To prevent this type of overstating, while at the same time provide incentives for appropriate treatment and cost-reducing effort, with an overall objective to maximise expected social welfare, the payment scheme will combine cost reimbursement and (possibly) an ex post reward for successful outcomes. The outcome of any treatment (recovery or not) can be verified, which itself is rather dubious. We furthermore ignore any type of professional ethics among the medical staff (except in section 5 where we regard a relaxed version of the model) , which is a rather restrictive assumption, as well. The paper is organised as follows: In section 2 the model is presented. This model is made up of a treatment-technology for each disease, mapping the choice of treatment (conditional on the disease), into a probability of success, with cost of treatment depending both on the true disease and the choice of treatment, and on the hospital's choice of cost-reducing effort, as well. The first best or complete information is derived, as a benchmark, where the regulator's objective is to maximise a weighted average of expected net benefit to the patients and rent to the hospital, with a higher (exogenous) weight put on patient interests. In section 3 we introduce private information and moral hazard, where the government has a goal of controlling cost of treatment by specifying treatment for any disease. (Treatment is then verifiable.) This approach can be seen as a way of setting a cost target for each disease, as the basis for the DRG-system. Realised cost of treatment can be observed, whereas internal cost-reducing effort

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cannot. In this case we show that there is no need for rewarding successful treatment. When cost of treatment is increasing in severity, the hospital can obtain a rent by disguising the true disease through coding. To prevent misrepresentation of the true disease (overstating), due to disease-dependent cost, the payment scheme, implementing the second-best optimum, can be seen as a combination of a DRG-price, with some cost reimbursement, with a fraction of realised cost being reimbursed by the government. The fraction of realised cost being paid by the government is shown to be increasing in severity. The rationale for this payment mechanism, being more and more low-powered the more severe disease is being treated, is that overstating then turns out to be less profitable for the hospital. To leave less rent to the hospital, a smaller fraction of the inflated cost (due to overstatement) will be kept as rent by the hospital. Only when cost of treatment is independent of disease itself, an optimal contract will be close to Prospective Payment System, with a fixed disease-contingent DRG-price paid to the health care provider. Because the hospital in this special case is not able to capture a rent, no distortions (so as to reduce rent) are necessary and the first-best solution can be implemented by ordinary DRG-prices.

The DRG-cost target setting in section 3 is based on a rather inflexible system, where the hospital is left with very little discretion as to the choice of appropriate treatment. It seems more likely that a treatment-effective health provider system should rely on the hospital's own expertise and judgement when it comes to the choice of an appropriate way of treating a person with some disease known only by the hospital. We therefore leave the inflexible cost targeting of section 3, and replace it with a system where treatment no longer can be verified by the government, but outcome still can. Because the hospital now has full discretion as to the choice of treatment, some reward or recovery-contingent bonus should be imposed. For this payment scheme to be incentive compatible, we show that it will be more high-powered for the least severe diseases, with the reward or "fixed payment" being higher (smaller) and the fraction of cost being reimbursed by the government being smaller (higher) for the least (most) severe illnesses. (This is also one conclusion drawn by Lewis and Sappington (op.cit.), where the issue is dumping or withholding of treatment from high-cost patients.) The payment scheme implementing the optimal solution when choice of treatment is non-verifiable becomes increasingly more low-powered, as more severe diseases are treated.

In section 5 we relate our findings to practical-life implementation where we relax some of the restrictive assumptions of the model used in section 4, whereas section 6 summarises the main conclusions. (The formal derivation of the main results is provided in the Appendix.)

2. The Model

We consider the regulation of a public hospital within an institutional setting where fully insured patients are assigned treatment in a hospital covering a certain geographical area. To focus on the relationship between quality of treatment (as measured by its likely success) and incentive issues, we suppose that each hospital's cost function consists of some common as well as some idiosyncratic element. The common part is publicly known, while it is common knowledge that the idiosyncratic part is independently and identically distributed among the hospitals. Hence, each hospital can be regulated independently. Because the patient, by assumption, has no choice about type of treatment and health provider, and does not make any direct payment to the hospital for being treated, there might be a problem whether the hospital will have any incentive to choose the appropriate treatment and to produce efficiently. These problems are of course related to what kind of reimbursement contracts offered by the government. Within an institutional setting like the one described above, the regulator should have a strong incentive to design a payment system so as to motivate the hospital to choose the appropriate treatment and by so provide sufficient care or treatment quality. The institutional setting of the health care industry in Norway is quite different from the organisation of the health care industry in countries like US, where quality is a commonly used instrument among competing private health providers to attract patients. Hence there is a closer link between quality and demand in the US-system than within the "non-optional" system in Norway. (The current health care reform in Norway intends to let patients have some choice of freedom as to where to have treatment.) To induce a public hospital to take the appropriate actions, especially when it comes to choice of treatment and provision of quality, while at the same time prevent the hospital from dumping any high severity patients, we need an incentive scheme that rewards quality. In this paper we let quality be related to whether treatment offered will help a patient to recover from the disease. These issues will be discussed within a model, with three groups of risk-neutral actors: Patients (playing a passive, but should, without doubt, play the leading role), a publicly

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owned health care provider or hospital, and the government (playing the role both as sponsor, procurer and regulator). We will focus on a hospital's primary task to treat patients suffering from some diseases or illnesses. The model is based on the set-up found in Gal-Or (op.cit.). In her setting, cost of treatment is does not vary with the severity of the patient's disease, which is private information to the hospital. In this paper we explicitly assume that cost of treatment does not only vary with treatment intensity and cost-reducing effort, but with severity of the illness as well. We'll see that this assumption has some impact on the optimal solution.

The hospital is being assigned a flow of patients during some given period of time. (The number of patients is normalised to one.) A patient has some disease, represented by s, where $s \in [0, 1] := S$ is the space of all diseases, where a higher s represents a more severe disease. We let s be a continuous stochastic variable, with cumulative distribution function F(s), differentiable and strictly increasing in s; hence the density f(s) is positive for any $s \in S$. (The distribution satisfies by assumption "the inverse hazard rate property"; saying that $\frac{d}{ds}\frac{F(s)}{f(s)} \geq 0$. The set S as well as the distribution function F(s) is common knowledge.) We will assume that the disease itself can be identified by the diagnosing effort of the hospital. The true disease is private information to the hospital.

There is some common treatment technology used by all hospitals. This technology, which is common knowledge, will assign a probability of recovery $P(n,s) \in [0, 1]$, for some patient with disease s, when treatment intensity (or aggressiveness of treatment) is n. (According to Rogerson (op.cit.; p.8), "Treatment intensity is a term used to refer to the level of resources a hospital employs to treat a particular illness. Treatment intensity can be increased, for example, by increasing length of stay, performing more tests, using more sophisticated equipment, etc.". We use n as an index for those in-door activities that will have some impact on the probability of recovery.) We let n be one-dimensional and continuous, normalised to be in the interval of unit length; i.e. $n \in [0,1]$ for any s. The upper bound on treatment intensity shows the physically maximal input of resources used per unit of time in treating a patient with some illness.

In the subsequent analysis we will make the strong assumption that treatment provided to some person with some disease s can be ex post verified as either a success or a failure. Ex ante a patient with disease s will, if being given treatment n, be cured with

probability *P(n,s)*. The social benefit or gain from recovery is *G(s)*. (If non-recovery, we adopt the convention that the benefit is zero. We furthermore assume that *G(s)* is sufficiently high so that any disease should be treated, but not necessarily with the same treatment intensity.) The treatment technology *P(n,s)* is assumed to be sufficiently differentiable, with the following "neo-classical" properties, where subscripts indicate partial derivatives:

A1: $P_n(n,s) > 0, P_{nn}(n,s) < 0, P_s(n,s) < 0, P_{ns}(n,s) \geq 0$

For any $s \in S$, the probability of recovery increases, but at a decreasing rate, with treatment intensity. For some $n \in [0,1]$ the probability of recovery is decreasing in severity, while intensified treatment will have a (weakly) stronger impact on the probability of recovery the more severe is the disease. We also assume *P(0,s)* is close to zero (or sufficiently small) for any s, $P_n(n,1) \to \infty$ as $n \to 0$, and $P_n(n,s) \to 0$ as n $\to 1$ for any $s \in S$. (For a subset of diseases, we might have $P(n,s) \to 1$ as $n \to 1$ or even for some $0 < n < 1$, which might typically be the case for less severe diseases with well-documented treatment programmes.) According to these assumptions, some treatment or input of resources is required to produce a positive recovery rate for any possible disease.

The hospital incurs a monetary cost of undertaking some treatment n for a patient with disease s as given, in general, by *C(n,e,s)*, where e is cost-reducing effort, normally unverifiable, with $e \in [0, 1]$. C is assumed to be sufficiently differentiable and convex in (n,e). Like Gal-Or (op.cit.), C is separable, with *C(n,s,e) = k(n,s) + g(e)*. This specification implies that cost-reducing effort affects only fixed costs of treating a patient. The cost function is assumed to satisfy the properties as given in A2:

$$k_n(n,s) > 0, k_{nn}(n,s) \geq 0, k_s(n,s) \geq 0, k_{ns}(n,s) \geq 0, k_{ss}(n,s) \geq 0$$

A2: $\quad g'(e) < 0, g''(e) > 0, with\ g'(0) = -\infty, g'(e) \to 0\ as\ e \to 1$

$$k_{ssn}(n,s) \geq 0, k_{snn}(n,s) \geq 0, and\ k_n(n,s)\ high\ as\ n \to 1$$

The cost function is strictly increasing and convex in treatment intensity, with both total and marginal cost of providing treatment intensity being increasing in severity of

the illness, whereas C, for any {n,s}, will be strictly decreasing and strictly convex in cost-reducing effort. (As mentioned above, Gal-Or (op.cit.) uses also a separable cost function, which however, depends only on n and e, but not on s as in the present paper. C is observable, but due to a random shock, no inference about (n,e) can be made from observing realised cost within her context.) In the present paper cost of treatment is also observable ex post, but because at least two of the arguments of the cost function can be verified, no inference can be made from observing C alone. Because we assume that realised cost has to be paid by the health care provider, any transfer from the government has the character of a gross transfer.

The disutility of exerting cost-reducing effort is given by a sufficiently differentiable, increasing and convex function $v(e)$, with $v(0) = v'(0) = 0$, $v'(e) > 0$ for any $e \in (0, 1]$ and $v''(e) > 0$ for any $e \in [0, 1]$. To avoid corner solutions, we assume that $v'(1)$ is sufficiently high.

We rule out lump-sum taxation, so any transfer to the health provider is raised through distortionary taxes. The marginal cost of public funds, m, is exogenous and positive.

The hospital's incentive for undertaking care and exerting cost-reducing effort can be modelled in a number of ways. Within some institutional settings, like the on in US, the hospital has a very clear perception of the link between treatment intensity (or provision of quality) and willingness to pay, whereas in others this link is almost non-existent or very weak. To focus on a setting like the one in Norway, where fully insured patients do not make any direct payment to the hospital, this link has to be internalised or imposed onto the hospital in some way. If this internalisation should happen to be successful, the hospital manager and the medical staff will normally have some notion of the relationship between treatment intensity and cost. If not, we'll experience cost-overruns due to lack of cost consciousness, which might be met by unpopular policy measures, say like longer waiting lists to get a specific treatment. (Bad incentives for cost consciousness along with too strong reliance on the ethics of the medical staff will in general not promote efficient use of resources.) A pitfall is that the desire to reduce costs might be emphasised too strongly by the politicians in the short run, causing an unintended fall in the provision of quality.

The issue raised in this paper is how to design an optimal compensation scheme, implementing the optimal trade-off between quality provision and cost of treatment.

Because treatment intensity and cost-reducing effort in general cannot be verified, the main problem facing the regulator is how to cope with moral hazard as well as interim private information. In the subsequent analysis we will introduce a bonus or reward system as part of the incentive scheme, related to the expected number of successful treatments, as given by the ex ante measure *P(n,s)*. This will be the mirror image of the "punishment" mechanism suggested by Gal-Or (op.cit.). In US more emphasis is put on malpractice liabilities, malpractice costs and losses in hospital reputation if the patient does not recover, than what we so far have experienced within a public health care system like the one in Norway. Therefore, when designing a compensation scheme for a system consisting mainly of public hospitals, we have to rely on other incentive mechanisms than what we usually find in well-defined markets.

Suppose first that we are in a world of symmetric information and that the regulator can fully enforce the treatment programme for any disease and also get the hospital to undertake the desired cost reductions. Expected benefit to a patient having disease s, when being offered a treatment given by n, is *P(n,s)G(s)*. The taxpayers have to finance total cost of treatment as well as any rent to the hospital. Let rent to the hospital for treating disease s be $U(s) = T(s) - [k(n,s) + g(e)] - v(e)$, where *T(s)* is some gross transfer associated with disease s. We will require U to be non-negative for any s, so as to avoid dumping by patients. Then the expected net welfare to consumers (taxpayers and patient with disease s) will be

(1) $R(s) = P(n,s)G(s) - (1 + m)T(s) = P(n,s)G(s) - (1+m)[k(n,s) + g(e) + v(e) + U(s)]$

Let for a moment social welfare be given by a weighted average of R and U, with a higher weight put on patient interests; $\beta \in (\tfrac{1}{2}, 1]$. If the regulator should be in a position to dictate treatment as well as cost-reducing effort, with a goal of maximising $W = \beta R + (1-\beta)U = \beta\{P(n,s)G(s) - (1+m)[k(n,s) + g(e) + v(e) + U(s)]\} + (1 - \beta)U$, for any s, under the constraint that U should be non-negative, the first-best allocation is characterised by:

Proposition 1.

Under complete information, optimal regulation (treatment, cost-reducing effort and hospital rent) for any disease $s \in S$, is characterised by

(2a) $P_n(n^*(s), s)G(s) = (1+m)k_n(n^*(s), s)$; $n^*(s) \in (0, 1)$

(2b) $v'(e^*) = -g'(e^*)$; $e^* \in (0, 1)$

(2c) $U^*(s) = 0$, because $\beta(2+m) > 1$

Hence first-best treatment of a patient with disease s is characterised by a treatment programme, $n^* \in (0,1)$, so that expected social marginal gain from assigning treatment is equal to the social marginal cost of providing treatment (treatment efficiency), with cost-reducing effort determined so as to minimise $\{g(e) + v(e)\}$; i.e. cost minimisation or internal efficiency, while no rent should be offered to the hospital (because transfers have a social cost due to distortive taxation). Due to the assumption that cost is separable, e^* is independent of s. (Whenever $\beta > \frac{1}{2}$, the complete information solution is independent of the weight put on rent; hence in the subsequent discussion we assume $\beta = 1$, so that only patient interests matter in the objective function of the social planner.)

A reasonable restriction to put on the solution of the model is that first-best optimal treatment should be increasing in severity, by definition of severity itself. Hence to have $n^*(s)$ increasing in s, we require that

$$\left\{(1+m)k_{ns}(n^*, s) - P_{ns}(n^*, s)G(s) - P_n(n^*, s)G'(s)\right\} < 0$$

which together with $[P(n,s)G(s) - (1+m)k(n,s)]$ being strictly concave in n, makes treatment increasing in s; i.e. we have $n^*(s') > n^*(s)$ *for any s' > s.*

Because there is a one-to-one correspondence between treatment and disease, we can write the gross transfer T as the sum of a treatment-contingent part, derived from the variable part of the cost function, $k(n^*(s), s) := K(s)$, on using (2a) in Proposition 1, and a fixed part $t_0 = g(e^*) + v(e^*)$. (The disease-dependent part of this transfer K(s) is strictly increasing in s.) When offering a modified gross DRG-transfer, as given by, $T(s) = K(s) + t_0$, the hospital will make choices compatible with the social optimum,

when information is complete and no incentive problems of the moral hazard-type exist. (The implementation issue is not a real issue under complete information, but we present it for completeness.) However, once we leave the world of complete information, this gross transfer will induce the hospital to take actions not compatible with the first-best solution. The hospital might then be induced to some kind of "artificial creaming", by pretending to disguise low severity patients as high severity ones, and then capture a socially costly rent. To reduce this rent, the regulator has to design a different set of contracts, an issue to which we now turn.

3. Regulation under incomplete information: Treatment chosen by the regulator

We first want to see the impact of both adverse selection and moral hazard on the transfer or incentive scheme, when the patient-biased regulator has a goal of controlling treatment cost by dictating some appropriate treatment for any disease. The hospital has private (interim) information about the patient's true disease, and can take a non-verifiable action so as to reduce cost of treatment (with cost being observable). The point of departure is that the hospital might be able to capture a socially costly rent due to what has been denoted "coding" or "creaming". Such behaviour might still be possible even though the regulator is able to dictate treatment for any disease. If the transfer rule, implementing the complete-information solution, should be offered in this case, the hospital is inclined to overstate the disease, so as to capture a rent. However, to alter these incentives, when the outcome of the treatment (success or not) can be verified, the payment scheme is expected to involve some cost sharing and (perhaps) some bonus or a recovery-contingent reward.

The timing of the game is as follows: At the ex ante stage of the game (before the hospital learns the true disease), the hospital and the regulator share the same information, as given by the probability distribution function F(s). At this stage of the game, the regulator designs (and commits to) a scheme of the following kind: For any reported disease $\hat{s} \in S$, a direct revelation mechanism { $t(\hat{s}), b(\hat{s}), \alpha(\hat{s}), n(\hat{s})$ } is offered to the hospital, specifying a disease-contingent transfer $t(\hat{s})$, a bonus $b(\hat{s})$ if success, a fraction of realised cost being reimbursed $\alpha(\hat{s}) \in$ [0, 1], and a specific treatment programme n($\hat{s}$). At the interim stage of the game, when the hospital learns the true disease of a patient, it chooses { $\hat{s}$, e} so as to maximise expected rent, given the mechanism, which is designed so as to induce truth-telling ($\hat{s} = s$). At this interim

stage of the game, the hospital has an expected rent as given by, see also Laffont (1995):

(3) $U(\hat{s}, e; s) = t(\hat{s}) + P(n(\hat{s}), s)b(\hat{s}) - (1 - \alpha(\hat{s}))[k(n(\hat{s}), s) + g(e)] - v(e)$

(The proposed mechanism is a modified DRG-system, with both some base payment (t), some performance pay (Pb) and some cost sharing. A scheme with $\alpha = 0$, leads to a fixed price (similar to prospective payment), whereas a scheme with $\alpha = 1$, means full cost reimbursement.) (These extremes will have quite different impact on the hospital's cost-reducing effort.)

At the last stage of the game, when cost is realised and the outcome can be verified, transfers take place according to the initial contract.

Let us restrict attention to differentiable mechanisms. As seen from the results derived in the appendix, the first- and second-order conditions for incentive compatibility will then be

(4-i) $\dot{U}(s) = P_s(n(s), s)b(s) - (1 - \alpha(s))k_s(n(s), s)$

(4-ii) $P_s(n, s)\dot{b}(s) + k_s(n, s)\dot{\alpha}(s) + [P_{sn}(n, s)b(s) - (1 - \alpha(s))k_{sn}(n, s)]\dot{n}(s) \geq 0$

According to our assumptions, a set of sufficient conditions for the second-order condition (4-ii) to hold is that b(s) is non-increasing, $\alpha(s)$ is non-decreasing and n(s) is non-decreasing (respectively, non-increasing) if the term within brackets in (4-ii) is non-negative (non-positive). When solving the regulator's problem, we'll ignore the second-order condition and check later whether the proposed candidate in fact obeys this condition; see the Appendix.

The interim net benefit to the group of taxpayers and the patient with disease s, is given by R(s) in (1), for some arbitrary set of instruments {b(s), α(s), n(s)}.
The regulator's objective ex ante is to maximise expected welfare, as given by

$W^E = \int_0^1 R(s)f(s)ds,$ subject to the set of feasibility constraints. (Hospital rent has no

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direct value in the social objective, because we let $\beta = 1$; cf. the remark following Proposition 1.) The problem is therefore to choose, within the class of incentive-compatible mechanisms, a scheme $\{b(s), n(s), \alpha(s); \forall s \in S\}$ so as to maximise W^E. (The set of feasible mechanisms has to obey the incentive constraints, including the first- and second-order conditions for truthtelling, the participation constraint and the moral hazard constraint.) In this problem treatment is under the control by the regulator, whereas the hospital is free to choose cost-reducing effort, as well as report the disease of the patient. To prevent "dumping", an ex post participation constraint is imposed for any s; hence we require $U(s) \geq 0$ for any s. (This case is therefore very similar to the problem leading to Observation 1 in Gal-Or (op.cit.). However, we'll see that our solution will differ from her result, because cost of treatment varies with s.) The problem is formulated in the appendix, where we demonstrate the following result:

Proposition 2.

When the regulator tries to control cost of treatment by specifying treatment programme for any disease, the hospital can choose cost-reducing effort and report the patient's disease, optimal regulation is characterised by: For any $s \in S$, there should be no recovery-contingent bonus, assigned treatment should (normally) be less intensive than under complete information and some cost sharing (being increasing in severity) should be imposed; as giver by

(5-i) $b(s) = 0$

(5-ii) $P_n(n,s)G(s) = (1+m)k_n(n,s) + (1+m)\dfrac{F(s)}{f(s)}(1-\alpha)k_{sn}(n,s)$

(5-iii) $\alpha g'(e(\alpha))\dfrac{\partial e}{\partial \alpha} = \dfrac{F(s)}{f(s)}k_s(n,s)$

if the second-order condition for incentive compatibility is obeyed for the set of contracts implicitly determined by (5i-iii).

(See the appendix for further details.)

The interpretation is as follows: Suppose that *{b(s), n(s), α(s)}* derived from these conditions in fact will obey the second-order condition for incentive compatibility.

When the regulator can assign treatment for any reported disease (and by so set a cost target for a fraction of the cost of disease-specific treatment), and can choose a cost-sharing arrangement, cost inefficiencies have to be traded off against rent extraction. As b = 0 for any s, we note from the state equation (4-i) that the absolute value of the slope of the rent function, is being reduced by reimbursing a higher fraction of realised cost (and so induce less cost-reducing effort), and, more indirectly, by lowering n so as to reduce $k_s(n,s)$. But when treatment intensity is being lowered, the likelihood for successful treatment is also reduced. Ideally the regulator should like to assign treatment for any disease so as to maximise expected social net benefit, with no cost sharing and no rent offered to the health provider; cf. Proposition 1. Due to interim private information about the true disease, the hospital will, if such a menu were offered ex ante, have a strong incentive to overstate the disease, through an artificial upgrading of the reported diagnosis, so as to capture an informational rent. Offering rent is socially costly, due to no weight placed on rent in the welfare function and the cost of tax-financing the transfer. Therefore the administered treatment chosen by the regulator should be less intensive, as compared to an ideal situation. This trade-off is captured in (5-ii). When the regulator offers a less intensive treatment programme for the severe diseases, as compared to what we would have preferred under complete information, the planner takes a social loss as direct expected net benefit will be reduced. At the margin, the loss will exactly balance the saving in hospital rent induced by a less aggressive treatment programme.

To implement this second best solution, some cost sharing is required. If the profile $\alpha(\cdot)$ is everywhere increasing, a higher fraction of cost should be reimbursed for a more serious disease than for a less serious one, making the induced distortion in treatment intensity smaller; cf. the last term in (5-ii). The rationale for this cost sharing arrangement is that if a higher fraction of realised cost is reimbursed, a smaller fraction of any inflated cost from overstating will be retained as rent by the hospital, thereby making it less profitable to overstate the true disease. Hence, to avoid upgrading, the incentive scheme is made more low-powered for the more serious diseases, starting with no cost sharing for the least serious disease; $\alpha(0) = 0$.

Proposition 1 has some implications, as stated in the subsequent corollaries.

Corollary 1

If treatment cost is independent of s, the first-best optimal solution can be implemented, with no recovery-contingent bonus and no cost sharing; b = α = 0 for any s∈S, with treatment programme for disease s identical to $n^*(s)$. Rent extraction is in this case no issue because the hospital cannot capture any rent by disguising the true disease.

(When cost is independent of s and when treatment programme is under the control by the regulator, so that each disease can be treated according to some cost target, the hospital has no way of manipulating information to get a rent. This result is identical to Observation 1 in Gal-Or, with the proper reinterpretation of b.)

In section 2 we noted that this solution could be implemented through a system of fixed disease-contingent transfers, interpreted as a DRG-price or prospective payment. We therefore have:

Corollary 2

When cost of treatment does not vary with s, the optimal payment system is a DRG-system (with some block payment), with price paid for treating disease s as given by T(s) = K(s) + t₀.

(This result follows directly from the complete information solution.)

Corollary 3

If cost of treatment is positively correlated with the disease, i.e. $k_s(n,s) > 0,$ but $k_s(n,s) = \phi(s)$ is independent of treatment intensity for any n∈[0,1], then it will be optimal to implement the first-best treatment programme. To reduce rent to the hospital, a fraction of cost is reimbursed, with the power of the incentive scheme being decreasing with s, with α(s) implicitly determined from, $\alpha g'(e)\dfrac{\partial e}{\partial \alpha} = \dfrac{F(s)}{f(s)}\phi(s)$.

(In this case the regulator will implement a treatment programme so as to maximise expected net surplus, but because the hospital is able to disguise the true disease so as to capture a rent, a higher fraction of realised cost should be reimbursed for the more

severe diseases. The power of the incentive contract is declining with severity of the disease.)

We have so far designed the optimal set of contracts when the regulator has power to fully specify treatment for any disease and when the hospital has interim private information about the patient's true disease. We have seen that treatment intensity (when treatment cost depends on disease, taxes are distortionary and when only patients' interest matters in the planner's objective function) should in general be distorted downwards compared to what would have been imposed under symmetric and perfect information. This distortion is imposed due to the desire to reduce expected rent to the hospital, when the interim participation constraint must be honoured (so as to prevent dumping). To provide incentives for the hospital to report truthfully, the incentive scheme is made more low-powered (with more cost sharing) for severe diseases. Hence, a fixed disease-contingent transfer, like a DRG-price or prospective payment, does not in general implement the optimal solution, as some cost sharing is shown to be socially desirable, inducing internal as well as external inefficiencies. This result differs from the one derived by Gal-Or (op.cit.) because cost of treatment is disease-dependent.

We now relax the assumption that the regulator is able to dictate treatment intensity. We have earlier remarked that this cost target system seems to be rather inflexible, leaving very little scope for the hospital's own medical staff to take advantage of its expertise and competence. If some policy reform in the future should impose a quasi-competitive system (yardstick competition) among public hospitals, we'll expect that it will be advantageous to let each hospital operate within a flexible system, with some degrees of freedom as to the choice of treating any disease. We therefore leave the inflexible system, and replace it with one with more flexibility, where each hospital is free to choose whatever treatment programme which it finds appropriate for any given disease, as well as how much resources that should be spent on reducing costs. This problem is very similar to one analysed by Gal-Or. However, we want to see how the optimal solution is affected within a public health care system by explicitly assuming a disease-dependent cost function.

4. Contracting when Treatment is Non-Verifiable

The case analysed above is somewhat restrictive and unrealistic. Regulators have seldom the power and ability to design such sophisticated contracts as outlined in the previous section. When relaxing the assumption that treatment can be set by the regulator, and instead let the hospital to be free to choose both cost-reducing effort and treatment intensity, we guess that the contractual arrangement will be altered.

In this case the hospital is offered a direct mechanism, $\{t(\hat{s}), b(\hat{s}), \alpha(\hat{s})\}$, so as to induce interim-revelation of the true disease ($\hat{s} = s$), or to resist any overstating. (Such misrepresentation is an issue as long as cost of treatment varies with s and when choice of treatment is under the control of the hospital.) When the health care provider is offered this mechanism, it will for any s (at the interim stage of the game) in general choose $\{\hat{s}, n, e\}$ to maximise interim expected utility as given in (6).

$$(6) \qquad U(\hat{s}, n, e, s) = t(\hat{s}) + P(n, s)b(\hat{s}) - (1 - \alpha(\hat{s}))[k(n, s) + g(e)] - v(e)$$

(Note that U is strictly concave in (n,e).) Hence, for any positive b, any $\alpha \in [0, 1)$, and for any report $\hat{s} \in S$, maximisation of U requires that the first-order conditions (7i-ii) – (9) below are satisfied:

$$(7\text{-}i) \qquad \frac{\partial U(\hat{s}, n, e, s)}{\partial n} = P_n(n, s)b(\hat{s}) - (1 - \alpha(\hat{s}))k_n(n, s) = 0$$

$$(7\text{-}ii) \qquad \frac{\partial U(\hat{s}, n, e, s)}{\partial e} = -(1 - \alpha(\hat{s}))g'(e) - v'(e) = 0, \text{ with } e = 0 \text{ if } \alpha = 1$$

The decision rules implicitly determined from (7i-ii) are common knowledge. For a given report $\hat{s}$, which gives rise to cost-sharing $\alpha(\hat{s})$ as well as a recovery-contingent bonus $b(\hat{s})$, (7i-ii) implicitly determine a set of decision rules, as given by $n(\alpha(\hat{s}), b(\hat{s}), s)$ and $e(\alpha(\hat{s}))$, where e(·) depends only on the function $\alpha(\hat{s})$.

When n is under the control by the hospital, we note that some bonus has to be offered so as to produce a positive likelihood for recovery, as opposed to the case when treatment was under the regulator's control, i.e. when n itself is verifiable.) Given the

separable cost function, n is strictly increasing in both b and α, whereas e is strictly decreasing in α, as seen from

$$(8) \quad \frac{\partial n}{\partial b} = \frac{-P_n}{bP_{nn} - (1-\alpha)k_{nn}} > 0, \quad \frac{\partial n}{\partial \alpha} = \frac{-k_n}{bP_{nn} - (1-\alpha)k_{nn}} > 0, \quad \frac{\partial e}{\partial \alpha} = \frac{-g'}{-(1-\alpha)g'' - v''} < 0$$

For b > 0, and for α → 0 (we approach a situation with no cost reimbursement or a fixed price contract), $e \to e^*$ from (2b) in Proposition 1, whereas n will be reduced, but will be positive given our assumptions. On the other hand, when we approach full cost reimbursement, as α → 1, then e → 0, whereas treatment will be very "generous", with n → 1. We therefore have that more cost sharing will increase the likelihood for recovery, but will also produce a high cost of treatment, as e approaches zero. On the other hand, a fixed price will have a negative impact on the likelihood for recovery, but will encourage cost reductions.

The first-order condition for truthful revelation is

$$(9) \quad \frac{\partial U(\hat{s}, n, e, s)}{\partial \hat{s}} = \frac{dt(\hat{s})}{d\hat{s}} + P(n, s)\frac{db(\hat{s})}{d\hat{s}} + \frac{d\alpha(\hat{s})}{d\hat{s}}(k(n, s) + g(e)) = 0 \text{ for } \hat{s} = s$$

(In an appendix the second-order condition for a local maximum is given. However, for ease of exposition we just assume in the subsequent analysis that the second-order condition is satisfied for the equilibrium contract.)

The hospital's interim expected utility when the true disease is revealed at this stage, and when the decision rules for the moral hazard variables n and e are used, is then

$$
\begin{aligned}
U(s) = {} & t(s) + P(n(\alpha(s), b(s), s), s)b(s) \\
& - (1 - \alpha(s))[k(n(\alpha(s), b(s), s), s) + g(e(\alpha(s)))] - v(e(\alpha))
\end{aligned}
$$
(10)

Then we can write the first-order condition for incentive compatibility as

$$(11) \quad \dot{U}(s) = P_s(n(\alpha, b, s), s)b(s) - (1 - \alpha(s))k_s(n(\alpha, b, s), s)$$

According to our assumptions, U(s) is non-increasing in s, indicating that the hospital has a unilateral incentive to overstate the true character of the disease, with U(1) ≥ 0 as a boundary constraint. (In Gal-Or (op.cit.) the incentive for misrepresentation goes in the same direction (overstatement), but within her context, as noted above, it was assumed that cost does not vary with s in a systematic way; hence a term like the last one in (11) does not appear in her model. As we will see later and already seen, whether cost of treatment varies systematically with s, do in fact have implications for the type of contracts being offered.)

The regulator's problem is now to determine the set of available instruments {b, α} so as to maximise expected net welfare, subject to the various constraints of the problem (incentive constraints, participation constraints and the two moral hazard constraints). The solution to this control problem, which is provided in an appendix, can be summarised as:

Proposition 3.

When the hospital has full discretion as to cost-reductions and treatment intensity, some recovery-contingent bonus has to be offered, along with some cost reimbursement, given by {b, α}, when assuming α∈ [0, 1), so that for any s∈S,

(12-i) $\quad b(s) > 0$

(12-ii) $\quad \alpha g'(e(\alpha)) \dfrac{\partial e}{\partial \alpha} = \dfrac{F(s)}{f(s)} \left[k_s(n,s) - P_s(n,s) \dfrac{\dfrac{\partial n}{\partial \alpha}}{\dfrac{\partial n}{\partial b}} \right] = \dfrac{F(s)}{f(s)} \left[k_s(n,s) - P_s(n,s) \dfrac{k_n}{P_n} \right]$

when using (8), with no cost sharing for the least severe disease, $\alpha(0) = 0$, and inducing treatment intensity $n = n(\alpha, b, s)$ according to

(12-iii) $\quad P_n(n,s)G(s) = (1+m)k_n - (1+m)\dfrac{F(s)}{f(s)} \left[bP_{ns} - (1-\alpha)k_{ns} + \dfrac{P_s}{\dfrac{\partial n}{\partial b}} \right]$

(We have implicitly assumed that the solution in Proposition 3 will satisfy the sufficient conditions, $\dot{b}(s) \leq 0$ and $\dot{\alpha}(s) \geq 0,$ for the second-order condition for incentive compatibility to hold. We also observe, due to cost sharing, that cost-reducing effort e(s) follows from the moral hazard-constraint (7-ii), with e$\in$ (0, e*] and e(0) = e*(0), but with e(s) < e*(s) for all other diseases. The payment scheme implementing the second-best optimal solution is more low-powered than a prospective payment system or a system with fixed disease-contingent (DRG) transfers.)

When "treatment-governance" is transferred to the hospital, we expect that the health care provider will be able to take advantage of a better position and therefore capture a higher rent. The reason (which will be relaxed in section 5) is that we have assumed that for the hospital to undertake any treatment at all, some recovery-contingent bonus (b > 0) has to be offered. The higher is b, the steeper is the slope of the rent function, $(-\dot{U}(s)) = (-P_s(n,s))b + (1-\alpha)k_s(n,s)$, but treatment will according to (8) be more aggressive as well. Condition (12-iii) captures the planner's trade-off between the interest of the patients (as well as the society) and rent extraction. This condition provides a rule for how to fix the bonus to be awarded the hospital if a patient with a reported disease s should recover. Given an optimal cost-sharing system. The bonus (b) for disease s, should be adjusted so that the increase in expected social surplus, induced by the hospital's incentive to use more resources on a patient with disease s,

$P_n(n,s)G(s)\dfrac{\partial n}{\partial b}f(s)$, should be equal to the increase in total expected social cost from a higher bonus. The social marginal cost can be split in two terms: First the social value of the direct marginal (resource) cost of treating a patient with disease s induced by the hospital's response as b gets higher, $(1+m)k_n(n,s)\dfrac{\partial n}{\partial b}f(s)$, and secondly, the social cost of the (inframarginal) increase in expected rent from increasing the bonus for disease s. When b(s) is increased, the aggressiveness of treating disease s will, according to (8), increase. But then it will also become attractive for the hospital, from the point of view of capturing a higher rent, to claim that all diseases less severe than the s-disease are more serious than what they in fact are. Hence, to induce truthtelling, while at the same time produce the desired treatment intensity for any disease s, more rent (higher transfer) must be awarded to the hospital for treating any of the diseases

less severe than the s-disease. The impact on inframarginal expected rent from a small increase in b(s)is captured by the following expression

$$(1+m)F(s)\left[(1-\alpha)k_{ns}\frac{\partial n}{\partial b} - bP_{ns}(n,s)\frac{\partial n}{\partial b} - P_s(n,s)\right] = (1+m)F(s)\frac{d}{db}(-\dot{U}(s))$$

This incentive correction term is non-negative according to our assumptions in (c-3) in the appendix. Treatment intensity should therefore again be distorted below the first-best level, with no distortion for the least severe disease.

This solution is implemented by offering a non-increasing recovery-contingent bonus (which itself should make it less tempting to overstate the true disease) and a cost-sharing contract so that the fraction of realised cost being reimbursed by the government is higher for the more severe diseases. The rationale for this cost-sharing arrangement is again that a smaller fraction of any inflated cost, due to overstating and due to the incentive to choose a more aggressive treatment so as to capture the bonus, is retained by the hospital as rent. The lower bonus and increased cost sharing will make the incentive contract more low-powered for serious diseases.

When comparing the implicit cost-sharing condition (12-ii) with the one in (5-ii), we observe that there is an additional positive term caused by the inability to write explicitly into a contract what treatment should be provided for any specific disease. Conditional on the induced choice of treatment, the power of the incentive contract becomes lower for the more serious diseases, so as to counteract the hospital's incentive to take advantage of its favourable position. Only for the least severe disease, the hospital should be motivated to minimise cost. For any of the remaining diseases, cost efficiency is sacrificed so as to get the hospital to allocate medical resources among the various groups of patients in the desired way.

From proposition 3, we get:

Corollary 4
When treatment is unverifiable and with cost of treatment independent of disease, there is still a need for extracting rent, which is accomplished by offering some cost sharing along with a recovery-contingent bonus.

(If $C_s(n,s,e) \equiv 0$, we observe from (12ii-iii) that $\alpha(0) = 0$, but $\alpha(s) \in (0,1]$ for any $s \in (0,1]$. In order to induce treatment the bonus has to be strictly positive for any disease. Comparing this result with the one in Corollary 1, we see the full impact on the payment scheme of introducing moral hazard.)

Let us try to characterise the payment scheme stated in Proposition 3 in some more detail. On using the decision rules (7i-ii) along with the first-order conditions (d2-3) in the appendix, we can express, in a way similar to what was done in Gal-Or, the cost-sharing parameter and the bonus as:

$$(13) \qquad \alpha(s) = \frac{G(s) - (1+m)\dfrac{F(s)}{f(s)}\dfrac{\dfrac{d(-\dot{U}(s))}{d\alpha}}{P_n\dfrac{\partial n}{\partial \alpha}} - b(1+m)}{G(s) - (1+m)\dfrac{F(s)}{f(s)}\dfrac{\dfrac{d(-\dot{U}(s))}{d\alpha}}{P_n\dfrac{\partial n}{\partial \alpha}} - \dfrac{(1+m)v'(e)\dfrac{\partial e}{\partial \alpha}}{P_n\dfrac{\partial n}{\partial \alpha}}} \in [0,\ 1]$$

$$(14) \qquad b(s) = \frac{(1-\alpha)}{1+m}\left[G(s) - (1+m)\frac{F(s)}{f(s)}\frac{\dfrac{d(-\dot{U}(s))}{db}}{P_n\dfrac{\partial n}{\partial b}}\right] \le \frac{G(s)}{1+m}$$

In (13) we have $\dfrac{d}{d\alpha}(-\dot{U}(s)) = -k_s(n,s) + (1-\alpha)k_{sn}(n,s)\dfrac{\partial n}{\partial \alpha} - bP_{sn}(n,s)\dfrac{\partial n}{\partial \alpha}$, which is non-positive by assumption. The slope of the rent function is in general made less steep by increasing α, which is seen from the result that more cost sharing is now being offered as compared to the preceding cases. (We have earlier assumed that $\dfrac{d}{db}(-\dot{U}(s)) = -P_s(n,s) + (1-\alpha)k_{sn}(n,s)\dfrac{\partial n}{\partial b} - bP_{sn}(n,s)\dfrac{\partial n}{\partial b}$, which is non-negative by assumption; cf. (c-3) in the appendix.)

Because (13) and (14) are not closed form solutions we can at most make some observations as to the relationship between the two policy instruments, and what kind of trade-offs will be reflected in the way these policy instruments are determined.

The first observation follows directly from (14):

Observation 1

The social value of the bonus cannot exceed the social benefit from a successful treatment.

(We have seen that some bonus has to be offered so as to get the hospital to undertake any treatment at all. Hence we have that the optimal reward $b \in (0, \dfrac{G(s)}{1+m}]$ for any $s \in S$, as seen from (14).)

We furthermore have:

Observation 2

The bonus b(s) and the cost-sharing parameter $\alpha(s)$ are negatively correlated.

(We should interpret the expressions in (13) and (14) with some care, because they are not explicit solutions, but only one way of characterising the policy instruments. However, according to the second-order condition for incentive compatibility, which holds by assumption, we get observation 2. As seen from (13) and (14), b and α seem, reasonably enough, to be inversely related. Suppose that for some reason a high fraction of realised cost of treating disease s is being reimbursed. According to the decision rules, this cost sharing creates weak incentives to exert cost-reducing effort, which makes the third term in the denominator (sign included) of (13) small. But for α to be high, say just below one, the last term in the numerator of (13) "must" be close to zero.)

The third observation is rather obvious:

Observation 3

For the least serious disease, s = 0, any cost of treatment should be borne by the hospital which should be made residual claimant for all its decisions, by receiving a bonus equal to the private valuation of the social benefit from a successful treatment;

i.e. $\alpha(0) = 0$ *and* $b(0) = \dfrac{G(0)}{1+m}$.

(The contract intended for the least serious disease will then induce treatment identical to what the regulator would have wanted under complete information, with $P_n(n(0),0)G(0) = (1+m)k_n(n(0),0),$ according to (7-i), as well as optimal cost-reducing effort induced by no cost sharing; i.e. $-g'(e) = v'(e)$) according to (7-ii) with $\alpha(0) = 0$.)

On combining Observation 2 - 3, the optimal payment scheme, for the less (more) severe diseases, seem to have the flavour of a fixed-price (cost-plus) contract.

The fourth observation is related to the bonus:

Observation 4

The recovery-contingent bonus for treating disease s is proportional to the "rent-adjusted social benefit" from a successful treatment (privately valued), with a factor of proportionality equal to the share of cost borne by the hospital itself.

(As seen from Observation 3, b(0) is just equal to the private valuation of the social benefit from successfully treating a patient suffering from the least severe disease. For any other disease, the bonus is related to the social benefit from having a patient with that specific disease fully recovered. However, when calculating the optimal bonus, the social benefit from recovery is adjusted downward by a term showing the relative effectiveness of changes in b on rent extraction (affecting all diseases less severe than the one considered) and on the change in the likelihood for recovery. We have seen that a lower value of the bonus will in general reduce rent. If the effectiveness on rent extraction of a lower b is small relative to the negative impact on the induced likelihood of recovery, we should have $b(s) \approx \frac{1-\alpha}{1+m} G(s)$. However, in the opposite case, when the effectiveness on rent extraction of a lower b is high relative to the impact on the changed likelihood for recovery, the bonus should be adjusted below $\frac{1-\alpha}{1+m} G(s)$. Hence we have the obvious conclusion that the stronger is the impact of a higher bonus on the likelihood for recovery relative to the ability to extract rent, the higher should the bonus be.)

The cost-sharing parameter implicitly determined above bears some close resemblance to the one outlined in Gal-Or (op.cit.). As seen from the expression in (13), the fraction of the cost of treating a patient suffering from disease s, being reimbursed by the government, should take into account the effectiveness on rent extraction relative to the increased likelihood for recovery, and the effectiveness on the incentive to reduce cost relative to the increased likelihood for recovery, induced by more cost sharing (or a higher value of α). But as noted above, a higher (lower) value of α will most likely be accompanied by a lower (higher) value of b.

At last we an make the following observation:

Observation 5

If increased cost sharing has a strong impact on the hospital's incentive to use medical resources in treating disease s (that is $\dfrac{\partial n}{\partial \alpha}$ being large for that disease), but cost sharing has a weak impact on both rent extraction and the incentive to reduce cost, then the optimal cost sharing for disease s will approximately be given as:

$$\alpha(s) \approx 1 - \frac{b(s)(1+m)}{G(s)}, \text{ with } b(0) = \frac{G(0)}{1+m} \text{ according to observation 3.}$$

(In this case of the model, the instruments seem to serve different purposes (a kind of dichotomy); cost sharing is an effective instrument to induce the hospital to choose appropriate treatment, whereas the bonus is adjusted so as to extract rent.)

Despite the huge informational requirements and the general nature of the model, let us try to use the results derived in this section to see in what way they might be implemented in real life or give some insight into practical-life politics.

5. A Discussion

As seen from (13) and (14), the nature of the compensation scheme or incentive contract seems to be rather complex, perhaps too complex to have any practical interest. However, despite the lack of immediate implementation, we might be able to draw some lessons as to what kind of contracts a public health care system like the one described in the model in section 4, should be offered for classes of diseases.

A rather strict assumption used in the model when treatment cannot be verified is that some bonus is required to get the hospital to undertake any treatment at all. This is of

course highly unrealistic, especially when we take into account the role "professional ethics" seem to play in the health care industry. Let us therefore do justice to "professional ethics", by supposing that even without any recovery-contingent bonus, the medical staff will choose some minimal disease-specific treatment intensity, denoted $n_0(s)$, increasing in s by definition of severity. Assume that even with this minimal input of medical resources, there is a positive probability for success; $P(n_0, s) \in (0,1)$ for any s. Let us retain A1, but modify slightly some of the requirements in A2. Furthermore, we assume that the social benefit from recovery from disease s, G(s), is independent of s itself. Hence in order to avoid some extremely difficult questions as to the valuation of being treated successfully from the various diseases, we let G(s) = g > 0 for any s∈S.

The new cost assumption: If a patient with disease s is offered treatment intensity $n \in (0, n_0(s))$, then $k(n,s)$ is assumed to be constant, following from the pure fixed-cost nature (admission, observation and diagnostic efforts) of initial treatment costs, with $k(n,s)$ increasing in s, while marginal cost of treatment $k_n(n,s) = 0$. For treatment intensity beyond $n_0(s)$, additional treatment-contingent costs (in excess of initial admission costs) are triggered, so as to get $k_n(n,s)$ to jump upwards in $n_0(s)$. We have $k(n,s)$ continuous in n for any $n \in (0,1]$, but the marginal cost of treatment might jump upward in $n_0(s)$: $k_n(n_0^-(s),s) = 0 \leq k_n(n_0^+(s),s)$. The magnitude of the jump itself might be increasing in severity. (Choosing $n_0(s)$ as the minimal input of medical resources to treat a patient with disease s without any bonus, is in accordance with the decision rule (7-i) in the preceding section.)

For the least serious diseases we can have $n_0(s)$ "small", with no jump (by assumption) in marginal cost of treatment (or $k_n(n,s)$ being everywhere continuous in n for each s), and with treatment having great impact on the likelihood for recovery. On the other hand, for more severe illnesses, initial fixed (admission) costs can be rather high, exhibiting a substantial increase in marginal cost due to escalation of many different and expensive activities when treatment provided increases from the level $n_0^-(s)$ to $n_0^+(s)$. In addition it is expected that treatment will have a weak (defined properly) impact on the likelihood for recovery.

In the remaining part of this section we will discuss the design of optimal incentive contracts for a coarse group of diseases. (The diseases in each class share some common features, to which we return.) We can therefore examine how the policy instruments might be stipulated for these different categories of diseases, when taking into account the complex interaction between the instruments' relative effectiveness on the hospital's decision variables and their effectiveness on rent extraction. We will consider four classes of diseases.

First we consider *the class of the least severe illnesses*. Any disease in this class can be easily identified through simple diagnostic techniques, and having well-documented and rather successful treatment programmes. Let this class of diseases be denoted $\underline{S} \subset S$, where $\underline{S} = [0, \underline{s}]$. For any $s \in \underline{S}$, $P(n_0, s)$ positive, perhaps close, but less than one, with $P_n(n_0, s)$ high so that $P_n(n_0, s)g > (1+m)k_n(n_0^-, s) = 0 = (1+m)k_n(n_0^+, s)$, as there is no jump in marginal cost at $n_0(s)$ for any $s \in \underline{S}$. Let us furthermore assume that *P(n,s)* is almost independent of s, with $P_s(n, s)$ as well as $P_{sn}(n, s)$ both close to zero. Cost of treatment is increasing in n beyond $n_0(s)$, but we assume that both $k_s(n, s)$ and $k_{ns}(n, s)$ being small for any $s \in \underline{S}$. (Treatment has a large impact on the likelihood for recovery, while the well-documented treatment programmes will mostly involve fixed costs of treatment, which do not vary too much with the disease in this class.)

For any disease in this class, the hospital should be offered a constant positive rent, because we now have $\dot{U}(s) = 0$ for any $s \in \underline{S}$, and second-best optimal treatment will coincide with first-best treatment for any disease in this class, i.e. $n(s) = n^*(s) > n_0(s)$ for any $s \in \underline{S}$.

To implement this solution, the hospital can be offered a fixed-price contract (with no cost sharing $\alpha = 0$), a constant recovery-contingent bonus $b = \dfrac{g}{1+m}$, in addition to a disease-specific transfer *t(s)*, so as to keep rent at the (desired) constant level for any $s \in \underline{S}$. This payment system has features close to a prospective payment system. We can therefore conclude with:

Corollary 5

Let technology and cost of treatment for the class of the least severe diseases have properties so that for any $s \in \underline{S}$, social benefit from recovery is constant, $G(s) = g > 0$, for any treatment programme $n \geq n_0$, we have $P(n_0, s) \in (0, 1)$, with

$$P_n(n_0, s)g > (1+m)k_n(n_0, s) = 0, \; P_s(n, s) = P_{ns}(n, s) = 0 \;\text{ and }\; k_s(n, s) = k_{sn}(n, s) = 0.$$

Optimal treatment n(s) for any $s \in \underline{S}$ coincides then with first-best treatment $n^*(s)$, and can be implemented through a fixed-price contract; with a disease-independent

bonus $b = \dfrac{g}{1+m}$, no cost sharing $\alpha = 0$, inducing cost efficiency, while leaving a positive, constant rent to the hospital, for any $s \in \underline{S}$.

Consider next *the set of diseases of medium severity*, $S^* \subset S$, where $S^* = (\underline{s}, s^*]$. The diseases within this class is slightly more difficult from a medical point of view, but not too difficult. For these diseases, we assume that $P(n_0, s)$ is small, and for any $n \geq n_0$, we have $P_n(n, s)$ being positive (but with a weaker impact on the likelihood for recovery than what was the case for $s \in \underline{S}$, from treatment beyond n_0). Let $P(n, s)$ decline slowly with s for any fixed $n \in [n_0(s), 1]$, and let $P_{ns}(n, s)$ also be close to zero. Cost of treatment is strictly increasing and strictly convex in $n \in (n_0(s), 1]$ for each $s \in S^*$, cf. A2, with marginal cost of treatment jumping up at $n_0(s)$, with $k(n, s)$ as well as $k_n(n, s)$ being increasing in s, for $n \in (n_0(s), 1]$. For any disease in S^* we assume that a set of well-developed treatment-technologies are available, but the main difference between diseases in this class and those in $\underline{S}$ stems from the cost structure. (It is more costly at the margin beyond n_0 to treat diseases in S^*.)

Given our assumptions, we easily see that optimal treatment is determined from the following condition; cf. (d-4) in the appendix:

$$(15) \quad P_n(n, s)g = (1+m)k_n(n, s) + (1+m)\frac{F(s)}{f(s)}(1-\alpha)k_{sn}(n, s); \; \forall s \in S^*$$

The desired aggressiveness for these diseases will be set below the first-best level, but above $n_0(s)$; i.e. we'll have $n \in (n_0, n^*)$, with n being identical to what would have been the case if treatment were under the regulator's control; cf. Proposition 2. The compensation scheme implementing the desired treatment will involve some cost sharing and some recovery-contingent bonus, similar to what was shown in (13) and (14). Rent extraction is accomplished by offering a more low-powered incentive scheme than for diseases in $\underline{S}$ (because $P_s(n,s)$ is negligible), so cost efficiency is sacrificed for diseases of medium severity. The fraction of cost being reimbursed will jump when we passing the boundary between the two classes $\underline{S}$ and S^*, with

$$\alpha(\underline{s}) = 0 < \alpha(\underline{s}^+) \in (0,1).$$

The bonus will be adjusted significantly below the maximal bonus $\dfrac{g}{1+m}$. A smaller bonus is implied by the fact that a higher fraction of realised cost is paid by the government (which itself calls for reducing the bonus, according to observation 2), and also because lowering the bonus for successful treatment of (say) the least severe disease $\underline{s}^+$ in S^*, will make it possible to reduce the transfer (and hence give away a lower rent) for diseases in "the easy group" $\underline{S}$. The transfer is adjusted to a level so that rent is continuous; implying $U(\underline{s}) = U(\underline{s}^+)$, for thereafter to be declining over the interval S^*. We can therefore conclude with:

Corollary 6
For the class of diseases of medium severity, the optimal compensation scheme which implements desired treatment, less aggressive than under complete information, for any $s \in S^*$, is more low-powered, with some cost sharing and some recovery-contingent bonus. The set of contracts for diseases in S^* will give the hospital a rent, which is declining on S^*.

Consider next the third class; i.e. *the class of very (not directly fatal) diseases* $\bar{S} = (s^*, s^\dagger]$, which can be recovered only at a high cost, with a social benefit if recovery equal to g for any $s \in \bar{S}$. Assume that for any $s \in \bar{S}$, we have $P(n_0, s)$ small,

and, furthermore, for any $n > n_0$, $P_n(n,s)$ is small, while $P_s(n,s)$ is large in absolute value, but with $P_{sn}(n,s)$ being close to zero, by assumption. (Treatment itself has a weak impact on the rate of recovery, which is highly influenced by the severity of the illness.)

Suppose furthermore that for any $s \in \overline{S}$, marginal cost of treatment makes a substantial jump at $n_0(s)$, and will also be rapidly increasing in n beyond this jump point. Treatment cost, for n $< n_0(s)$, is high (and constant) whatever disease we are considering in this class, but not high enough so as to reject treatment altogether. For any n$\in (n_0(s)$, 1] we assume that $k(n,s)$ as well as $k_n(n,s)$ will be high, but affected only by n itself, not s. Hence we have $k_s(n,s) = 0$, implying that $k_{ns}(n,s) = 0$ for any $s \in \overline{S}$ and for any $n > n_0$ as well.

Let us then assume that diseases in $\overline{S}$ have such a property that treatment aggressiveness just above the minimal level will produce a significant upward (but not too high) jump in marginal cost of treatment, so that the following inequality will hold for any s in $\overline{S}$

(16) $P_n(n_0, s)g - (1+m)k_n(n_0^+(s), s) > 0$

(Note that this condition is only necessary, not sufficient, for having treatment intensity above n_0, as seen from (d-3) in the appendix.)

Given our assumptions about cost and technology for this class, we now have that $\frac{d}{d\alpha}(-\dot{U}(s)) = 0$; hence cost sharing is in this case an ineffective instrument for rent extraction, but will of course have an impact on the hospital's choice of treatment through $\frac{\partial n}{\partial \alpha}$, which is positive; cf. (8). Furthermore, because "marginal productivity" of treatment $P_n(n,s)$ is low, by assumption, n is expected to be weakly affected by changes in b, but changes in b will have an impact on rent extraction, as seen from $\frac{d}{db}(-\dot{U}(s)) = -P_s(n,s) > 0$. One conjecture which obeys the second-order condition for incentive compatibility and the decision rule (7-i) is that contracts for diseases in $\overline{S}$

should be subject to even more cost sharing than the ones in S^* with less use of bonus payments for successful treatment for one disease in this class. Suppose that for these diseases, socially desired treatment is above the minimal treatment level $n_0(s)$ but below first-best treatment n^*. As compared to the optimally chosen instruments in S^* we might have a upward jump in α, and a jump downward in the bonus b, as we are going from diseases in S^* to diseases in $\overline{S}$; $b(s^{*-}) > b(s^{*+}) > 0$ so as to reduce rent and $0 < \alpha(s^{*-}) < \alpha(s^{*+}) < 1$, to get the hospital to choose aggressiveness beyond $n_0(s)$ for any $s \in \overline{S}$. (The contracts in $\overline{S}$ become more low-powered, with rent being declining throughout $\overline{S}$.) As seen from Observation 5 above, the instruments $\{\alpha, b\}$ can now be used selectively, as outlined above, so as to meet the goal of the regulator.
We can therefore conclude:

Corollary 7

For any disease in the class $\overline{S}$ for which (16) holds, desired treatment beyond what is implemented by "professional ethics", is implemented through an incentive contract, which combines recovery-contingent bonus (b > 0) and cost sharing ($\alpha \in (0,1)$), obeying (13) and (14), being more low-powered than the set of incentive contracts for diseases in S^*.

At last consider *the class of very or fatal diseases* $S^\dagger = (s^\dagger, 1]$ for which the jump in marginal cost of providing treatment beyond $n_0(s)$, $\forall s \in S^\dagger$ is significant, as given by the following condition

(17) $P_n(n_0, s)g - (1+m)k_n(n_0^-(s), s) \geq 0 > P_n(n_0, s)g - (1+m)k_n(n_0^+(s), s)$

where $k_n(n_0^-(s), s) \equiv 0$. Diseases that are marginally very expensive to treat, with a low recovery rate, should, according to the model, satisfy the following (straightforward) properties:

Corollary 8

Fatal diseases (i.e. $s \in S^t$) that are very expensive to treat beyond $n_0(s)$ for any $s \in S^t$, should in optimum be provided the minimal intensity of treatment that follows from "professional ethics"; i.e. $n_0(s)$ for each $s \in S^t$, satisfying (17). This solution is easily implemented through a pure cost-plus contract, with full cost reimbursement, $\alpha = 1$, inducing no cost-reducing effort, no bonus, b = 0, and a transfer so that the hospital is offered no rent.

(This low-aggressiveness solution might have, whether we like it or not, some implications as to how we should take care of patients with fatal diseases. But the solution above does not necessarily mean that the treatment offered patients with very severe illnesses, like various types of cancer or AIDS, will be of poor quality. Because we explicitly have assumed that $n_0(s)$ is increasing in s, the low-intensity treatment might even be "high" for the most severe illnesses.)

One conclusion that can be made from this discussion is that under asymmetric information and moral hazard, a public health care system should be governed by (piecewise continuous) contracts being more low-powered for the more severe diseases. High-powered contracts like the prospective payment based on DRG-prices, are shown to be desirable only for those diseases with well-documented treatment programmes, with a high recovery rate and a highly fixed-cost treatment technology. For all the other (more severe) diseases, the incentive contracts move towards cost-plus contracts.

6. Concluding comments

We have considered some variations of a model studied by Gal-Or, to analyse contracting for public health care services when the public hospitals have informational advantages, can take non-verifiable actions, and when the outcome of any treatment can be verified, when cost of treatment is disease-dependent. The objective of the patient-biased regulator is to get the hospital to undertake treatment and cost control so as to maximise expected social benefit, under the constraint of no dumping of any patient, and when hospital rent does not enter the social welfare function in a direct

way. Because of distortive taxation, leaving rent to the hospital has a social cost. Without any cost-sharing arrangements, as will be the case for prospective payment schemes using DRG-prices that are increasing in severity, the hospital will have an incentive to overstate the true disease of any patient, so as to capture a socially costly rent. (The hospital can benefit from such overstatement because cost is assumed to be disease-dependent and because more severe diseases will usually have higher DRG-prices than less severe ones.) To counteract these incentives, the regulator can offer a compensation scheme, which is a combination of a bonus (if successful treatment) and cost sharing. In the institutional setting first considered, treatment was assumed to be under the control by the regulator. It was demonstrated that there is no need for any bonus, but if marginal cost of treatment is increasing in severity, it is socially desirable for the government to reimburse a fraction of realised cost. Rent extraction will now be accomplished by offering a set of low-powered contracts (more low-powered for the more severe diseases) and require less intense treatment than under complete information. The reason for imposing cost sharing is that a smaller fraction of any overstated or inflated cost will be retained as hospital rent, while under-provision of medical resources (lower treatment intensity) will lower the cost target for any disease, which in turn will reduce the hospital's gain from overstating. However, more cost sharing will induce the hospital to exert less cost-reducing effort, so internal cost efficiency is given up. (Only when cost of treatment is independent of disease, there is no way the hospital can benefit from disguising the true disease, implying that the optimal contract is fully prospective, with no cost sharing, and no deviations in treatment from first best; cf. Gal-Or.

In the second institutional setting, which is more realistic, we relax the assumption that treatment is under the regulator's control. Instead treatment is under control by the health provider, with outcome (but not treatment) being verifiable. We have demonstrated that in this case successful outcome of any treatment should be rewarded (so as to get the hospital to undertake treatment). But in addition there should be some cost sharing. For the compensation scheme to be truly incentive compatible, bonus payment should be decreasing in severity, whereas cost sharing should be higher for the more severe diseases, which makes the contract more low-powered as more severe illnesses are treated. Together, the optimally chosen pair of instruments will induce the hospital to undertake less intense treatment as what would have been required under complete information, except for the least severe (group) of diseases.

The conclusion to be drawn from this lesson is that within a public health care system, fully prospective payment schemes or fixed-price contracts, will in general not meet the regulator's goal of maximising expected social welfare.

Appendix.

- *On incentive compatibility when treatment is dictated by the regulator (section3)*

For any reported disease $\hat{s} \in S$, the mechanism { $t(\hat{s}), b(\hat{s}), \alpha(\hat{s}), n(\hat{s})$ } is offered to the hospital ex ante. (We restrict attention to differentiable mechanisms.) At the interim stage of the game, when the hospital learns the true disease, it chooses { $\hat{s}, e$} so as to maximise expected rent, given the mechanism, which is designed so as to induce truth-telling ($\hat{s} = s$). At this interim stage of the game, the hospital has an expected rent as given by

$$(a\text{-}1) \qquad U(\hat{s}, e; s) = t(\hat{s}) + P(n(\hat{s}), s)b(\hat{s}) - (1 - \alpha(\hat{s}))[k(n(\hat{s}), s) + g(e)] - v(e)$$

The mechanism should induce interim-revelation of the true disease ($\hat{s} = s$). When the health provider is offered this mechanism, it will for any s (at the interim stage of the game) choose { $\hat{s}, e$ } to maximise interim expected utility in (a-1). Hence, for any non-negative b, any $\alpha \in (0, 1)$, and for any report $\hat{s} \in S$ which implies some treatment, a local interior maximum requires the following first-order conditions to hold, as given by (a2-3):

$$(a\text{-}2) \qquad \frac{\partial U(\hat{s}, e, s)}{\partial e} = -(1 - \alpha(\hat{s}))g'(e) - v'(e) = 0$$

which is a moral hazard constraint of the problem. (This relationship is common knowledge.) Due to the separable cost function, cost-reducing effort will depend negatively on the cost-sharing parameter, $\alpha(\hat{s})$, i.e. $e(\alpha(\hat{s}))$, with $\dfrac{\partial e}{\partial \alpha} = \dfrac{g'}{(1-\alpha)g'' + v''}$ which is negative. (As $\alpha \to 0$, no cost reimbursement, we have $e \to e^*$ from (2b),

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whereas full cost reimbursement, $\alpha \to 1$, will eliminate any incentive to reduce cost; i.e. $e \to 0$.)

Truthful revelation requires that

$$(a\text{-}3) \quad \frac{\partial U(\hat{s}, e, s)}{\partial \hat{s}} = \frac{dt(\hat{s})}{d\hat{s}} + P(n(\hat{s}), s)\frac{db(\hat{s})}{d\hat{s}} + P_n(n(\hat{s}), s)b(\hat{s})\frac{dn(\hat{s})}{d\hat{s}}$$
$$+ \frac{d\alpha(\hat{s})}{d\hat{s}}(k(n(\hat{s}), s) + g(e)) - (1 - \alpha(\hat{s}))k_n(n(\hat{s}), s) = 0$$

for $\hat{s} = s$, with a (local) second-order condition

$$(a\text{-}4) \quad P_s(n, s)\dot{b}(s) + k_s(n, s)\dot{\alpha}(s) + \left[P_{sn}(n, s)b(s) - (1 - \alpha(s))k_{sn}(n, s)\right]\dot{n}(s) \geq 0$$

According to our previous assumptions, sufficient conditions for this second-order condition to hold are that b(s) is non-increasing, α(s) is non-decreasing and n(s) is non-decreasing (non-increasing) if the term within brackets in (a-4) is non-negative (non-positive). When solving the regulator's problem, we'll ignore the second-order condition and check ex post whether the proposed candidate will obey this condition.

The hospital's interim expected utility when the true disease is revealed at this stage, can the be expressed as

$$(a\text{-}5) \quad U(s) = t(s) + P(n(s),s)b(s) - (1 - \alpha(s))[k(n(s),s) + g(e(\alpha(s)))] - v(e(\alpha(s)))$$

from which we directly get that the first-order condition for incentive compatibility can be written as

$$(a\text{-}6) \quad \dot{U}(s) = P_s(n(s), s)b(s) - (1 - \alpha(s))k_s(n(s), s)$$

- *Proposition 2 (section 3)*

The solution in proposition 2 follows from solving the following problem:

[RP-1]

$$Maximise \ W^E = \int_0^1 R(s)f(s)ds$$

s.t.

$R(s) = P(n(s),s)G(s) - (1 + m)[U(s) + k(n(s),s) + g(e(\alpha(s))) + v(e(\alpha(s)))]$

$\dot{U}(s) = P_s(n,s)b(s) - (1 - \alpha(s))k_s(n,s) \ (IC_1)$

$P_s(n,s)\dot{b}(s) + k_s(n,s)\dot{\alpha}(s) + [P_{sn}(n,s)b(s) - (1 - \alpha(s)k_{sn}(n,s)]\dot{n}(s) \geq 0 \ (IC_2)$

$U(0)$ *is "free" and* $U(1) \geq 0$

$e(\alpha)$ *obeys the moral hazard constraint:* $v'(e) = -(1 - \alpha)g'(e)$

The set of instruments: $b \geq 0$, $n \in [0, 1]$ *and* $\alpha \in [0, 1]$ *for any* $s \in S = [0, 1]$

We will solve this problem as an ordinary control problem, when ignoring the second-order condition (IC_2), and check later when our candidate will obey (IC_2). U is the state variable, everywhere continuous, and $\{n, b, \alpha\}$ being the vector of continuous control variables. We will start out by looking for a menu of contracts for which the control variables are everywhere differentiable.

When a solution exists, we can find a non-negative co-state variable λ, associated with the state variable U. The Hamiltonian is then

$$H(U,n,b,\alpha,\lambda,s) = [P(n,s)G(s) - (1 + m)(U + k(n,s) + g(e(\alpha)) + v(e(\alpha)))]f(s)$$
$$+ \lambda[P_s(n,s)b - (1 - \alpha)k_s(n,s)]$$

On using the Maximum Principle, the co-state variable $\lambda(s)$ has to obey

(b-1) $\qquad \dot{\lambda}(s) = -\dfrac{\partial H}{\partial U} = (1 + m)f(s) > 0 \ \forall s \in S$

(b-2) $\qquad \lambda(1)U(1) = 0, \ \lambda(1) \geq 0 \ (= 0 \ if \ U(1) > 0), \ \lambda(0) = 0 \ as \ U(0) \ is \ free,$

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implying that $\lambda(s) = (1+m)F(s) \geq 0, (= 0$ only for s = 0). (Earlier we have assumed

that $\dfrac{d}{ds}\dfrac{F(s)}{f(s)} \geq 0 \ \forall s \in S.$)

We claim that the optimal solution will obey:

For any $s \in [0, 1]$ optimality requires: $b = 0$, $0 < n \leq n^* < 1$, $\alpha \in [0, 1)$

To see this, consider

(b-3) $\dfrac{\partial H}{\partial n} = \left[P_n G(s) - (1+m)k_n(n,s)\right]f(s) + \lambda\left[P_{sn}b - (1-\alpha)k_{sn}(n,s)\right]$

(b-4) $\dfrac{\partial H}{\partial \alpha} = -\alpha g'(e)\dfrac{\partial e}{\partial \alpha}(1+m)f(s) + \lambda k_s(n,s)$

(b-5) $\dfrac{\partial H}{\partial b} = \lambda P_s(n,s)$

Because $\lambda \geq 0$ and $P_s(n,s) < 0$ for any (n,s), we immediately have that b = 0 for any s from (b-5), as long as b is restricted to be everywhere continuous. When treatment can be fully administered by the regulator there is no need to offer the hospital any reward for successful treatment. The incentives to choose the desired treatment or to report the true disease will be taken care of by the cost-reimbursement rule.

On using that b = 0 for any s in (b-3), we get that treatment programme has to obey:

(b-6) $P_n(n,s)G(s) = (1+m)k_n(n,s) + (1-\alpha)(1+m)\dfrac{F(s)}{f(s)}k_{sn}(n,s)$

where the second term on the RHS is non-negative according to our assumptions. This incentive correction term will obviously vanish for the least serious disease, s = 0, whatever admissible value the cost-sharing parameter takes. Earlier it has been assumed that the ideal (first best) treatment intensity $n^* \in (0,1)$ for any $s \in S$; hence we have $n \leq n^*$. Because the technology satisfies $P_n(n,s) \to \infty$, when n $\to$ 0, we have $n > 0$; hence $n \in (0, n^*]$.

The optimal cost sharing for disease s, is found from (b-4), where we use the decision rule (a-2), with $g'(0) = -\infty$ and $g'(e) \to 0$ as $e \to 1$. From the term showing the relationship between e and α, the response $\dfrac{\partial e}{\partial \alpha}$ will approach zero as $e \to 1$. (We have assumed that $v'(0) = 0$.) It then follows that

$$\frac{\partial H}{\partial \alpha} = -\alpha \cdot g'(e(\alpha)) \frac{\partial e}{\partial \alpha}(1+m) f(s) + \lambda(s) k_s(n,s) \begin{cases} \geq 0 & if & \alpha = 1 \\ = 0 & if & \alpha \in (0,1) \\ \leq 0 & if & \alpha = 0 \end{cases}$$

On using (a-2), we have e = 0 for α = 1, and $e = e^* \in (0,1)$, by assumption, for α = 0. We can immediately conclude that $\alpha(0) = 0$, because $\lambda(0) = 0$. For any $s \in (0,1]$, $\alpha > 0$, inducing less cost-reducing effort as compared to what would have been required in first best, whenever $k_s(n, s) > 0$. Full cost-reimbursement, α = 1, will induce no cost-reducing effort at all, e(1) = 0, and given the properties of the g-function, we can assume that $[-g'(e(1)) \dfrac{\partial e(1)}{\partial \alpha}(1+m) + \dfrac{\lambda(s)}{f(s)} k_s(n,s)] < 0$ for any admissible (n,s). In that case, $\alpha(0) = 0 < \alpha(s) < 1$ for any $s \in (0, 1]$, and α(s) will be determined implicitly by:

(b-7) $\qquad \alpha(s) = \dfrac{k_s(n(s), s)}{g'(e(\alpha)) \dfrac{\partial e}{\partial \alpha}} \dfrac{F(s)}{f(s)} \in [0, \ 1) \ for \ any \ s \in S$

Before we can conclude that the solution with b = 0, treatment intensity and cost-reimbursement jointly satisfying (b6-7), in fact solves the problem, we have to check whether the second-order condition for incentive compatibility will hold.
The second order condition (IC$_2$), with b = 0 is for any s, reduced to the condition
$k_s(n,s) \cdot \dot{\alpha}(s) - (1-\alpha(s)) \cdot k_{sn}(n,s) \cdot \dot{n}(s) \geq 0$.

Let $h_{ij} := \dfrac{H_{ij}}{f(s)}$, where $H_{ij} := \dfrac{\partial}{\partial j} H_i$, for i,j = n,$\alpha$, with $H_n = H_\alpha = 0$ from (b3-4). We have implicitly assumed that H is strictly concave in (n,α); hence we have, according to (A1-2) that D below is positive

$$D := h_{nn}h_{\alpha\alpha} - h_{\alpha n}^2 > 0, \text{ where}$$

$$h_{nn} := P_{nn}G(s) - (1+m)(k_{nn} + (1-\alpha)k_{snn}\frac{F(s)}{f(s)}) < 0$$

$$h_{\alpha\alpha} := -g'(e)\frac{\partial e}{\partial \alpha} - \alpha\frac{\partial}{\partial \alpha}(g'(e)\frac{\partial e}{\partial \alpha}) < 0$$

$$h_{n\alpha} := (1+m)\frac{F(s)}{f(s)}k_{ns} \geq 0$$

$$h_{ns} := P_nG'(s) + P_{ns}G(s) - (1+m)k_{ns} - (1+m)(1-\alpha)(\frac{F(s)}{f(s)}k_{sns} + k_{ns}\frac{d}{ds}\frac{F(s)}{f(s)})$$

$$h_{\alpha s} := (1+m)(k_{ss}\frac{F(s)}{f(s)} + k_s\frac{d}{ds}\frac{F(s)}{f(s)}) \geq 0$$

(We note that h_{ns} can take either sign.) From (b3-4) we then get whenever n and α are differentiable

(b-8)

$$h_{nn}\dot{n}(s) + h_{n\alpha}\dot{\alpha}(s) = -h_{ns}$$

$$h_{\alpha n}\dot{n}(s) + h_{\alpha\alpha}\dot{\alpha}(s) = -h_{\alpha s}$$

with a solution for $(\dot{n}(s), \dot{\alpha}(s))$ as given by

(b-9) $$\dot{n}(s) = \frac{1}{D}(-h_{\alpha\alpha}h_{ns} + h_{n\alpha}h_{\alpha s})$$

(b-10) $$\dot{\alpha}(s) = \frac{1}{D}(-h_{nn}h_{\alpha s} + h_{\alpha n}h_{ns})$$

In the subsequent discussion we assume that $\frac{d}{ds}(P_n(n,s)G(s)) > 0$, which was underlying Proposition 1.

If the cost function is independent of s, $k_s(n,s) = 0$ for any (s,n), as was assumed by Gal-Or, the optimal solution will satisfy:

(b-11) $$n(s) = n^*(s), b(s) = 0, \alpha(s) = 0, U(s) = 0, \forall s \in S$$

cf. corollary 1 in the text. Rent extraction is in this case no issue because when the principal can dictate treatment, with cost being disease-independent, the hospital is unable to capture any rent by disguising the true disease. The reason is of course that cost itself does not vary with s.

Secondly, if $k_s(n,s) > 0,$ but independent of n, so that $k_{sn} = 0$ for any n$\in$[0,1], implying $h_{ns} > 0 = h_{n\alpha}$, then from (b-7), $\alpha(s) \in$ [0,1), and from (b-10) it follows that $\alpha(s)$ is increasing. When $k_{ns}(n,s) = 0,$ we have from (b-6) that $n(s) = n^*(s)$, which was assumed to be increasing. In this case, there is no need to distort treatment away from first best, whereas rent extraction is accomplished by reimbursing a higher fraction of realised cost, the more severe is the disease. The second-order condition is now reduced to $k_s(n,s)\dot{\alpha}(s) \geq 0$, which is satisfied by our solution. Hence, the candidate in Proposition 2 will be the (second-best) optimal solution when the cost function is disease-dependent and increasing in severity, but $k_s(n,s) = \phi(s)$ being independent of treatment intensity, i.e. with $k_{sn}(n,s) = 0$ for any admissible pair (n,s).

At last, if $k_s(n,s) > 0$, with $k_{sn}(n,s) > 0$, some distortion should be imposed on treatment intensity, whereas a fraction of realised cost should be reimbursed for any disease s$\in$(0,1], with $n(0) = n^*(0)$ and $\alpha(0) = 0.$ In this case, the treatment profile $n(\cdot)$ might not be monotonic, which might be the case for $\alpha(\cdot)$ as well. Even though we cannot rule out that h_{ns} might become negative for some diseases s$\in$(0, 1], we will restrict attention to $h_{ns} \geq 0$ for any {n,α,s}, which, along with our remaining assumptions, is sufficient for $n(\cdot)$ and $\alpha(\cdot)$ to be strictly increasing throughout S. But this candidate might violate the second-order condition for incentive compatibility. (If it should obey this condition, Proposition 2 will hold.) If on the other hand the candidate in Proposition 2 does not obey the second-order condition on some subset of S, then we have to impose this condition as a mixed constraint onto the optimisation programme. It is beyond the scope of this paper to go into a detailed analysis of such a complex problem. Instead we look for conditions so that candidate in proposition 2 in fact obeys the second-order condition.

Let us assume that h_{ns} is close to zero for the candidate in Proposition 2. A sufficient condition for this candidate to obey the second-order condition is then

$$P_{nn}G(s) - (1+m)\left\{ k_{nn} + (1-\alpha)\frac{F(s)}{f(s)}\left[k_{snn} + \frac{k_{sn}^2}{k_n} \right] \right\} \le 0$$

which is satisfied according to A1 and A2. Hence, if we have h_{ns} close to zero for the candidate obeying (b6-7) with $b = 0$, then Proposition 2 provides the optimal solution to the regulator's programme when treatment is under the regulator's control.

- *On the Second-Order Condition for Incentive Compatibility (section 4)*

The first-order condition for revealing information is given by

(c-1) $\quad \dfrac{\partial U(\hat{s}, n, e, s)}{\partial \hat{s}} = \dfrac{dt(\hat{s})}{d\hat{s}} + P(n, s)\dfrac{db(\hat{s})}{d\hat{s}} + \dfrac{d\alpha(\hat{s})}{d\hat{s}}(k(n, s) + g(e)) = 0 \;\; for \; \hat{s} = s$

with $n = n(\alpha(\hat{s}), b(\hat{s}), s)$ and $e = e(\alpha(\hat{s}))$ from (7i-ii). The second-order condition which follows from using (c-1) as an identity in s, i.e. for $\hat{s} = s$, is given by

(c-2) $\quad \dfrac{\partial^2 U(\hat{s}, n, e, s)}{\partial \hat{s}\partial s} = \dfrac{db(\hat{s})}{d\hat{s}}\left\{ P_n(n, s)\dfrac{\partial n}{\partial s} + P_s(n, s) \right\} + \dfrac{d\alpha(\hat{s})}{d\hat{s}}\left\{ k_n\dfrac{\partial n}{\partial s} + k_s \right\} \ge 0$

Assume that for any $s \in S$ and for any $n \in [0, 1]$, we have $\dfrac{d}{ds}P(n, s) \le 0$ and

$\dfrac{d}{ds}k(n, s) \ge 0,$ saying that whatever treatment is chosen, the overall probability for a patient to recover will be non-increasing in s, and cost of treatment be non-decreasing in s. Then a set of sufficient conditions for the second-order condition (c-2) to hold, is that the bonus b is non-increasing in s and that the share of cost being reimbursed by the government is non-decreasing in s.

Note that from the decision rule (7-i) we have for a given set of instruments $\{\alpha,b\}$,

assigned for the reported disease, that $\dfrac{\partial n}{\partial s} = \dfrac{P_{ns}b - (1-\alpha)k_{ns}}{-(bP_{nn} - (1-\alpha)k_{nn})}$. On using this

together with $\dfrac{\partial n}{\partial b} = \dfrac{P_n}{\tilde{D}}$, where $\tilde{D} \equiv -(bP_{nn} - (1-\alpha)k_{nn}) > 0$, we get:

$(c\text{-}3)$ $\qquad \dfrac{d}{ds} P(n,s) = \dfrac{P_n}{\tilde{D}} \left[P_{ns} b - (1-\alpha) k_{ns} + \dfrac{P_s}{\dfrac{\partial n}{\partial b}} \right] \leq 0$, according to our assumption

above.

- *Proposition 3 (section 4)*

The problem when {n,e} is chosen by the hospital is very similar to the one underlying proposition 2, but now we have to take into both moral hazard constraints, as well as the first- and second-order conditions for incentive compatibility, and the participation constraint.

The problem is therefore to a pair of paths {$b(\cdot),\alpha(\cdot);\forall s\in S$} so as to solve the following problem:

[RP-2]

$\qquad$ *Maximise* $W^E = \displaystyle\int_0^1 \tilde{R}(s) f(s) ds$

$\qquad$ *s.t.*

$\qquad \tilde{R}(s) = P(n,s)G(s) - (1+m)[U(s) + k(n,s) + g(e) + v(e)]$

$\qquad \dot{U}(s) = P_s(n,s)b(s) - (1-\alpha(s))k_s(n,s)$ *(IC₁)*

$\qquad U(0)$ *is "free" and* $U(1) \geq 0$

$\qquad e(\alpha)$ *obeys the moral hazard constraint:* $v'(e) = -(1-\alpha)g'(e)$

$\qquad n(\alpha,b,s)$ *obeys the moral hazard constraint:* $P_n(n,s)b - (1-\alpha)k_n(n,s) = 0$

$\qquad$ *The set of instruments:* $b \geq 0$ *and* $\alpha\in[0, 1]$ *for any* $s\in S = [0, 1]$, *with* $b(s)$ *non-increasing and* $\alpha(s)$ *non-decreasing.*

The Hamiltonian associated with this problem is

$H(U,\alpha,b,\lambda,s) = P(n(\alpha,b,s),s)G(s) - (1+m)\{k(n(\alpha,b,s),s) + g(e(\alpha)) + v(e(\alpha))$

$\qquad\qquad + U\}f(s) + \lambda[P_s(n(\alpha,b,s),s)b - (1-\alpha)k_s(n(\alpha,b,s),s)]$

Optimality requires that

(d-1) $\dot{\lambda}(s) = (1+m)f(s) \Rightarrow \lambda(s) = (1+m)F(s)$

(d-2) $\dfrac{\partial H}{\partial b} = \{P_n G - (1+m)k_n + (1+m)\dfrac{F(s)}{f(s)}\{bP_{sn} + \underbrace{\dfrac{P_s}{\partial n}}_{\partial b} - (1-\alpha)k_{sn}\}\}\dfrac{\partial n}{\partial b}f(s) \le 0$

(d-3)

$\dfrac{\partial H}{\partial \alpha} = \{P_n G - (1+m)k_n - (1+m)\alpha g'(e)\dfrac{\dfrac{\partial e}{\partial \alpha}}{\dfrac{\partial n}{\partial \alpha}}$

$+ (1+m)\dfrac{F(s)}{f(s)}\{bP_{sn} - (1-\alpha)k_{sn} + \dfrac{k_s}{\dfrac{\partial n}{\partial \alpha}}\}\}f(s)\dfrac{\partial n}{\partial \alpha}\begin{cases} \le 0 & for & \alpha = 0 \\ = 0 & for & \alpha \in (0,1) \\ \ge 0 & for & \alpha = 1 \end{cases}$

when having used the moral hazard constraint for cost-reducing effort in (d-3).
Suppose that it is socially undesirable to have full cost sharing, so some cost-reducing
effort should take place in equilibrium. Furthermore, to induce treatment, b should be
strictly positive. Then, given that the second-order condition is satisfied, the second-
best optimal set of contracts has to obey the following necessary conditions:

(d-4) $P_n G(s) - (1+m)k_n + (1+m)\dfrac{F(s)}{f(s)}\{bP_{sn} - (1-\alpha)k_{sn}\} = -(1+m)\dfrac{F(s)}{f(s)}\dfrac{P_s}{\dfrac{\partial n}{\partial b}}$

which together with (d-3) yields for any s∈S

(d-5) $\alpha \cdot g'(e)\dfrac{\partial e}{\partial \alpha} = \dfrac{F(s)}{f(s)}\left[k_s - P_s \dfrac{\dfrac{\partial n}{\partial \alpha}}{\dfrac{\partial n}{\partial b}} \right] \ge \dfrac{F(s)}{f(s)}k_s(n,s)$

Given our assumptions, we again have α(0) = 0. Furthermore because the path α(·)
obeys, by assumption, the sufficient condition for the second-order condition for
incentive compatibility, it is increasing in s. We also note that when treatment is non-
verifiable, there is an additional distortion in the cost-sharing rule, making it more

likely to have a more low-powered incentive scheme than what should be the case when treatment was under the regulator's control. Furthermore, because some bonus is required for undertaking any treatment, we have b > 0 for any s∈ S according to (7-i), with b(s) non-decreasing in s, by assumption.

On rewriting (d-4), we get, on using (c-3), that

(d-4)' $\qquad P_n G(s) = (1+m)k_n - (1+m)\dfrac{F(s)}{f(s)}\dfrac{\tilde{D}}{P_n}\dfrac{d}{ds}P(n,s) \geq (1+m)k_n$

Hence, when comparing this solution with the first-best solution, induced treatment as a response to the optimal values of {b,α} is less aggressive for any disease.

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