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From global hospital budgets to the mixed reimbursement system: Incentives for activity and efficiency

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From global hospital budgets to the mixed reimbursement system: Incentives for activity and efficiency

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Abstract

Reimbursement of hospitals in the National Health Service type of healthcare systems has gone through massive changes during the last two decades. One of the trends has been an introduction of DRG-based case reimbursement (also described as activity-based reimbursement (ABR)). Although often analyzed in isolation, the by far most common implementation of the DRG-based case reimbursement is in combination with global hospital budgets and is referred to as a mixed reimbursement system. This paper aims to analyze incentives for hospital activity and efficiency created by this type of mixed reimbursement. The literature on the mixed reimbursement systems regards predominantly the blend of the DRG-based case payments and cost reimbursement. The incentive effects of the mixed reimbursement comprising of the DRG-based case payments and global hospital budgets has not been analyzed equally extensively. One of the questions that remain without an explicit answer is whether a transition from the reimbursement system based solely on global budgets to a mix of global budgets and DRG-based case payments allows the public payer to induce hospitals to produce more for the same budget or, in other words, produce the same volume of activity for a lower unit price. Another open question is about the optimal proportions in which the global budgets and the DRG-based case payments should be mixed in total revenue of hospitals. The analysis presented in this paper is an attempt to address these two questions.

I. INTRODUCTION

Health economics literature discusses a broad variety of hospital reimbursement methods (see, e.g. Jegers et al, 2002; Chalkley and Malcomson, 2000, for an overview). The general conclusion is that each particular method of hospital reimbursement involves trade-offs between, e.g. efficiency in production and providing the appropriate amount o services to each patient or between creating incentives for high activity and retaining control over total expenditures on hospital care (Broyles and Rosko, 1985; Ellis and McGuire, 1986; Newhouse 1996; Street and Maynard, 2007). As a solution to the problem a mix of different reimbursement methods has been proposed. Initially, Ellis and McGuire (1986; 1990) promoted a reimbursement system that combines prospective activity-based payment, employing Diagnosis Related Group (DRG) case-mix classification system, with cost-reimbursement. Their papers coined the term "mixed reimbursement system". In Scandinavian countries, the by far most common reimbursement system for hospitals is also referred to as a mixed reimbursement system. It is not, however, the mixed reimbursement system as understood by Ellis and McGuire (1986; 1990) as it involves only prospective payment methods, i.e. DRG-based case payments and what is traditionally referred to as global hospital budgets (Biørn et al., 2003; Kastberg and Siverbo, 2007; Jakobsen, 2009). The subject of this article is the mixed reimbursement system as implemented in Scandinavian countries, with a special focus on Denmark, where the mix of the global budgets and the DRG-based case payments replaced a system which relied exclusively on the global budgets. Similar reforms took place in Norway and Sweden (Biørn et al., 2003; Kastberg and Siverbo, 2007).

Under the reimbursement relying solely on the global hospital budgets payment to individual hospitals was via a block budget coupled with an activity target, usually defined as a number of acute and elective patients at a specialty level. Each hospitals budget and activity target were outcomes of negotiations between a county, a hospitals management, and the management of individual departments within the hospital. The main decision-criterion to the local politicians was a unit price of activity with a given quality within a calendar year (Alban and Jeppesen, 1995). The key advantage of block hospital budgets is control over global expenditures, which is, however, accompanied by the risk of hospitals not meeting population needs (Barnum et al., 1994; Hagen, 1997; Robinson, 2001). In comparison, DRG-based payment incentivizes hospitals to meet the demand, but in its basic form might also induce them to maximize revenue through increasing the number of cases/diagnoses even if this should be medically inappropriate and financially unsustainable (Ellis and McGuire, 1986). Consequently, in Denmark DRG-based case payments have been added to the longstanding system of block hospital budgets coupled with activity targets, instead of replacing the latter entirely. The intention was to develop an incentive structure that facilitates achievement of dual goals: increasing hospital activity and retaining control over global expenditures. The resulting mixed reimbursement system is viewed as a cautious way of introducing DRG-based case payment, which can balance its undesired features with the key advantage of block budgets.

After the transition to the mixed reimbursement each hospital's revenue comprises of a fraction of the 'old' global budget, which is, however, not coupled with the activity target any more. Additionally, hospitals receive DRG-based case payments, which are reduced by 30-80 per cent of their full monetary value in order to account for marginal rather than average unit cost of activity (also referred to as marginal payments).[1] The global activity targets prevail in the form of primary, secondary, and sometimes also tertiary activity targets. The applicable rate of the DRG tariffs changes (usually downwards) with each consecutive activity target, e.g. hospitals receive 55, 30, and 20 percent of DRG tariffs for activity up to the primary, secondary, and tertiary targets, respectively.

The mixed reimbursement is expected to provide a specific set of incentives that is different from other hospital payment methods (Biørn et al., 2003; Kastberg and Siverbo, 2007; Lindqvist, 2008; Roed and Sjuneson, 2008; Street et al., 2011; Street et al., 2007; Wiley, 1992). However, the discussion of the exact modus operandi of the system is short on detail (especially that the models cited to demonstrate advantages of this system (Ellis and McGuire, 1986; Ellis, 1998; Ma, 1994; Newhouse, 1996), regard combination of DRG-based case payments with cost reimbursement). The achievement of the above-mentioned dual goals would require some combination of activity expansion and reduction in unit cost of activity. Still, it remains unclear whether a change from a reimbursement system based solely on the global budgets to a mix of the global budgets and DRG-based case payments allows the public payer to induce hospitals to produce more within the same total budget or, in other words, produce the same for a lower unit price. In particular, the existing literature does not account for the activity targets, which are an integral part of both the old global budget system and the new mixed reimbursement. Whether a hospital reaches the activity target or not influences the hospital's revenue. Thus, it is important to analyze whether and how the relation between the total sum of the money transferred to the hospitals and the activity targets has been altered with the change of the reimbursement system. Another question is why the mixed reimbursement system is perceived to be superior to a system based exclusively on DRG-based case payments, especially if the latter one is coupled with activity targets. Finally, in the discussion of the mixed reimbursement systems, there remains an open question with regards to the proportions in which the global budgets and the DRG-based case payments should be mixed. This article presents a theoretical analysis, which addresses the above-mentioned questions, in particular the questions:

1. Is it possible to achieve a given level of activity for a lower unit price when hospital reimbursement based solely on global budgets is replaced by a reimbursement based on the mix of global budgets and DRG-based case payments?
2. Whether and how do the different proportions of the global budgets and the DRG-based payments in the hospitals total revenue matter for the hospitals activity and efficiency?

The remaining part of the paper is organized in the following way: Section II presents a model of hospital and public payer behaviour; Section III analyses the model, with a number of subsections presenting the analysis for different classes of the hospital's utility functions; Section IV discusses and summarizes the findings.

II. THE MODEL

Any theoretical analysis of hospital behaviour requires a statement about hospitals goal. Most of the models of hospital behaviour assume that the goal of the hospital is consistent with the goal of the group dominating the decision-making process and/or the production process. Two groups of actors have been identified within hospitals: the physicians and the managers (physician-managers) (McGuire, 1985). There is, nevertheless, no consensus on which of the groups should be taken as the dominating one. A tendency appears to be that models of the for-profit private hospitals assume the physicians, who are rational profit-maximizers, to hold power within the hospitals, while models of the not-for-profit hospitals present hospital managers as the main actors, who also pursue goals different from profit-maximization, e.g. number and quality of treatments, along with the financial goals (Crainich et al., 2010). There also exist approaches that analyze hospital behaviour as a physicians and managers cooperative, illustrating that the objective function of a hospital can be represented as a combination of the objective functions of these two groups of actors (Pauly and Redish, 1973; Custer et. al., 1990). Following the latter approach, in this paper, we assume that the objective function of the hospital reflects both the interests of the physicians and the managers.

Another actor of interest for the current analysis is the third party payer, in this particular case, the public payer. There seems to be more consensus in the literature about the elements in the objective function of the public payer, which is most often assumed to consist of money and some measure of patients' benefits such as , e.g. number of cases treated in a given period. The two following sub-sections present the model and discuss the assumptions made about the objective function of the hospital and the pubic payer.

A. The hospital

The utility function U of the hospital depends on the surplus s, the number n, of treated patients, and the

[1] In Denmark, the DRG-based case payments reflect average cost of production within each DRG among all hospitals. For details see Ankjær-Jensen et al. (2006).

effort exerted in treatment of patients e,

$$U = U(s, n, e). \tag{1}$$

The surplus is understood here as a difference between the lowest possible costs of treatments, i.e. the costs that would be incurred if the hospital provided treatments in a most cost-effective manner, and the real costs reported by the hospital. In other words, the surplus represents some kind of margin the hospital earns. Since the public hospitals are not-for-profit institutions in the explicit financial terms, the surplus can be understood as a measure of the so-called managerial slack. (For similar interpretation, see, e.g. Agrell et al., 2007). The surplus can also have a negative sign, i.e. when a hospital runs a budget deficit. Hence, the surplus represents here a substitutability relation between efficiency increasing (managerial and/or physicians') efforts and the margin the hospital enjoys.

The utility function U of the hospital is a rising function of the surplus s as well as the number n and a decreasing function of the effort e,

$$U_s > 0, \qquad U_n > 0, \qquad U_e < 0, \tag{2}$$

where the italic subscripts stand for partial derivatives. Furthermore, the rates of change are decreasing functions of the corresponding variable,

$$U_{ss} < 0, \qquad U_{nn} < 0, \qquad \text{and} \qquad U_{ee} < 0. \tag{3}$$

The surplus s equals the difference between the budget b and the costs c,

$$s = b - c. \tag{4}$$

The budget b is a function of the number n,

$$b = b(n), \tag{5}$$

and will be specified below. What seems, however, worth mentioning at this point is that the introduction of the DRG-based case payments is usually referred to as an implementation of activity-based reimbursement (ABR). The latter might wrongly suggest that under the reimbursement system based solely on the global budgets, the hospitals' revenue was independent of the hospitals' activity. Yet, in both systems the hospitals' revenue depends on the realized activity. Each global budget used to be coupled with an activity target. Moreover, according to the formal rules, in case a hospital did not realize the contracted activity target, the global budget was reduced by a proportional amount.[2]

[2] Concerns are often expressed whether these rules were followed in practice. Yet, the current analysis regards the incentive effects as produced by the formal models. Moreover, even if the formal models are not applied in practice and thus, the models' incentives distorted, this problem regards not only the global budget system but all types of the reimbursement models as discussed, for example, in Jakobsen (2009).

The costs c are the product of the number n and the specific direct costs of treatment per patient $\mathfrak{c}$,

$$c = n\mathfrak{c}. \tag{6}$$

$\mathfrak{c}$ denotes the costs for the treatment produced in a most cost-effective manner. As mentioned above, the difference between the real costs reported by the hosptal and $\mathfrak{c}$ is here counted as the surplus s or, in other language, the effect of the managerial slack. The effort e is given by the product of the number n and the specific effort $\mathfrak{e}$ of treament per patient,

$$e = n\mathfrak{e}. \tag{7}$$

B. The public payer

The public payer's utility V increases with the number n and decreases with the budget b paid to the hospital,

$$V = V(n, b), \tag{8}$$

where

$$V_n > 0 \qquad \text{and} \qquad V_b < 0. \tag{9}$$

Moreover, the rates of change are decreasing functions of the corresponding variable,

$$V_{nn} < 0 \qquad \text{and} \qquad V_{bb} < 0. \tag{10}$$

First, let us consider budgets that are linear functions of the number n,

$$b = a + rn, \tag{11}$$

where $a \geq 0$ and $r \geq 0$. It is important to note here that a reimbursement system based solely on the global budgets and a pure DRG-based case reimbursement are both a special case of such a budget, where $a = 0$ and $r > 0$. The difference between the two systems is only how the unit of reimbursement is defined. Traditionally, in the block budget the unit of reimbursement used to be some rate per capita. Naturally, it is necessary to find a common budgetary unit when we compare two budgets. This does not pose a problem, as one can easily translate a budget expressed in rates per capita into a budget expressed in DRG tariffs.

As for the mixed reimbursement system, it is a budget where both $a > 0$ and $r > 0$. Here a represents the remaining part of the global budget and rn the DRG-based part of the mixed reimbursement, where a is an intercept and does not depend on the hospital's activity in the current budgeting period. This is an important difference to the earlier-described relationship between the budget and the activity in the reimbursement system based solely on the global budgets. a figuring as an intercept reflects the formal rules, according to which the mixed reimbursement system is formed. In general, this part of the hospital's total revenue is treated as if it was corresponding to the hospital's fixed costs (Søberg Roed and Sjuneson, 2008). Hence, if a hospital does not reach the agreed activity target, a is not subject to the budget reductions.

III. OPTIMISATION

A. The public payer

The public payer optimizes the utility V by varying the input parameters a and r, which will influence the number n at the optimum of the utility U, i.e. n^*. Hence, the utility V at the optimum of the utility U is a function of these two parameters,

$$V \mapsto V\{n^*(a,r), b[n^*(a,r)]\}. \tag{12}$$

The optimum is where,

$$V_a^* = 0 \qquad \text{and} \qquad V_r^* = 0. \tag{13}$$

This results in,

$$\begin{aligned} 0 &= V_a^\star = V_n^\star (n_a^*)^\star + V_b^\star b_a^\star, & (14)\\ 0 &= V_r^\star = V_n^\star (n_r^*)^\star + V_b^\star b_r^\star. & (15)\end{aligned}$$

The budget b depends on the parameters a and r explicitly and additionally, implicitly through the optimum number n^*. For the budget function (11), we obtain

$$\begin{aligned} 0 &= V_n^\star (n_a^*)^\star + V_b^\star \cdot [1 + r^\star (n_a^*)^\star], & (16)\\ 0 &= V_n^\star (n_r^*)^\star + V_b^\star \cdot [(n^*)^\star + r^\star (n_r^*)^\star]. & (17)\end{aligned}$$

The task is now to extract information on the dependence of the optimal number n^* from optimizing the utility U.

B. The hospital

The utility U depends on the independent variable n,

$$U = U[s(n), n, e(n)]. \tag{18}$$

Hence, the optimum is found where the gradient of the utility with respect to the number n equals zero,

$$\mathrm{d}_n U^* = 0, \tag{19}$$

where d_n stands for the total derivative with respect to n, or at a boundary: n is non-negative,

$$n > 0. \tag{20}$$

According to the chain rule of differentiation, Eq. (19) becomes,

$$0 = U_s^* s_n^* + U_e^* e_n^* + U_n^*. \tag{21}$$

Here,

$$\begin{aligned} s &= b(n) - n\mathfrak{c}, & (22)\\ e &= n\mathfrak{e}. & (23)\end{aligned}$$

Hence,

$$\begin{aligned} s_n &= b_n - \mathfrak{c}, & (24)\\ e_n &= \mathfrak{e}. & (25)\end{aligned}$$

Together,

$$0 = U_s^* \cdot (b_n^* - \mathfrak{c}) + U_e^* \mathfrak{e} + U_n^*. \tag{26}$$

Specializing to the budget function (11), the last condition turns into

$$0 = U_s^* \cdot (r - \mathfrak{c}) + U_e^* \mathfrak{e} + U_n^*. \tag{27}$$

1. *Substitutability*

For the sake of simplicity, let us temporarily assume substitutability of the surplus s, the number n, and the negative effort $-e$, i.e.,

$$U \to u(s + n - e). \tag{28}$$

In that case,

$$1 + r = \mathfrak{c} + \mathfrak{e}. \tag{29}$$

The dependence of the parameter a drops out completely. As a consequence, the public payer's optimization problem has an optimum on the boundary

$$a = 0 \tag{30}$$

and otherwise, becomes one-dimensional,

$$0 = V_n^\star (n_r^*)^\star + V_b^\star \cdot [(n^*)^\star + r^\star (n_r^*)^\star]. \tag{31}$$

From Eq. (29) one can see further that for a utility function of the type (28), there results full complementarity between $\mathfrak{c}$ and $\mathfrak{e}$; they only appear in the combination $\mathfrak{c} + \mathfrak{e}$.

Moreover, the condition (29) is also independent of the number n, which is due to the much too simplistic assumption of substitutability, which, for example, entails a complete blindness towards the capacity of the hospital. While the condition is satisfied exactly, from the hospital's point of view, every value of n would give an equal amount of utility. If $1+r$ were only slightly smaller than $\mathfrak{c} + \mathfrak{e}$ the hospital would prefer no to produce at all. Were it slightly bigger, it would like to produce an infinite amount.

The picture can be stabilized by analyzing the optimization problem for the public payer and generalizing the budget function to piecewise linear, as we had announced before. Then the public payer must pay slightly more than given by (29) up to the point where the contributions in its first-order condition cancel,

$$0 = \underbrace{\underbrace{V_n^\star}_{>0} \cdot \underbrace{(n_r^*)^\star}_{>0}}_{>0} + \underbrace{\underbrace{V_b^\star}_{<0} \cdot [\underbrace{(n^*)^\star}_{>0} + \underbrace{r^\star \cdot (n_r^*)^\star}_{>0}]}_{<0}. \tag{32}$$

From this point onward, the public payer would have to pay slightly less than given by Eq. (29) including the possibility of ceasing to pay altogether.

2. *Complementarity*

In order to see, which of the above findings are of a general nature and which of them are linked to the choice of the class of the utility function, let us continue with the different case of a complementary utility function. By that we mean a utility function of the form

$$U \to u[s \cdot n \cdot (t - e)], \tag{33}$$

where t is the absolutely maximal effort the hospital can exert. Then the first-order condition for the hospital reads

$$\frac{\mathfrak{c}}{s^*} + \frac{\mathfrak{e}}{t - e^*} \stackrel{!}{=} \frac{r}{s^*} + \frac{1}{n^*}. \tag{34}$$

Making the dependence on n explicit everywhere leads to a quadratic equation in n, with the solutions

$$n^* = \frac{1}{3}\frac{(r-\mathfrak{c})t - a\mathfrak{e}}{\mathfrak{e}\cdot(r-\mathfrak{c})} \pm \sqrt{\left(\frac{1}{3}\frac{(r-\mathfrak{c})t - a\mathfrak{e}}{\mathfrak{e}\cdot(r-\mathfrak{c})}\right)^2 + \frac{at}{3\mathfrak{e}\cdot(r-\mathfrak{c})}} \tag{35}$$

The argument is always non-negative. As a consequence, there is always one and usually two solutions. The utility depends on one independent variable, n. Therefore, the solution is ascertained by

$$\mathrm{d}_n^2 U \stackrel{n=n^*}{<} 0. \tag{36}$$

This translates into

$$u' \mathrm{d}_n^2[s \cdot n \cdot (t-e)] + u''\{\mathrm{d}_n[s \cdot n \cdot (t-e)]\}^2 \stackrel{n=n^*}{<} 0, \tag{37}$$

where u' and u'' stand for the first and second derivatives of u with respect to its argument, respectively. The second addend is zero on an extremum. Due to Eqs. (2), the solution is ensured if

$$\mathrm{d}_n^2[s \cdot n \cdot (t-e)] \stackrel{n=n^*}{<} 0, \tag{38}$$

which we can solve for n^*,

$$n^* > \frac{1}{3}\frac{(r-\mathfrak{c})t - a\mathfrak{e}}{\mathfrak{e}\cdot(r-\mathfrak{c})}. \tag{39}$$

This condition selects the '+' solution from Eq. (35).

For analyzing the public payer's optimization problem in all its details, we would have to specify a particular utility function. Even without doing so, however, we can find out, in how far the public payer can influence the hospital according to its preferences. We can, for example, ask, what is the minimum budget b needed to entice the hospital to treat a given target number $\mathtt{n}$ such that $n^* = \mathtt{n}$. Solving the first-order condition

$$\mathrm{d}_n[s \cdot n \cdot (t-e)] \stackrel{n=n^*}{=} 0 \tag{40}$$

for r, we find

$$r = \mathfrak{c} - \frac{a}{\mathtt{n}}\frac{t - 2\mathfrak{e}\mathtt{n}}{2t - 3\mathfrak{e}\mathtt{n}}. \tag{41}$$

Using this expression to eliminate r from the budget function, we get

$$b = a + \mathfrak{c}\mathtt{n} - a\frac{t - 2\mathfrak{e}\mathtt{n}}{2t - 3\mathfrak{e}\mathtt{n}}. \tag{42}$$

Optimisation with respect to a yields,

$$0 = 1 - \frac{t - 2\mathfrak{e}\mathtt{n}}{2t - 3\mathfrak{e}\mathtt{n}} \tag{43}$$

or

$$t = \mathfrak{e}\mathtt{n}. \tag{44}$$

Being a utility function u in Eq. (33) must be a rising function of its argument, which here additionally is required to be positive. The previous solution, however, puts it exactly at $u(0)$, which is the minimum value. As a consequence, we have to look at optima on the boundaries. The boundaries are given by $a = 0$ and $r > 0$, on one hand, and $a > 0$ and $r = 0$, on the other. In each of the cases the non-zero component must be chosen such that the target $\mathtt{n}$ is reached.

Starting with $a = 0$, we find from Eq. (35)

$$n^* = \frac{2}{3}\frac{t}{\mathfrak{e}} \tag{45}$$

independent of r. This is the largest achievable target value, as t and $\mathfrak{e}$ are fixed. The hospital cannot be made to produce any larger number by any choice of r, however large it may be. Nevertheless, r must be large enough for the hospital to prefer this option over $u(0)$. Given Eq. (45) the argument of u is positive as long as

$$s = (r - \mathfrak{c})\mathtt{n} \stackrel{!}{>} 0. \tag{46}$$

Hence, the public payer has to offer $r^\star > \mathfrak{c}$ leading to $b^\star > \mathfrak{c}\mathtt{n}$.

For the other boundary, $r = 0$, if the target $\mathtt{n}$ is to be met by the hospital we find from the first-order condition

$$b = a = \mathfrak{c}\mathtt{n}\left(1 + \frac{t - \mathfrak{e}\mathtt{n}}{t - 2\mathfrak{e}\mathtt{n}}\right). \tag{47}$$

If the effort $\mathfrak{en}$ is smaller than half the maximum value t this budget exceeds the one for $a = 0$. Even if $\mathfrak{en} > t/2$ the budget could never be less than $\mathfrak{nc}$ as otherwise the argument of the utility function would become negative, and not to produce at all would be the optimal choice for the hospital. Taking stock, the option with the maximum value for r, i.e., the $a = 0$ option, is always either less expensive than the $r = 0$ option or costs the same.

If we had allowed for a maximum deficit $d \geq 0$, $U \to u[(d + s) \cdot n \cdot (t - e)]$ the minimally achievable budget would be $\mathfrak{en} - d$.

3. Additively separable

In order to gain yet more insight, let us study an additively separable utility function

$$U \to S(s) + N(n) + E(e), \tag{48}$$

where S', $N' > 0$ and E', S'', N'', $E'' < 0$. This leads to

$$\begin{aligned} \mathrm{d}_n U &= S' \cdot (r - \mathfrak{c}) + N' + \mathfrak{e}E' \overset{n=n^*}{=} 0, & (49)\\ \mathrm{d}_n^2 U &= S'' \cdot (r - \mathfrak{c})^2 + N'' + E''\mathfrak{e}^2 \overset{\checkmark}{<} 0, & (50)\\ (\mathrm{d}_n U)_a &= S'' \cdot (r - \mathfrak{c}), & (51)\\ (\mathrm{d}_n U)_r &= S' + S'' \cdot (r - \mathfrak{c})n. & (52) \end{aligned}$$

If, as above, we would like to optimize the budget at fixed n^*, we obtain from

$$\mathrm{d}_r n^* \overset{r=r^\star}{=} 0 \tag{53}$$

that

$$\begin{aligned} &[(r-\mathfrak{c})^2 S'']^2 - 2n^{-1}(N' + E'\mathfrak{e})[(r-\mathfrak{c})^2 S''] - & (54)\\ &\qquad - n^{-1}(N' + E'\mathfrak{e})(N'' + E''\mathfrak{e}^2) \underset{n=n*}{\overset{r=r^\star}{=}} 0, \end{aligned}$$

which is solved by

$$(r-\mathfrak{c})^2 S'' \underset{n=n*}{\overset{r=r^\star}{=}} \frac{N' + E'\mathfrak{e}}{n} \left(1 \pm \sqrt{1 + n\frac{N'' + E''\mathfrak{e}^2}{N' + E'\mathfrak{e}}}\right). \tag{55}$$

The fraction under the square root is negative, which makes the square root smaller than unity. Consequently, the right-hand side is always positive. To the contrary, S'' is required to be negative. Therefore, there is no solution to this equation other than $r^\star = \mathfrak{c}$. That this leads to the optimal, i.e., the minimum budget follows also from investigating how the budget b changes as a function of r with n^* held fixed,

$$b_r|_{n^*\ \text{fixed}} = a_r + n^* = \left.\frac{S'}{-S'' \cdot (r - \mathfrak{c})}\right|_{n=n^*}, \tag{56}$$

where we have determined a_r from Eq. (49). The thus found b_r has the same sign as $r - \mathfrak{c}$. Hence, the budget increases if r is moved away from $\mathfrak{c}$ in either direction. Furthermore, at $r^\star = \mathfrak{c}$, the dependence on a drops out of the first-order condition (49). Therefore, a does not influence the optimization problem for the hospital, but only causes disutility for the public payer. Hence, the optimum is at $a^\star = 0$.

Taking stock, here a carefully chosen value of r leads to the minimum budget for a given fixed value of n^*.

4. General case

Finally, let us take a look at the general case (1), where we have the first-order condition (21). From there, we can construct once more,

$$b_r|_{n^*\ \text{fixed}} = a_r + n^* = n^* - \left.\frac{(\mathrm{d}_n U)_r}{(\mathrm{d}_n U)_a}\right|_{n=n^*}. \tag{57}$$

We find,

$$\begin{aligned} (\mathrm{d}_n U)_a &= U_{ss} \cdot (r - \mathfrak{c}) + U_{es}\mathfrak{e} + U_{ns} & (58)\\ (\mathrm{d}_n U)_r &= n f_a + U_s, & (59) \end{aligned}$$

which leads to

$$\begin{aligned} b_r|_{n^*\ \text{fixed}} &= -\left.\frac{U_s}{(\mathrm{d}_n U)_a}\right|_{n=n^*} = & (60)\\ &= -\left.\frac{U_s}{U_{ss} \cdot (r - \mathfrak{c}) + U_{es}\mathfrak{e} + U_{ns}}\right|_{n=n^*}. \end{aligned}$$

The findings are not changed qualitatively with respect to the previous cases, but there is a quantitative correction to the position of the optimum, which previously has been found at $r^\star = \mathfrak{c}$. $U_{es}\mathfrak{e} + U_{ns}$ is not necessarily negative. Hence, the sign of the correction to the optimum is, in general, indeterminate. The common feature of all utility functions is, however, that the change of the sign of $b_r|_{n\ \text{fixed}}$, which determines the optimum, occurs where $(\mathrm{d}_n U)_a$ is zero, i.e., where the first-order condition is independent of a. Hence, we can conclude that $a^\star = 0$ is always the optimal choice.

5. Multiplicatively separable

Interestingly, for a multiplicatively separable utility function

$$U \to S(s) \cdot N(n) \cdot E(e), \tag{61}$$

where S, N, E, S', $N' > 0$ and E', S'', N'', $E'' < 0$ and

$$\mathrm{d}_n U = U \cdot \left[\frac{S'}{S} \cdot (r - \mathfrak{c}) + \frac{N'}{N} + \frac{E'}{E}\mathfrak{e}\right] \overset{n=n^*}{=} 0, \tag{62}$$

we find

$$b_r|_{n^*\ \text{fixed}} = -\left[\frac{S''}{S'}(r - \mathfrak{c}) + \frac{N'}{N} + \frac{E'}{E}\mathfrak{e}\right]^{-1}_{n=n^*}, \tag{63}$$

which by virtue of the first-order condition (62) can be turned into

$$b_r|_{n^*\text{ fixed}} = \underbrace{-\left[\frac{S''}{S'} - \frac{S'}{S}\right]^{-1}_{n=n^*}}_{>0} (r - \mathfrak{c})^{-1}, \qquad (64)$$

which also always has the sign of $r - \mathfrak{c}$, which puts the optimum at $r^\star = \mathfrak{c}$ again.

IV. DISCUSSION AND SUMMARY

In the model we simulate the interplay between a public payer who sets the conditions for the budget and a representative hospital that reacts to a given budget by adjusting its activities.

In conclusion, let us return to the questions from the introduction:

1. Is it possible to achieve a given level of activity for a lower unit price when hospital reimbursement based solely on global budgets is replaced by a reimbursement based on the mix of global budgets and DRG-based case payments?

2. Whether and how do the different proportions of the global budgets and the DRG-based payments in the hospitals total revenue matter for the hospitals activity and efficiency?

The answer to the first question is negative. The hospital reimbursement, which is referred to as the mixed reimbursement system does not bring about the expected gains. In order to induce the hospitals to reach a given production level for a lower unit price it is better to implement either the system that relies solely on global budgets or DRG-based case payments coupled with activity targets. As discussed earlier, the two systems are structurally equivalent, i.e. in both the total revenue of a hospital depends on the unit rate of reimbursement multiplied by the volume of activity. The intuition behind the negative answer to the first question is the following: In the mixed reimbursement system, the hospital receives a part of the revenue independently of the activity. Hence, if the contracted activity target is not reached the reduction in the hospital's total revenue is proportionally smaller than under the systems which link the whole of the revenue to the hospital's activity. In other words, under the mixed reimbursement system the hospitals are less likely to reach the contracted activity targets as the degree to which the reimbursement is activity-based is in fact lower than in the other systems.

There is naturally a question about how to find an optimal unit rate of reimbursement. As it is clearly indicated in the analysis, the efficiency gains depend on how well the unit rate of reimbursement corresponds to what could be the lowest possible unit cost. One can reasonably argue that the DRG-based case payments bring the unit rate of reimbursement closer to the optimum than the system relying on the rate per bed-day or per capita. Still, it must be stressed that the efficiency gains are an effect of the change of the reimbursement rate (unit price) and not the change of the reimbursement mechanism as such.

The block part of the total budget in the mixed reimbursement system is also argued to secure the aim of global cost control. Yet, in the view of the current analysis this aim can be secured with the other reimbursement systems as long as there is a global expenditure cap applied at the right level.

Since, the answer to the first question is negative, investigating into the matter of the second one is of a minor relevance. It is easily seen that the smaller the intercept in the budget function the more likely is the hospital to reach the given activity target for a lower unit price.

The findings here show also that the effect of a change of budget depends strongly on the present situation of the hospital thus, predicting the effects necessitates a very detailed knowledge about the current situation of a hospital, and especially, might have converse effects for different hospitals.

Finally, the arguments in favor of the mixed reimbursement are often supported by recalling the fact that under the reimbursement relying exclusively on global budgets the activity targets often remained unmet and/or hospitals were running large budget deficits. Such state of affairs is usually accounted to weak budget discipline, i.e. neither the missing activity nor the budget deficits were transferred between the budgetary years. Instead, the hospitals were bailed out of their financial problems (Jakobsen, 2009; Søberg Roed and Sjuneson, 2008). It should be noticed, however, that the mixed reimbursement or, in fact, any other reimbursement method, does not automatically remove the political willingness to bail out the hospitals.

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