SIER Working Paper Series No. 104

Theoretical Analysis of Heterogeneous Hospital Response to a Per Diem Prospective Payment System

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March, 2019

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March 5, 2019

Abstract

Motivated by the Japanese PPS reform, aimed at curbing high length of stay in Japanese hospitals, we develop a theoretical model to study how hospitals' financial incentives differ between the two reimbursement systems: a pre-reform fee-for-service (FFS); and a post reform length-of-stay-dependent stepwise decreasing per diem rate (SDR). First, we show that hospitals with shorter (longer) average length of stay under FFS have longer (shorter) average length of stay under SDR. Second, we show that hospitals with longer stay under the FFS reimbursement system are more likely to use planned readmission in order to decrease the length of stay associated with a single admission. Finally, we show that profit-wise, it is hospitals with the shortest pre-reform length of stay who gain from a change to the SDR reimbursement rule. The theoretical predictions of our model closely match empirical evidence from the literature.

JEL Classification Codes: I12, I18, C23, D21, D22

Keywords: Health care financing; Prospective payment system, per-diem rate; length of stay; readmission rate

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1 Introduction

Health care is an example of an industry where providers exercise much influence on the choice of medical services by consumers (Christianson and Conrad 2011; Mayes 2007). Combined with volume-based fee-for-service (FFS) reimbursement, the power of health care providers leads to supplier-induced demand, overuse of resources, and overspending. A prospective payment system (PPS), which is an umbrella terms for payment methodologies where insurance reimbursement is a predetermined fee regardless of services provided, is well-recognized way to increase cost efficiency of hospital production. When facing the same fixed payment for every treatment episode, hospitals start to bear the financial burden of excessive medical treatment leading to an increased cost efficiency of hospital production.

Japan, like many other OECD countries, has been struggling with the containment of soaring health care costs since as early as the seventies. By 2012, central government financed 25.3% of health care expenditure (MHLW, 2012c), which represented 10.2% of the government budget (Ministry of Finance, 2012). Initially, Japanese government relied on higher coinsurance rates and lowering of fees in the united fees schedule, however, their effect was exhausted by early 2000s (Ikegami, 2009). Consequently, the Ministry of Health, Labor, and Welfare (MHLW) decided to introduce an inpatient prospective payment system for acute care hospitals in order to create incentives for cost containment.

The inpatient prospective payment system introduced by the MHLW is a mixed system that combines elements of the retrospective system (FFS) and prospective system which is based on diagnosis-procedure combinations (DPCs). Most of the DPCs have a sufficiently large number of cases and can be viewed as homogeneous. The shares of retrospective and prospective components are 0.3 and 0.7 respectively (Okugama et al., 2005). Within a given DPC the prospective component is constructed as a per-diem rate, where the actual rate is based on the hospitals' length of stay. Initial period, corresponding to 25-percentile of average length of stay (ALOS) for a given DPC, is reimbursed at the highest per-diem rate; the second period is reimbursed at a lower per-diem rate; and the third period is reimbursed at the lowest per-diem rate. The purpose of introducing the stepdown per-diem rate was to incentivize hospitals to reduce ALOS in Japanese hospitals, which is the highest among OECD countries (see Figure 1).

The Japanese PPS immediately resulted in decline of the ALOS at the level of individual hospitals and nationally (MHLW 2005). Since ALOS reflects optimal resource use and, therefore, is

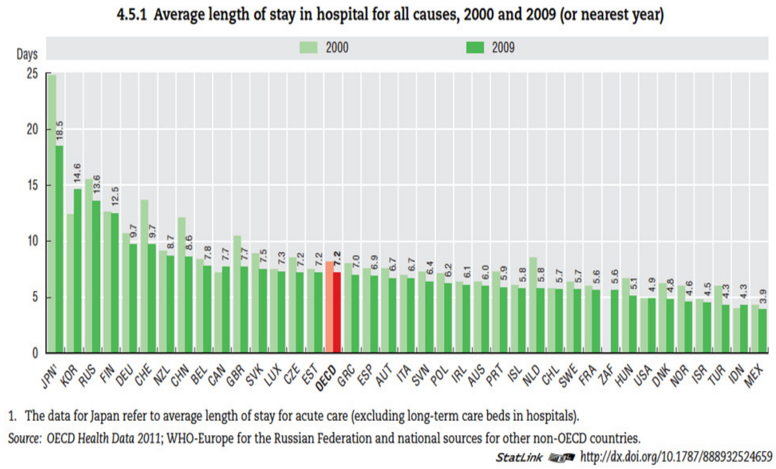

Figure 1: Average Length of Stay in OECD Countries Source: OECD (2011) .

often treated as a proxy for hospital efficiency (Lopes et al., 2004; Rapoport et al., 2003; Heggestad, 2002), a fall in ALOS is arguably associated with increased efficiency (Kuwabara et al. 2011). Yet, both technical and cost efficiency of Japanese hospitals demonstrate only a minor improvement owing to the reform (Besstremyannaya 2012) and the impact on hospital costs is ambiguous (Nishioka 2010; Yasunaga et al. 2006; Yasunaga et al. 2005a).

Furthermore, empirical evidence suggests that a national decrease in an ALOS was not uniform across all hospitals. Nawata and Kawabuchi (2012) show that decrease of mean ALOS for the population of PPS hospitals might be disentangled into increase of ALOS at some hospitals and decrease of ALOS at other hospitals. Finally, the decrease in ALOS was accompanied by quality deterioration reflected in a rise of the early readmission rate and, specifically, planned readmissions (Hamada et al. 2012; Yasunaga et al. 2005a; Okamura et al. 2005). Notably, empirical evidence indicates that an increased reliance on planned readmission was specifically caused by the stepdown feature of the Japanese PPS, whereby longer LOS is reimbursed under lower per-diem rate (Kondo and Kawabuchi, 2012).

To provide a theoretical framework of understanding the mixed effect of the Japanese PPS reform we develop a theoretical framework to model how financial incentives of hospitals differ between the fee-for-service reimbursement scheme, FFS, which corresponds to the pre-reform system, and a per diem PPS with a LOS-dependent step-down rate, SDR, which corresponds to the post-reform system. To separate the effect of the switch to per diem system from the effects of LOS-dependent per diem we also study an intermediate reimbursement system with a flat per diem rate, we label this reimbursement system as PD. The main questions that we are interested in are how the reform affects the length of stay; and whether and when hospitals have incentives to rely on planned readmission in order to benefit from higher per-diem rates paid for shorter LOS.

Given the focus on financial incentives we model hospitals as profit-maximizing agents that vary in their cost functions.[1] This heterogeneity can be due to many factors such as difference in equipment cost, human capital, or opportunity cost due to differences in bed occupancy rates. Other things being equal, for hospitals with lower (higher) costs it is optimal to treat patients with longer (shorter) length of stay.

We show that due to heterogeneity of hospitals' cost functions, the impact of the reform will differ across hospitals. Introduction of PD gives hospitals with shorter pre-reform ALOS incentives to lengthen it, and to hospitals with longer pre-reform ALOS incentives to decrease it. Adding LOS-dependent reimbursement rates such that initial stay is reimbursed at a higher tariff, as in SDR, has unambiguously perverse incentives on hospitals. The higher initial tariff increases hospitals' marginal benefit from longer stay without affecting marginal cost. Effectively, all hospitals, except for those with the longest ALOS, find it profitable to treat patients longer. The total effect, therefore, is not uniform. While some hospitals do shorten their LOS (those with long pre-reform LOS), others (those with short pre-reform LOS) increase their LOS. This is consistent with evidence from Nawata and Kawabuchi (2012) who showed that not all hospitals decrease their ALOS. Evidence from Besstremyannaya (2014) provides the most direct empirical test of our theoretical prediction and shows that, indeed, it is hospitals with shorter (longer) pre-reform ALOS that increase (decrease) their post-reform LOS.

In order to model the effect on planned readmission rate, we allow hospitals to choose whether to treat a patient with one or two admissions, and if the hospital chooses to use two admissions we treat the second one as a planned readmission. In our model the decision to use planned readmission is due to financial incentives, however, there are also pure medical reasons why hospitals would choose to use planned readmission.[2] We show that the reform and, specifically, the stepdown

[1]See Hodgkin and McGuire 1994; Ellis and McGuire 1996; Ma 1998; Grabowski et al. 2011 who also model hospitals as profit-maximizing suppliers of health care volume and quality.

[2]According to MHLW (2005) readmissions are classified into planned, anticipated, and unplanned. The reasons for anticipated readmissions are: 1)anticipated worsening of medical condition; 2)anticipated worsening of comorbidity; 3)patient was temporarily discharged to raise his/her quality of life; 4)discharged from previous hospital stay at the patient's request; 5)other.

The reasons for planned readmissions are: 1)operation after preliminary tests; 2) planned operation or procedures;

rate financially encourages hospitals to use planned readmission. We show that under the SDR system hospitals with longer pre-reform ALOS have stronger incentives to treat patients using planned readmission. Intuitively, since each admission is reimbursed separately, the SDR system enables hospitals to benefit twice from higher initial rates by means of planned readmission. The implication of this result is two-fold. First, we should expect an increase in the planned readmission rate for hospitals with the longest ALOS. Second, hospitals with the longest ALOS can use planned readmisisons to decrease the reported ALOS, even though the full treatment takes longer. This result is consisted with evidence reported in Kondo and Kawabuchi (2012). Besstremyannaya (2014) provides a most direct empirical test of our model prediction and finds that for most MDCs (Major Diagnostic Category) it is the case that hospitals with longer pre-reform ALOS report an increased planned readmission rate.

The remainder of this paper is structured as follows. Section 2 provides a description of the major features of the Japanese inpatient prospective payment system. Section 3 sets up a theoretical model for a profit-maximizing hospital as a supplier of health care and quality, and evaluates the effect of the reform on the length of stay. Section 4 studies the effect of the reform on hospitals' profitability; and Section 5 studies the effect on quality as measured by readmission rates. Section 6 provides a concluding remarks. All the proofs are given in the Appendix.

2 Japan's inpatient prospective payment system

This section provides a brief description of the specifics of the Japan's inpatient prospective payment system, and it closely follows Besstremyannaya (2014).

The Japanese inpatient PPS is effectively a mixed system. The reimbursement is the sum of DPC and fee-for-service components. The DPC component is constructed as a per diem step-down rate, related to the hospital's length of stay. For each DPC, the amount of the daily inclusive payment is flat over each of the three consecutive periods: period 1 represents the 25-percentile of ALOS calculated for all hospitals submitting data to MHLW;[3] period 2 contains the rest of the ALOS; and period 3 includes two standard deviations from the ALOS. After period 3 expires, hospitals are reimbursed according to the FFS system. To create incentives for shorter length of stay,

3) chemotherapy or radiation theraphy; 4) planned examinations/tests; 5) examination/operation was stopped during the previous treatment, and the patient was discharged; 6) patient was sent home to recuperate before an operation.

[3]The initial rates were set on the basis of 267,000 claim data on patients discharged from 82 targeted hospitals in July-October 2002.

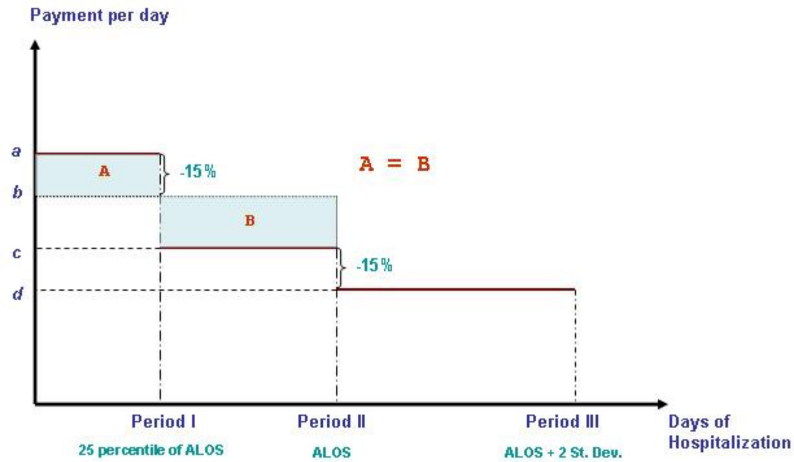

Figure 2: Step-down per diem payment scheme for a given DPC. Source: MHLW (2011).

per diem DPC payment in the first period is set 15% above the standard per diem reimbursement (Figure 2).

The first version of DPCs consisted of 2552 diagnosis groups. Most of the groups (1860) had a sufficiently large number of cases and were rather homogeneous (Ikegami 2005). The per diem rates were set on the basis of these groups, which corresponded to about 90% of admission. The numbers of diagnoses and DPCs gradually increased from 2003, and as of 2012 there were 2927 diagnosis groups and 2241 DPCs. Along with the diagnosis, each DPC incorporates three essential issues: algorithm, procedure, and co-morbidity. Diagnoses are coded according to ICD-10 and the Japanese Procedure Code (commonly used under FFS reimbursement) is employed for coding procedures (Matsuda et al. 2008, MHLW 2004).

The DPC component covers basic hospital fee, hospital expenditures on examinations, diagnostic images, pharmaceuticals, injections, and procedures costing less than 10,000 yen. The fee-for-service component reimburses the cost of medical teaching, surgical procedures, anaesthesia, endoscopies, radioactive treatment, pharmaceuticals and materials used in operating theatres, as well as procedures worth more than 10,000 yen (MHLW 2012a; Yasunaga et al. 2005a).

The introduction of inpatient PPS is a voluntary reform for each Japanese hospital. The records of the Ministry of Health, Labor, and Welfare, and anecdotal evidence (e.g., Okuyama 2008) demonstrate that participation in PPS is voluntary: the decision is made by the hospital itself with no governmental pressure. There are several eligibility criteria: a hospital has to meet a threshold value of the MHLW nurse staffing ratio equal to 2 inpatients per nurse; has to follow the methodology for accounting of inpatient expenditure; and has to collect standardized data on prescribed drugs. In particular, the methodology for accounting inpatient expenditure includes the employment of special administrative staff, detailed book keeping, ICD-10 coding, and data processing (Sato 2007).

3 Basic Setup. Length of Stay.

This section develops a theoretical framework to analyze how changing the reimbursement system from fee-for-service (FFS) to a per-diem PPS with stepdown rate affects hospitals' financial incentives regarding the patients' length of stay. Given the focus on a financial component of hospitals' operations we assume hospitals to be profit-maximizing agents. We consider three reimbursement systems: fee-for-service (FFS), which corresponds to the system used before the reform; the per diem prospective system (PD); and the per diem prospective system with a *s*tep*d*own *r*ate (SDR), which corresponds to the post-reform reimbursement, as explained in the previous section. The PD system is an intermediary between the FFS and the SDR, and enables us to isolate the effects of the switch to a per diem system from the effects of different per diem rates.

Consider a diagnosis (DPC). We assume that there is a variety of medical procedures and input combinations that could be used to treat a given condition, that we classify as discretionary and non-discretionary. Non-discretionary procedures and input combinations is something that, for medical reasons, has to be done in order to treat the patient's condition. Discretionary inputs and procedures is something that is employed beyond non-discretionary procedures either to complement or enhance the effect of non-discretionary procedures. Discretionary inputs are not wasteful in terms of patients' health and could include items such follow-up tests or pre-treatment screening.

Given that non-discretionary inputs procedures is something that the hospital has to perform, we will normalize them to zero. As for discretionary inputs, we will label them as I, where $I \in [0, \infty)$. Employing discretionary inputs increases the patient's length of stay as given by a function $L(I)$ where $L(0) = 0$ and $L'(I) > 0$. As hospitals deal with many cases of a given diagnosis, we can think of $L(I)$ as the average length of stay for the diagnosis in a hospital.

The hospitals' cost associated with the length of stay is given by a function $\gamma g(L)$, where g is strictly increasing and convex function such that $g'(\infty) = \infty$.[4] We assume that different

[4] The assumption that g is a strictly increasing function of L is not innocuous because one can imagine that a faster treatment could be considerably costlier as it might require modern and more expensive equipment. Thus, the situation where g declines at first and becomes an increasing function later is conceivable. Note, however, that

hospitals have different γ, so that cost (and marginal cost) is higher for hospitals with higher γ. The heterogeneity parameter γ may reflect difference in equipment costs, human capital, or opportunity costs due to availability of personnel or bed occupancy rates. In addition, there is a direct cost associated with purchasing discretionary inputs which is equal to cI, where $c \geq 0$. Thus the total hospital's cost is $cI + \gamma g(L)$.

Two remarks are in order. First, the functional form above is used for its simplicity. One could use a more general cost function $h(\gamma, I, L)$. Under specific technical conditions, such as h is an increasing function of all three inputs, convexity and $h''_{\gamma L} > 0$, the results below will hold. Second, given that L is a function of I, discretionary inputs affect the cost via two sources: directly and indirectly via L. This is to reflect the fact that there is direct cost of running a given test or procedure and then there are also costs associated with keeping a patient in the hospital. As mentioned earlier, the latter can come from the load on medical personnel and medical equipment as well as the bed occupancy rate.

3.1 Fee-for-service system

We model the fee-for-service as a system which reimburses hospital's inputs usage at a fixed rate p_I, where $p_I > c$. The hospital's maximization problem is

$$\max_I p_I I - cI - \gamma g(L).$$

To allow comparison with per-diem and step-down per diem prospective payment systems, that we introduce later in the paper, we can equivalently re-write it as

$$\max_L p_I I(L) - cI(L) - \gamma g(L).$$

In what follows we assume that the total cost, $cI(L) + \gamma g(L)$ is a convex functions of L. A sufficient condition for that is that $I(L)$ is a convex function of L (equivalently $L(I)$ is concave), which we will maintain throughout the paper.

Optimal L is given by the FOC

$$p_I I'_L = cI'_L + \gamma g'(L). \tag{1}$$

The second-order condition is

$$p_I I'' - cI'' - \gamma g''(L) < 0.$$

neither the FFS nor the PD systems will lead to a choice of L at the interval where g declines.

which we can re-write as

$$p_I < c + \gamma \frac{g''(L)}{I''(L)}.$$

In what follows we assume that $g''(L)/I''(L)$ converges to infinity when $L \to \infty$ so that the SOC is satisfied for any $\gamma > 0$.

We denote the solution to (1) as L_{FFS}. It is immediate to verify that it is a decreasing function of γ:

$$\frac{\partial L_{FFS}}{\partial \gamma} = -\frac{-g'(L)}{p_I I'' - cI'' - \gamma g''(L)} < 0.$$

Here the denominator is the SOC and is negative, while term $g'(L)$ is positive since $g(\cdot)$ is an increasing function of L. Intuitively, higher γ results in higher costs associated with the LOS and, therefore, it is optimal for hospitals to choose lower L.

The reasoning above established Proposition 1.

Proposition 1 *The optimal length of stay under the fee-for-service system, L_{FFS}, satisfies (1) and it is a decreasing function of γ.*

3.2 Per diem prospective payment system

Under the flat per-diem PPS, hospitals are paid a fixed per-diem rate, $\bar{d}$, for each day that a patient stays in the hospital. The profit-maximization problem under the per diem PPS is, therefore,

$$\max_L \bar{d}L - cI(L) - \gamma g(L). \tag{2}$$

This formulation of a per diem PPS is related to, though different, from that in Grabowski et al. (2011) who study the Medicare's adoption of a per diem PPS for skilled nursing facilities (SNFs) in 1998. The differences are as follows. First, in Grabowski et al. (2011) the intensity and the length of stay are two independent choice variables for SNFs. In our model, the only choice variable for hospitals is the length of stay, which is a function of intensity, i.e. I-inputs. Second, in our model the per diem rate is either constant (as in this section), or a decreasing step function of the length of stay (later in the paper). This assumption is appropriate given the specifics of the Japanese PPS reform. In Grabowski et al. (2011) the per diem rate is not a constant and directly depends on the intensity. Finally, Grabowski et al. (2011) explicitly introduce demand for SNF services which is a function of patients' benefit of stay. Given our focus we, instead, model the hospital's choice as the trade-off between higher financial benefits associated with a longer patient's stay and the higher cost that a longer stay involves.

The post-reform per-diem rate in Japan, $\bar{d}$, was determined according to the average per diem reimbursement under the pre-reform fee-for-service system. Specifically, as in the previous Section let L_{FFS} be the optimal LOS under fee-for-service system for a given hospital with a given γ. Then, for a given hospital, the effective per diem reimbursement under FFS was

$$d = \frac{p_I I(L_{FFS})}{L_{FFS}}.$$[5]

Taking the average over all hospitals we get the expression for $\bar{d}$:

$$\bar{d} = E_\gamma \left[\frac{p_I I(L_{FFS})}{L_{FFS}} \right]. \tag{3}$$

The optimal length of stay under the per-diem PPS, L_{PD}, satisfies the FOC for (2):

$$\bar{d} - cI'(L_{PD}) - \gamma g'(L_{PD}) = 0, \tag{4}$$

and, as one would expect, it implies that higher values of $\bar{d}$, *ceteris paribus*, lead to longer LOS.

The next proposition compares the LOS under the fee-for-service and per-diem systems. It turns out that the difference depends on the pre-reform length of stay.

Proposition 2 *Assume the reform changes a reimbursement rule from the fee-for-service to the per-diem PPS. The LOS will decline ($L_{PD} < L_{FFS}$) for hospitals with high pre-reform LOS; it will increase ($L_{PD} > L_{FFS}$) for hospitals with low pre-reform LOS.*[6]

The proof of Proposition 2 is given in the Appendix. In the proof we establish that there exists a threshold value of γ_0 such that for hospital with γ above it, i.e. for hospitals with low values of L_{FFS}, the post-reform LOS will increase; at the same time for hospitals with γ below γ_0, i.e. for hospital with high L_{FFS} the post-reform LOS will decrease.

The intuition is straightforward. Under the per-diem PPS the marginal benefit does not depend on L and is equal to $\bar{d}$. Under FFS the marginal benefit is $p_I I'(L)$ and it *does* depend on L. Given convexity of $I(L)$, hospitals with lower L_{FFS} have lower marginal benefit under FFS. A switch to

[5]Under FFS, of course, hospitals were not reimbursed based on per-diem rate. We use term *effective per-diem rate* for an average daily payment the hospital effectively received under the FFS system.

[6]We assumed here that $L(I, \bar{D})$ is a concave function of I. One can easily adapt the proof of Proposition 2 to the case of convex L. In the case of convex L it is hospitals with low pre-reform LOS that will experience a further decline in LOS, while hospitals with high LOS will experience an in crease in LOS. However, the evidence from Besstremyannaya (2014) provides an empirical support for the assumption of concave L. We will focus on the case of concave L throughout the paper.

the per-diem system will increases their marginal benefit making longer LOS optimal. Similarly, hospitals with higher L_{FFS} have higher marginal benefit under the FFS. A switch to the per-diem system will result in a decline of the marginal benefit making shorter stay optimal. The hospital for which $p_I I'(L) = \bar{d}$ is what determines the threshold value of γ_0. For this hospital the LOS will not change.

We illustrate Proposition 2 with the following stylized example. Let $c_I = 0$, $g(L) = L^3$ and $L(I) = \sqrt{I}$, so that L is a concave function of I. Then the profit function under the FFS system is

$$p_I I - \gamma \cdot (I)^{3/2}.$$

The optimal level of I-inputs is given from the FOC, $I = \frac{4}{9}\frac{p_I^2}{\gamma^2}$, and $LOS_{FFS} = \sqrt{I} = \frac{2}{3}\frac{p_I}{\gamma}$. The average daily payment to a hospital with a given γ is

$$\frac{p_I I}{L(I)} = \frac{2p_I^2}{3\gamma}.$$

Under the PD system the maximization problem is

$$\bar{d}L - \gamma L^3.$$

From the first order condition we get that $L_{PD} = \sqrt{\frac{\bar{d}}{3\gamma}}$.

Figure 3 shows the lengths of stay under the FFS and the PD systems when $\gamma \sim U[0.1, 2.1]$ and $p_I = 3$.[7] For this parameter values $\bar{d} \approx 11.14$. As proved in Proposition 2, hospitals with longer LOS under the FFS ($L_{FFS} > 0.71$) decrease the LOS. Hospitals with shorter LOS under the FFS ($L_{FFS} < 0.71$), on the other hand, choose to increase the length of stay.

3.3 Per diem prospective payment system with a step-down rate

The previous section analyzed the impact of the switch from the FFS to PD reimbursement rules on the length of stay. In this section we add an additional feature to the PD reimbursement to capture the specifics of the health care reform in Japan, where the per-diem rate is not constant but depends on the length of stay as shown on Figure 2. Period 1, which corresponds to the 25-percentile of ALOS reported by all hospitals submitting data to MHLW, has the highest per-diem rate; period 2, which contains the rest of ALOS has a lower per-diem rate; period 3 which includes two standard deviations from the ALOS has the lower per-diem rate.

[7] We exclude 0 from the support of the γ's distribution as otherwise $\bar{d}$ is infinity.

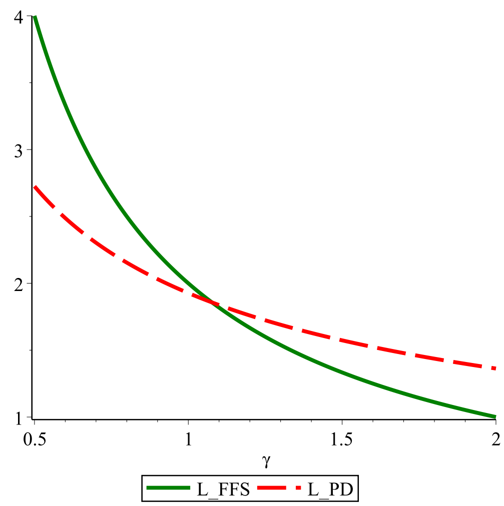

Figure 3: LOS for a given DPC under PD (solid line) and FFS (dashed line) systems.

In our model we simplify the system by assuming that there are two, and not three as in the Japanese inpatient PPS, periods. Let $\bar{L}$ denote the the average LOS under the FFS system. During the initial $\alpha\bar{L}$ a higher per diem rate $q\bar{d}$ is paid, where $q > 1$ and $\alpha < 1$; a regular per diem rate, $\bar{d}$, is paid afterwards.

The hospital's profit function under the SDR is:

$$\pi(L) = \begin{cases} q\bar{d}L - cI(L) - \gamma g(L) & \text{if } L \leq \alpha\bar{L} \\ (q\bar{d}) \cdot \alpha\bar{L} + \bar{d}(L - \alpha\bar{L}) - cI(L) - \gamma g(L) & \text{if } L > \alpha\bar{L} \end{cases} \tag{5}$$

The next Proposition describes the optimal choice of the length of stay depending on values of γ. In Proposition 3 we use $L^*_{PD}(\gamma)$ and $L^{SDR}(\gamma)$ to denote the optimal lengths of stay under PD and SDR reimbursement rules.

Proposition 3 *There exist γ_1 and γ_2 such that $\gamma_1 > \gamma_2$ and*

i) if $\gamma \leq \gamma_2$ then then $\alpha\bar{L} < L^*_{SDR}(\gamma) = L^*_{PD}(\gamma)$;

ii) if $\gamma_2 < \gamma \leq \gamma_1$ then $L^*_{PD}(\gamma) = L^*_{SDR} = \alpha\bar{L}(\gamma)$;

iii) if $\gamma > \gamma_1$ then $L^*_{PD}(\gamma) < L^*_{SDR}(\gamma) < \alpha\bar{L}$.

The intuition is as follows. For low values of γ, case i), introducing higher premium for shorter stay does not affect hospitals' behavior compared to the PD system. With low γ the cost associated with LOS is small so that extra benefits from shorter stay are not sufficient to change hospitals' incentives. For intermediate values of γ, case ii), a higher per diem rate makes hospitals willing to keep patients longer than they would under PD, however, only up until the moment when the higher per-diem expires. Finally, for high values of γ, case iii), hospitals will discharge the patients before less favorable per-diem rate is being paid. The difference with case ii) is that the cost associated with the LOS is too high, so that it is not profitable to keep patients until $\alpha\bar{L}$ is reached.

The three possible cases are illustrated on Figure 4:

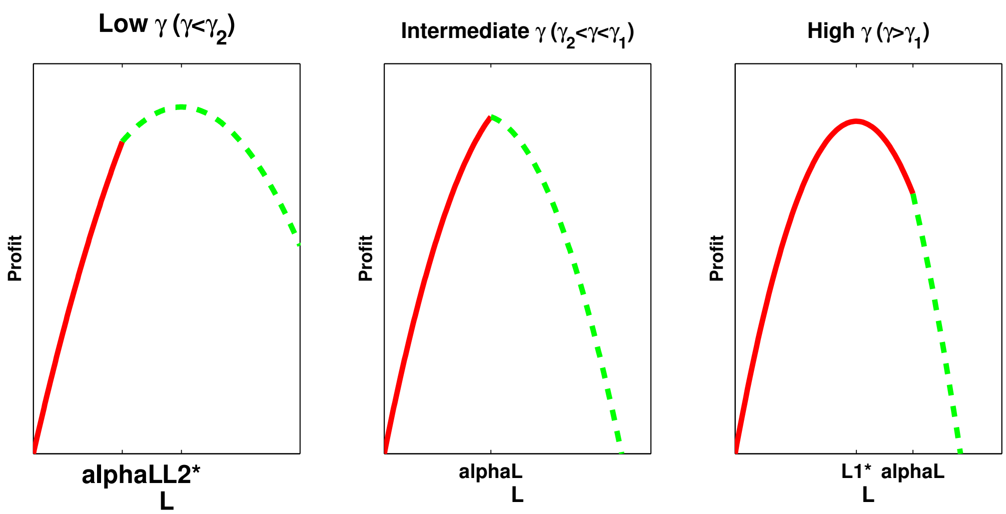

Figure 4: Graphical representation of hospital's profit function for low (left graph), intermediate (central graph) and high (right graph) values of γ.

Proposition 3 shows that the effect of introducing step-down rate with an increased per-diem rate during initial $\alpha\bar{L}$ days of stay has perverse incentives on hospitals, as far as shortening of the length of stay is concerned. With the exception of hospitals with the longest LOS (those with $\gamma < \gamma_2$) the LOS goes up instead of going down.

The combined effect of the change from FFS to SDR reimbursement systems is, in general ambiguous. It depends on the sizes of $FFS \to PD$ and $PD \to SDR$ effects, which in turn depend on parameter values, such as q and α. However, for hospitals with high γ, those with $\gamma > \max\{\gamma_0, \gamma_1\}$, and for hospitals with low γ, those with $\gamma < \min\{\gamma_2, \gamma_0\}$, both a$FFS \to PD$ and $PD \to SDR$ changes have the same effect on the LOS. The Table below summarizes it:

	low γ (high LOS)	high γ (low LOS)
$FFS \to SDR$	$L_{FFS} > L_{SDR}$	$L_{FFS} < L_{SDR}$

Thus, our model predicts that hospitals will respond differently depending on their pre-reform LOS. Those with high LOS will, indeed, have incentives to decrease it as the reform intends; those with low LOS, however, will have financial incentives to pro-long it in order to enjoy a higher per-diem rate. Nawata and Kawabuchi (2012) were the first to document that the national decrease in ALOS came along with some hospitals increasing their ALOS. The most direct test of our theoretical predictions comes from Besstremyannaya (2014) whose results confirm our predictions. Table IV shows a significant post-reform increase among hospitals with the shortest (0 to 25 percentile) pre-reform length of stay and a significant decrease in the length of stay among hospitals with longest pre-reform LOS (51-100 percentile). Furthermore, the decrease of the ALOS is larger for hospitals in higher percentiles of the pre-reform length of stay.

4 Profit

In this section we compare hospitals' profitability under different reimbursement systems. First, we compare profitability under FFS and PD systems. Under FFS, for a given choice of L the hospital's total reimbursement is $p_I I(L)$ and the effective per-diem rate is

$$d(L) = \frac{p_I I(L)}{L}.$$

Thus, we can re-write the hospital's maximization problem in terms of the effective per-diem rate $d(L)$:

$$\max_L d(L)L - cI(L) - \gamma g(L). \tag{6}$$

We denote the hospital's optimal choice of L as L^*_{FFS}, which depends on γ, and the hospital's pre-reform per-diem rate is

$$d(L^*_{FFS}) = \frac{p_I I(L^*_{FFS})}{L^*_{FFS}}. \tag{7}$$

Under the PD system, the per diem rate is determined based on the average daily payments under the FFS system, that is

$$\bar{d} = E_\gamma \left(\frac{p_I I(L^*_{FFS})}{L^*_{FFS}} \right),$$

and the optimization problem is as before:

$$\max_L \bar{d}L - cI(L) - \gamma g(L). \tag{8}$$

From (7) and convexity of $I(L)$ follows that effective per-diem rate under FFS is an increasing function of LOS. That is hospitals with a longer length of stay (smaller γ) have higher effective per-diem rate under the FFS system; hospitals with a shorter length of stay receive lower effective per-diem rate under the FFS system.

As we will show that means that the switch from FFS to PD will increase profitability of hospitals with shorter pre-reform length of stay, and will negatively impact the profitability of hospitals with longer pre-reform length of stay. The intuition is straightforward. Consider, for example, hospitals with high γ. For these hospitals L^*_{FFS} is low and so is the effective per-diem rate, $d(L^*_{FFS})$. A switch to PD results in a higher per-diem rate $\bar{d}$ which improves hospitals' profits.

That effectively implies that profit-wise the change from FFS to PD will benefit hospitals with shorter LOS. Indeed, consider a hospital whose γ is such that $d(L^*_{FFS}) < \bar{d}$. Then

$$\begin{aligned}\pi_{FFS} &= d(L^*_{FFS})L^*_{FFS} - cI(L^*_{FFS}) - \gamma g(L^*_{FFS}) < \\ &< \bar{d}L^*_{FFS} - cI(L^*_{FFS}) - \gamma g(L^*_{FFS}) \leq \bar{d}L^*_{PD} - cI(L^*_{PD}) - \gamma g(L^*_{PD}) = \pi_{PD}.\end{aligned}$$

Here, the first inequality comes from the fact that $d(L^*_{FFS}) < \bar{d}$, and the second inequality comes from the fact that under per-diem rate $\bar{d}$ it is L^*_{PD}, not L^*_{FFS}, that is optimal.

One can similarly show that hospitals with long LOS will have lower profit as a result of the reform. Specifically, for hospitals such that $d(L^*_{PD}) > \bar{d}$ the profit will decline. And since effective per-diem rate is a decreasing function of L, indeed, hospitals with longer pre-reform LOS will experience a negative impact on profit after the switch to PD.

$$\begin{aligned}\pi_{PD} &= \bar{d}L^*_{PD} - cI(L^*_{PD}) - \gamma g(L^*_{PD}) < \\ &< d(L^*_{PD})L^*_{PD} - cI(L^*_{PD}) - \gamma g(L^*_{PD}) \leq d(L^*_{FFS})L^*_{FFS} - cI(L^*_{FFS}) - \gamma g(L^*_{FFS}) = \pi_{FFS}.\end{aligned}$$

The first inequality comes from $d(L^*_{PD})\bar{d}$, the second inequality comes from the fact that under FFS it is L^*_{FFS}, not L^*_{PD}, that is optimal.

As for the move from the PD to the SDR it is profit improving for all hospitals. This is because under the SDR the stay up to $\alpha\bar{L}$ is reimbursed with a premium rate $q\bar{d} > \bar{d}$. Thus, $\pi_{SDR}(L) > \pi_{PD}(L)$ for every L and, therefore, $\pi_{SDR}(L^*_{SDR}) > \pi_{PD}(L^*_{PD})$. Thus for hospitals with high γ (and low pre-reform LOS) both changes (from FFS to PD and from PD to SDR) are profit-improving. The total effect then is also positive. For hospitals with low γ (high pre-reform LOS) a change from FFS to PD has a negative effect on profit and a change from PD to SDR has a positive effect on profit. The total effect, therefore, is ambiguous and depends on values of q and $\alpha\bar{L}$. Clearly if either q is close to 1, or $\alpha\bar{L}$ is close to zero then the positive profit effect of PD to SDR change is negligible. On the other hand, for sufficiently large q and $\alpha\bar{L}$ the positive effect of the PD-to-SDR change will outweigh the negative effect of the FFS-to-PD change. The proposition below summarizes our reasoning.

Proposition 4 *For hospitals with low pre-reform LOS the reform will have positive effect on their profitability. For hospitals with high pre-reform LOS the total effect is ambiguous and depends on values of q and $\alpha\bar{L}$.*

5 Quality. Planned Readmission

Although there is still much inconsistency in economic research about the association between readmission and inpatient care (Ashton and Wray 1996), a number of studies demonstrate that early readmissions may serve as an indicator of quality for hospital performance (Halfon et al. 2006; Lopes et al. 2004; Weissman et al. 1999; Ashton et al. 1997). In our model we focus on the *planned* readmission rate, assuming that there are strong personal relations and a high degree of trust between doctor and patient (Muramatsu and Liang 1996). Therefore, the patient would tolerate being discharged at the hospital's discretion when still sick. Moreover, the patient would seek continuation of his or her inpatient care at the same hospital.

The planned readmission rate is in direct relation to the ALOS. Hospitals can use planned readmission to shorten the average length of stay at each readmission since, even if the same patient is readmitted with the same diagnosis, his or her treatment is recorded and reimbursed as a separate instance. Needless to say, the most common reasons for planned readmission are of a medical nature. Nonetheless, Kondo and Kawabuchi (2012) argue that patients who require long treatment (e.g. rehabilitation after surgery owing to hip fractures) are vulnerable to premature discharges owing to the incentives inherent to the step-down per-diem inclusive payment. Therefore, it is important to understand a hospital's financial incentives regarding planned readmissions and how the FFS and the SDR reimbursement systems affect these incentives.

The possibility of readmission changes a hospital's optimization problem as follows. In addition to determining the optimal length of stay the hospital needs to decide whether to treat a patient using one admission or two admissions, where the second would be a planned readmission. We assume that the decision regarding the number of admissions is made at the beginning of the treatment.

If a hospital chooses to treat a patient with one admission its cost is $cI + \gamma g(L)$. Here, as before, cI is the cost of using discretionary inputs to treat a patient, and L is the LOS which is an increasing function of I, $L(I)$. If a hospital chooses to treat a patient with planned readmission and uses I_1 units of discretionary inputs and procedures during the first stay and I_2 during the second stay then its cost is $cI_1 + cI_2 + \gamma g(L_1 + L_2) + F$.[8] Here $L_1 = L(I_1)$ is the length of stay during the first admission, $L_2 = L(I_2)$ is the length of stay during the second admission. $F \geq 0$ is the fixed cost of the readmission due to the planned readmission. We assume that F is a random variable, distributed with cdf $\Phi(\cdot)$. The reason for the assumption is two-fold. First, with a deterministic F, a planned readmission is a 0/1 decision, which is different from what is observed in the data. Second, random F captures the idea that the cost of readmission can vary depending on the circumstances such as patient condition or hospital occupancy rate.

5.1 Fee-for-service system

First, we look at hospitals' financial incentives to use planned readmission under the FFS system. Hospital's profit without the readmission is

$$\max_{L_1} p_I I(L) - cI(L) - \gamma g(L).$$

If a planned readmission is used the hospital's profit is

$$\max_{L_1, L_2} p_I I(L_1) + p_I I(L_2) - cI(L_1) - cI(L_2) - \gamma g(L_1 + L_2) - F.$$

The next proposition shows that under the FFS there are no financial incentives to use planned readmission:

Proposition 5 *Under FFS hospitals will not use planned readmission iff $F \geq 0$.*

Proof. Assume not. Let $L_1 > 0$ and $L_2 > 0$ be the optimal LOS under the first and second admissions. Without loss of generality we can assume that $L_1 \geq L_2$. From the convexity of $I(\cdot)$ follows that for a small $\varepsilon > 0$

$$(p_I - c)I(L_1 + \varepsilon) + (p_I - c)I(L_2 - \varepsilon) - \gamma g(L_1 + \varepsilon + L_2 - \varepsilon) - F > (p_I - c)I(L_1) + (p_I - c)I(L_2) - \gamma g(L_1 + L_2) - F,$$

which is a contradiction to $L_1 \geq L_2 > 0$ being optimal. Thus the two strict optima are $(L^*, 0)$ and $(0, L^*)$, and therefore it is always optimal to avoid cost F and use one admission. ■

5.2 Per diem prospective payment system with a step-down rate

Next we study hospital's financial incentives to have planned readmissions under the SDR system. As before, let $\bar{d}$ be the average of effective per-diem rates paid to hospitals prior to the reform.

[8] Alternatively one could use term $\gamma g(L_1) + g(L_2)$ in the cost function instead of $\gamma g(L_1 + l_2)$. The only difference is that the latter makes planned readmission less attractive financially because of convexity of function $g(\cdot)$.

Following the inpatient Japanese PPS we assume that during the initial stay of $\alpha\bar{L}$ days, the per-diem rate is higher: $q\bar{d}$ where $q > 1$.[9] For a given length of stay L, the profit without the planned readmission is given by (5). For given L_1 and L_2 the profit with the planned readmission is

$$-F - cI(L_1) - cI(L_2) - \gamma g(L_1 + L_2) + \begin{cases} q\bar{d}(L_1 + L_2) & \text{if } L_1, L_2 \leq \alpha\bar{L} \\ 2(q\bar{d}) \cdot \alpha\bar{L} + \bar{d}(L_1 + L_2 - 2\alpha\bar{L}) & \text{if } L_1, L_2 \geq \alpha\bar{L} \\ q\bar{d}L_j + (q\bar{d}) \cdot \alpha\bar{L} + \bar{d}(L_i - \alpha\bar{L}) & \text{if } L_i > \alpha\bar{L} > L_j \end{cases} \quad (9)$$

The first part of (9) is the treatment cost which does not depend on whether L_1, L_2 are greater above or below the threshold $\alpha\bar{L}$. As for the reimbursement (the second part of (9)) it is calculated based on the length of each admission. The top line in (9) corresponds to the reimbursement when the length of both admission is *short*, i.e. shorter than $\alpha\bar{L}$, so that the hospital is reimbursed under the premium per-diem rate $q\bar{d}$. The middle line corresponds to the case when both admissions are *long*, i.e. longer than $\alpha\bar{L}$, and end up receiving daily payment $\bar{d}$ for stays above $\alpha\bar{L}$. The last line is hospital's profit when one admission is long and another is short.

Let π^1 denote the optimal profit without the readmission and π^2 the optimal profit with the readmission *without* the fixed cost F. Planned readmission is more profitable if and only if $\pi^2 - \pi^1 > F$, that is when gain in profit is higher than the cost of the second admission. On average then, for a given hospital the likelihood of using planned readmission is $\Phi(\pi^2 - \pi^1)$. Note that the likelihood of readmission is a readmission rate, which is an observable variables (e.g. it is reported in MHLW's administrative database).

The next statement consists of two parts. The first part shows that $\pi^2 - \pi^1$ is a decreasing function of γ, which means that hospitals with low γ have stronger incentives to use planned readmission than with high γ. The immediate and testable corollary of this result is that, other things being equal, hospitals with higher LOS are more likely to use planned readmission for financial reasons. The second part, concerns the length of stay. Recall from the previous section that the SDR reimbursement encourages longer stays. This is because the marginal benefit for extra day is increased by factor q during initial $\alpha\bar{L}$ days. However, as we show with the planned readmission hospitals can split treatment between two stays, thereby reducing the LOS per admission. Importantly, when hospitals choose to use planned readmission to decrease ALOS they succeed in that $(L_1^* + L_2^*)/2 \leq L^*$. However, it is not due to faster and more efficient treatment of patients, as $L^* \leq L_1^* + L_2^*$, but rather due to increased financial incentives to treat patients with two admissions.

[9] As mentioned earlier the inpatient Japanese PPS has three periods with three different per-diem rates. In our model, we assume two periods with two different per-diem rates.

Proposition 6 *Let L^* be the optimal LOS without readmission and L_1^* and L_2^* be two LOS with planned readmission. Then $L_1^* = L_2^*$ and*

i) $\pi^2(L_1^*, L_2^*) - \pi^1(L^*)$ is a decreasing function of γ.

ii) $(L_1^* + L_2^*)/2 \leq L^* \leq L_1^* + L_2^*$ for every γ. The former inequality is strict for hospitals with low γ. The latter inequality is strict for hospitals with intermediate values of γ.

The proof of the proposition is somewhat technical and is given in the Appendix. The intuition, however, is straightforward. A higher per diem rate during the initial period of stay incentivizes hospitals to double the number of days for which they receive the premium rate. Hospitals with low γ, i.e. those with longer LOS have more to gain from planned readmission, as a long LOS can be split in two, thus doubling the number of days for which hospitals is compensated under the higher rate $q\bar{d}$. Hospitals with higher γ, on the other hand, have short LOS so that their entire stay is reimbursed at a premium per diem rate. Therefore, there is no additional monetary benefits from splitting a treatment into two admissions.

As argued earlier, hospitals will use planned readmission if and only if $\pi^2(L_1^*, L_2^*) - \pi^1(L^*) > F$. Thus the likelihood of planned readmission is $\Phi(\pi^2(L_1^*, L_2^*) - \pi^1(L^*))$ and as follows from Proposition 6 it is a a decreasing function of γ. Which effectively established the following Corollary.

Corollary 1 *The likelihood of planned readmission is $\Phi(\pi^2(L_1^*, L_2^*) - \pi^1(L^*))$ and it is a decreasing function of γ. Under the SDR rule, as compared to the FFS reimbursement rule, hospitals with lower (higher) LOS are more (less) likely to use planned readmission.*

Corollary 1 can be tested. The evidence indicates that the post-reform decrease of ALOS was accompanied by a rise of the early readmission rates and, specifically, planned readmission rates (Hamada et al. 2012; Yasunaga et al. 2005a; Okamura et al. 2005). This is consistent with our model. The most direct test of Corollary 1 was conducted in Besstremyannaya (2014). Table V shows that for hospitals in 76-100 percentiles of the pre-reform ALOS the readmission rate increased for eleven out of 15 MDCs,[10] as well as for the pooled data where all MDCs are combined.

[10] MDC means Major Diagnostic Category, which is an aggregate group of diagnoses such as Nervous System (MDC 1), Eye system (MDC 2) and so on. In total there are 18 MDCs, however for Table V data for 15 MDCs was used. See Besstremyannaya (2014) for more details.

6 Concluding Remarks

The paper presents a theoretical model to compare the incentives of hospitals under three reimbursement policies: a standard fee-for-service system (FFS); a per diem PPS system with the per diem rate equal to the average daily payments under the FFS system (PD); and a per diem PPS with a step-down tariff (SDR), where the per diem rate during the initial period of stay is higher than for the rest of the patient's stay. The model is designed to incorporate the essential features of the inpatient PPS with an LOS-dependent step-down tariff, as implemented in Japan.

Our main results are as follows. We show that the introduction of any form of per diem PPS (either with a flat tariff or with a length-of stay dependent tariff), leads to a heterogeneity in hospital response. Hospitals with the shortest ALOS under FFS lengthen patients' treatment under PPS, while hospitals with the longest ALOS under FFS reduce the length of treatment under PPS. Contrary to the expectations, a higher per diem rate for initial periods, e.g. for the first 25% of ALOS, does not generate incentives to shorten the length of stay. Instead, hospitals prefer to treat patients longer in order to fully benefit from the higher per diem rate. Finally, given the emphasis on shorter ALOS under the SDR system, hospitals have incentives to use planned readmission to shorten the reported length of stay of a single admission. This can be done, since each admission, whether planned or not, is reimbursed on a separate basis. Finally, we show that hospitals with the longer ALOS under FFS have the strongest incentives to treat patients using planned readmissions.

Our finding is similar to the conclusion of Okamura et al. (2005) about a disincentive for a sharp decline in ALOS within the Japanese per diem tariff. Also, the average outcomes of Japanese inpatient PPS can be contrasted with those of German PPS in the late 1990s, where the per diem rate was not degressive (Busse and Schwartz 1997). As for the planned readmission rate, the economic theory suggests that it increases when a readmitted patient has a higher revenue-to-cost margin compared with a potential patient who might have been admitted to sustain the same bed occupancy rate (Hockenberry et al. 2013). Our model reveals that the per diem PPS with a step-down rate serves as a perfect example of this.

Although Japan acknowledges the limitations of the per diem rates, the country does not plan a changeover to the pure PPS. Moreover, introduced in 2003 with the name "inclusive payment system according to diagnosis-procedure combinations", the Japanese PPS was renamed in 2010 as "diagnosis-procedure combination/per diem payment system", or DPC/PDPS (MHLW 2012a). In 2012 in an attempt to fine-tune the step-down per diem rates, Japan introduced a modification of the reimbursement schedule: regardless of a hospital's position in the empirical distribution of ALOS, no more than 50% of days for each hospital stay can be reimbursed at the highest rates. Based on our model, we predict that this change has no effect on less efficient hospitals. However, the incentives of more efficient hospitals to keep patients longer are weakened. Therefore, the attempt to loosen the stimuli within the step-down per diem rate is beneficial from a social planner point of view.

7 Appendix

Proof of Proposition 2: To compare L_{FFS} and L_{PD} recall that from (1)

$$p_I I'(L_{FFS}) = cI'(L_{FFS}) + \gamma g'(L_{FFS}),$$

and from (4) follows that

$$\bar{d} = cI'(L_{PD}) + \gamma g'(L_{PD}).$$

Recall that by assumption the cost function is convex and, therefore, the RHS, which is the derivative of the cost function, is an increasing function of L. Therefore,

$$L_{FFS} \lesseqgtr L_{PD} \text{ if and only if } p_I I'(L_{FFS})) \lesseqgtr \bar{d}.$$

The per-diem rate, $\bar{d}$, does not depend on γ. Term $p_I I'(L_{FFS}))$ is a decreasing function of γ. Indeed, $I'(L)$ is an increasing function of L because $I(L)$ is convex; and in Proposition 1 we established that, L_{FFS} is a decreasing function of γ.

Let γ_0 be such that $\left.\frac{p_I}{(L_{FFS})'_I}\right|_{\gamma=\gamma_0} = \bar{d}$. Then

1. if $\gamma > \gamma_0$ then $\frac{p_I}{(L_{FFS})'_I} < \bar{d}$ and $L_{PD} > L_{FFS}$;
2. if $\gamma < \gamma_0$ then $\frac{p_I}{(L_{FFS})'_I} > \bar{d}$ and $L_{PD} < L_{FFS}$.

As the length of stay is a decreasing function of γ, the Proposition is proved. ■

Proof of Proposition 3: From (5), $\pi(L)$ is a concave function of L. It is differentiable everywhere except for the kink point at $L = \alpha\bar{L}$. Therefore, the optimum is either reached at the point where $\pi'(L) = 0$ or at $\alpha\bar{L}$. Let $L_1^*(\gamma)$ denote the unconstrained maximum of the first part of (5) and and $L_2^*(\gamma)$ denote the unconstrained maximum of the second part of (5). Formally, $L_1^*(\gamma)$ satisfies

$$q\bar{d} = cI'(L) + \gamma g'(L),$$

and $L_2^*(\gamma)$ satisfies

$$\bar{d} = cI'(L) + \gamma g'(L).$$

Note that since $(q\bar{d})\alpha\bar{L}$ does not depend on L, $L_2^*(\gamma) = L_{PD}^*(\gamma)$. From the convexity of g and I follows that $L_1^*(\gamma) > L_2^*(\gamma)$, and that both are decreasing functions of γ. Let γ_2 be such that $L_2^*(\gamma_2) = \alpha\bar{L}$ and γ_1 be such that $L_1^*(\gamma_1) = \alpha\bar{L}$. Since $L_i^*(\gamma)$ are decreasing functions we have that $\gamma_2 < \gamma_1$.

By definition of γ_2 and γ_1 we have that there are three cases possible:

i) when $\gamma < \gamma_2$. In this case $L_1^*(\gamma) > L_2^*(\gamma) > \alpha\bar{L}$ and, therefore, the global optimum is $L_{SDR}^*(\gamma) = L_2^*(\gamma)$. It is the global optimum because $\pi(L)$ is an increasing function for $L < \alpha\bar{L}$. And as argued earlier, $L_2^*(\gamma) = L_{PD}^*(\gamma)$ for every γ, implying that when $\gamma < \gamma_2$ then $L_{SDR}^*(\gamma) = L_{PD}^*(\gamma)$;

ii) when $\gamma_2 < \gamma < \gamma_1$ then the optimum is reached at $\alpha\bar{L}$. For this range of γ's the first function in (5) is increasing (since $L_1^*(\gamma) > \alpha\bar{L}$) and the second function is decreasing (since $L_2^*(\gamma) < \alpha\bar{L}$) on their respective domains. Compared to the PD system, the LOS goes up, since $L_2^*(\gamma) < \alpha\bar{L}$.

iii) when $\gamma > \gamma_1$ then the maximum is reached at point $L_1^*(\gamma) < \alpha\bar{L}$. Comparing it to the PD case, the LOS goes up. The marginal benefit for longer stay is higher, due to premium $q > 1$, but the marginal cost is the same as under the PD. ■

Proof of Proposition 6: First, it follows from (9) that it is never optimal to have one admission short and another admission long, that is $L_i > \alpha\bar{L} > L_j$. This is because the per diem payment on short admission j pay at premium q, whereas the one on admission i does not. It is better to increase the j's admission by shortening the i's admission.

Thus, we only need to consider cases on the cases where either both admissions are long or both are short. The next lemma shows that then both admissions will have the equal length.

Lemma 1 *At the optimum $L_1^* = L_2^*$.*

Proof. First, consider the case $L_1, L_2 < \alpha\bar{L}$. Thus they satisfy the FOCs:

$$q\bar{d} - cI'(L_1) = \gamma g'(L_1 + L_2)$$
$$q\bar{d} - cI'(L_2) = \gamma g'(L_1 + L_2),$$

thereby implying that $L_1^* = L_2^*$ and both satisfy $q\bar{d} - cI'(L_2^*) = \gamma g'(2L_2^*)$. The case $\alpha\bar{L} < L_1, L_2$ is similar.

Having $L_i = \alpha\bar{L} < L_j$ is not optimal. The FOCs are

$$\begin{aligned} q\bar{d} &> cI'(\alpha\bar{L}) + \gamma g'(L_1 + L_2) > \bar{d} \\ \bar{d} &= cI'(L_j) + \gamma g'(L_1 + L_2). \end{aligned}$$

The first lines reflect that $L_i = \alpha\bar{L}$ where the profit function is not differentiable. Thus, we have

$$cI'(\alpha\bar{L}) > cI'(L_j),$$

which is a contradiction to the fact that $\alpha\bar{L} < L_j$. Similarly, having $L_i < \alpha\bar{L} = L_j$ is not optimal either. The FOCs are

$$\begin{aligned} q\bar{d} &= cI'(L_i) + \gamma g'(L_1 + L_2) \\ q\bar{d} &> cI'(\alpha\bar{L}) + \gamma g'(L_1 + L_2) > \bar{d}, \end{aligned}$$

and they imply

$$cI'(L_i) > cI'(\alpha\bar{L}),$$

which is a contradiction to $L_i < \alpha\bar{L}$. ■

It follows from Lemma 1 that both admissions have equal length, $L_1^* = L_2^*$, and we will use L_2^* to denote it. If $L_2^* < \alpha\bar{L}$ then $q\bar{d} = I'(L_2) + \gamma g(2L_2)$; if $L_2 = \alpha\bar{L}$ then $q\bar{d} > cI'(L_2) + \gamma g'(2L_2) > \bar{d}$; if $L_2 > \alpha\bar{L}$ then $\bar{d} = cI'(L_2) + \gamma g(2L_2)$.

Next, we will consider several cases for different values of γ. We start with hospitals with the highest γ.

1. γ is such that $\gamma g'(2\alpha\bar{L}) + cI'(\alpha\bar{L}) > \gamma g'(\alpha\bar{L}) + cI'(\alpha\bar{L}) \geq q\bar{d}$. For these parameter values the profit with readmission has the global maximum at point where $\gamma g'(2L_2^*) + cI'(L_2^*) = q\bar{d}$, and the profit without readmission has the global maximum at point $\gamma g'(L^*) + cI'(L^*) = q\bar{d}$. Then $2L_2^* > L^* > L_2^*$. That $L^* > L_2^*$ follows from

   $$\gamma g'(2L^*) + cI'(L^*) > \gamma g'(L^*) + cI'(L^*) = q\bar{d} = \gamma g'(2L_2^*) + cI'(L_2^*).$$

   That $2L_2^* > L^*$ follows from

   $$\gamma g'(2L_2^*) + cI'(2L_2^*) > \gamma g'(2L_2^*) + cI'(L_2^*) = q\bar{d} = \gamma g'(L^*) + cI'(L^*).$$

   Let $\Delta\pi$ denote $\pi_2 - \pi_1$. We can write it as

   $$\Delta\pi = \left[q\bar{d}(2L_2^*) - 2cI(L_2^*) - \gamma g(2L_2^*)\right] - \left[q\bar{d}(L^*) - cI(L^*) - \gamma g(L^*)\right].$$

By the envelope theorem

$$\frac{\partial \Delta\pi}{\partial \gamma} = -g(2L_2^*) + g(L^*) < 0.$$

2. γ is such that $\gamma g'(2\alpha\bar{L}) + cI'(\alpha\bar{L}) > q\bar{d} > \gamma g'(\alpha\bar{L}) + cI'(\alpha\bar{L}) > \bar{d}$. The last two inequalities imply that that $L^* = \alpha\bar{L}$. The first inequality means that if a hospital is to use planned readmission it is optimal to use two short planned readmissions. Thus, $L_2^* < \alpha\bar{L} = L^*$. That $2L_2^* > L^*$ follows from

$$\gamma g'(2L_2^*) + cI'(2L_2^*) > \gamma g'(2L_2^*) + cI'(L_2^*) = q\bar{d} > \gamma g'(L^*) + cI'(L^*),$$

where the last inequality follows from the fact that $\alpha\bar{L} = L^*$.

In this case $\Delta\pi$ becomes

$$\Delta\pi = \left[q\bar{d}(2L_2^*) - 2cI(L_2^*) - \gamma g(2L_2^*)\right] - \left[q\bar{d}(\alpha\bar{L}) - cI(\alpha\bar{L}) - \gamma g(\alpha\bar{L})\right].$$

By the envelope theorem the derivative of the first term with respect to γ is $-g(2L_2^*)$. Since $\alpha\bar{L}$ is a constant and does not depend on γ the derivative of the second term is $-g(\alpha\bar{L})$. Thus again $\partial\Delta\pi/\partial\gamma < 0$.

Now two cases are possible depending on which happens first, as we decrease γ. Either $\gamma g'(2\alpha\bar{L}) + 2cI'(\alpha\bar{L}) = q\bar{d}$, or $\gamma g'(\alpha\bar{L}) + cI'(\alpha\bar{L}) = \bar{d}$ We label these two cases as Case 3 and Case 3'.

3. γ is such that $q\bar{d} \geq \gamma g'(2\alpha\bar{L}) + cI'(\alpha\bar{L}) > \gamma g'(\alpha\bar{L}) + cI'(\alpha\bar{L}) > \bar{d}$. Then the optimal solution with the readmission is to have $L_1^* = L_2^* = \alpha\bar{L}$. The optimal solution without the readmission is also $L^* = \alpha\bar{L}$. Thus $L_2^* = L^* < 2L_2^*$. The profit difference is

$$\Delta\pi = \left[q\bar{d}(2\alpha\bar{L}) - 2cI(\alpha\bar{L}) - \gamma g(2\alpha\bar{L})\right] - \left[q\bar{d}\alpha\bar{L} - cI(\alpha\bar{L}) - \gamma g(\alpha\bar{L})\right],$$

and its derivative with respect to γ is negative.

3'. Alternatively we consider the case when γ is such that $\gamma g'(2\alpha\bar{L}) + cI'(\alpha\bar{L}) > q\bar{d} > \bar{d} \geq \gamma g'(\alpha\bar{L}) + cI'(\alpha\bar{L})$. In this case without readmission hospitals would go for long admission and with readmission the hospital would go for two short admissions. Thus $L^* \geq \alpha\bar{L} > L_2^*$. And by the same logic as in case 2 we conclude that $2L_2^* > L^*$. Thus, with planned readmission LOS, $L_2^* < L^*$ will decrease but the total number of days will go up $2L_2^* > L^*$.

As for profit difference,

$$\Delta\pi = \left[q\bar{d}(2L_2^*) - 2cI(L_2^*) - \gamma g(2L_2^*)\right] - \left[q\bar{d}\alpha\bar{L} + \bar{d}(L^* - \alpha\bar{L}) - cI(L^*) - \gamma g(L^*)\right],$$

its derivative with respect to γ is $-g(L_1^* + L_2^*) + g(L^*) < 0$.

4. γ is such that $q\bar{d} > \gamma g'(2\alpha\bar{L}) + cI'(\alpha\bar{L}) > \bar{d} > \gamma g'(\alpha\bar{L}) + cI'(\alpha\bar{L})$. The solution with the readmission is $L_1^* = L_2^* = \alpha\bar{L}$ and without it is a long readmission L^* such that $\gamma g'(L^*) = \bar{d} + cI'(L^*)$. Thus $L_2^* = \alpha\bar{L} < L^*$. That $2\alpha\bar{L} > L^*$ follows from

$$\gamma g'(2\alpha\bar{L}) + cI'(2\alpha\bar{L}) > \gamma g'(2\alpha\bar{L}) + cI'(\alpha\bar{L}) > \bar{d} = \gamma g'(L^*) + cI'(L^*).$$

Thus, the LOS declines but the total stay goes up. Profit difference is

$$\Delta\pi = \left[q\bar{d}(2\alpha\bar{L}) - 2cI(\alpha\bar{L}) - \gamma g(2\alpha\bar{L})\right] - \left[q\bar{d}\alpha\bar{L} + \bar{d}(L^* - \alpha\bar{L}) - cI(L^*) - \gamma g(L^*)\right],$$

and its derivative is $-g(2\alpha\bar{L}) + g(L^*) < 0$.

5. γ is such that $\bar{d} \geq \gamma g'(2\alpha\bar{L}) + cI'(\alpha\bar{L}) > \gamma g'(\alpha\bar{L}) + cI'(\alpha\bar{L})$. For these parameter values the profit with readmission has the global maximum at point where $\gamma g'(2L_2^*) + cI'(L_2^*) = \bar{d}$, and the profit without readmission has the global maximum at point $\gamma g'(L^*) + cI'(L^*) = \bar{d}$. Thus $L_2^* > \alpha\bar{L}$ and $L^* > \alpha\bar{L}$. Furthermore, one can show that $2L_2^* > L^* > L_2^*$.

   That $L^* > L_2^*$ follows from

$$\gamma g'(2L^*) + cI'(L^*) > \gamma g'(L^*) + cI'(L^*) = \bar{d} = \gamma g'(2L_2^*) + cI'(L_2^*).$$

   That $2L_2^* > L^*$ follows from

$$\gamma g'(2L_2^*) + cI'(2L_2^*) > \gamma g'(2L_2^*) + cI'(L_2^*) = \bar{d} = \gamma g'(L^*) + cI'(L^*).$$

   As before the derivative of the profit difference with respect to γ is equal to $\partial\Delta\pi/\partial\gamma = -g(2L_2^*) + g(L^*) < 0$.

Thus we showed that for every γ using the readmission becomes more lucrative as γ goes down. And $2L_2^* \geq L^* \geq L_2^*$. This concludes the proof of the Proposition 6. ■

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