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Abstract

In early 2000s Japan introduced a special version of an inpatient prospective payment system (PPS) that contains incentives to increase efficiency and shorten the average length of stay (ALOS). This paper presents a theoretical model, which explains heterogeneous dynamics of volume and quality in a mixed PPS system. The model exploits two essential features of Japanese PPS: per diem payments and a length-of-stay dependent PPS tariff. The novelty of the model is that it incorporates hospital's heterogeneity through an explicit parameter of hospital's cost efficiency. The model predicts different directions of the change in ALOS for efficient and inefficient hospitals. Moreover, the decline in ALOS is shown to be associated with a rise in the rate for planned early readmissions. Using an administrative database for 684 Japanese PPS hospitals in 2007-2011, we conduct avearge treatment effect estimations with dynamic panel data and find an empirical support for the predictions of the theoretical model.

*Contributors: Galina Besstremyannaya researched the topic and background, conducted empirical analysis and policy interpretation of the results, and contributed to the discussion about the theoretical model. Dmitry Shapiro constructed the theoretical model and contributed to the policy interpretation of the results.

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1 Introduction

In concern about the soaring healthcare costs and exceptionally long length of hospital stay (LOS), Japan introduced a special version of an inpatient prospective payment system (PPS) that contains incentives to increase efficiency and shorten the average length of stay (ALOS). For each group of diagnoses – which are called diagnosis-procedure combinations, DPCs – the amount of the inclusive *per diem* payment is a step-wise decreasing function of the patient's length of stay. At the same time, expensive procedures are reimbursed on a fee-for-service (FFS) basis. The total tariff is the sum of the fixed payment and a retrospective payment, and therefore, the Japanese inpatient PPS may be regarded as a cost-sharing system, which allows for an appropriate balance between cost-efficiency and quality (Laffont and Tirole 1993), widely used in a number of countries (Jegers et al. 2002). Since daily reimburesement is an integral part of the Japanese PPS, in 2010 the name of the system has been officially changed to per diem payment system, DPC/PDPS (MHLW 2012a).

The Japanese PPS immediately resulted in a decline in the ALOS (MHLW 2005). Although a part of the variation of the length of stay may be attributed to the factors unrelated to hospital's behavior (Chalkley and Malcomson 2000; Miller and Sulvetta 1995), a fall in the 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 PDPS reform (Besstremyannaya 2012) and the impact on hospitals costs is ambiguous (Nishioka 2010; Yasunaga et al. 2006; Yasunaga et al. 2005a). An explanation may be related to a heterogeneous effect of the Japanese PPS on the ALOS. In particular, the decrease in the mean LOS for the population of the PDPS hospitals might be disentangled into an increase of LOS in some hospitals and a decrease of LOS in other hospitals.

A large amount of empirical literature pays attention to a differential response of hospital's ALOS to PPS (Sood et al. 2008; Ellis and McGuire 1996; Gold et al. 1993; Coulam and Gaumer 1991). Yet, to the best of our knowledge moral hazard explanation of larger supply of LOS to patients with longer LOS (Ellis and McGuire 1996) and Yasunaga et al.'s (2006; 2005b) statistical comparison of per diem profits for DPCs with high and low material costs are the only attempts to theoretically exploit the potential sources for heterogeneity in the dynamics of ALOS after the PPS reform. It should be noted that a reverse side of the Japanese PPS is quality deterioration, reflected in the rise of early readmission rate (Hamada et al. 2012; Yasunaga et al. 2005a) through an increase in planned readmissions (Besstremyannaya 2010; Okamura et al. 2005). Since the major reason for the increase in the early readmission rate is LOS-dependent per diem PPS tariff, the heterogeneity in Japanese hospital's response to the PDPS might be reflected both in dynamics of ALOS and early readmission rate.

The purpose of this paper is to present a theoretical model, which explains heterogeneous dynamics of volume and quality in a mixed PPS system. The model encompasses two essential features of Japanese PPS: per diem payments and a length-of-stay dependent PPS tariff. The novelty of the model is that it incorporates hospital's heterogeneity through an explicit parameter of hospital's cost efficiency. The model predicts different directions of the change in ALOS for efficient and inefficient hospitals. The decline in ALOS is shown to be associated with increased prevalence of planned early readmissions. Using an administrative database for 684 Japanese PPS hospitals in 2007-2011, we conduct difference-in-difference estimations with dynamic panel data and find an empirical support for the predictions of the theoretical model.

The remainder of the paper is structured as follows. Section 2 provides a description of the major features of Japanese inpatient PPS. Section 3 sets up a theoretical model for a profit-maximizing hospital as a supplier of healthcare volume and quality. Section 4 describes the Japanese Ministry of Health, Labor, and Welfare's database on DPC hospitals, which we used for our analysis. The database is supplemented with hospital characteristics, taken from the Handbook of Hospitals, and hospital financial variables from the Ministry of Internal Affairs' database on local public hospitals. The specifications for empirical analysis are given in section 5. Section 6 presents the results of the empirical estimations, and Section 7 generalizes the findings of our theoretical and empirical analysis.

2 Japanese inpatient prospective payment system

The issue of cost containment became on the agenda of Japanese health care policy makers in 1980s-1990s, when the rate of health care expenditure growth started to exceed the rate of growth in GDP. By early 2000s the effects of increased coinsurance rates and lowered fees in the unified fee schedule as the measures to decrease health care costs have been exhausted. 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 first attempt to employ an inpatient PPS was implemented in 1990, when inclusive per diem rates were introduced in 50% of geriatric hospitals in Japan (Ikegami 2005). Then, inpatient PPS was piloted in 10 acute care national hospitals in 1998. Finally, in 2003 the PPS was intorduced in 82 specific function hospitals, which provide high-technology health care (80 public and private university hospitals as well as two national centers: for cancer and cardiovascular diseases). The subsequent years saw an increasing number of hospitals, voluntaryily joining the PPS. As of July 2010, 18 percent of acute care (general) hospitals, which account for 50 percent of hospital beds in Japan, are financed according to PPS.

The Japanese inpatient PPS is essentially a mixed system. The two-part tariff is the sum of DPC and fee for service components. The DPC component is constructed as a per diem stepdown rate, related to 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 in all the hospitals,[1] period 2 contains the rest of the ALOS, and period 3 encloses two standard deviations from the ALOS. To create incentives for shorter length of stay, per diem DPC payment in the first period is established 15% larger than the standard per diem reimbursement (Figure 1).

The first version of DPCs consisted of 2552 groups of diagnoses. Most of the groups (1860) had

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

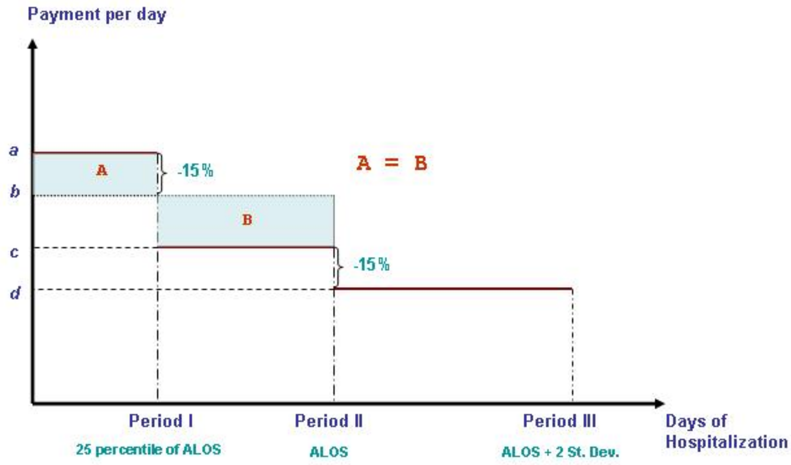

Figure 1: Stepdown per diem payment scheme for a given DPC. Source: MHLW (2011).

sufficient cases and were rather homogeneous (Ikegami 2005). For these groups, which corresponded to about 90% of admission cases, the rates were set. The numbers of diagnoses and DPCs were gradually increasing since 2003, and as of 2012 there are 2927 groups of diagnoses 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).

3 Theoretical model

The section focuses on the length of stay as a proxy for hospital volume. The prevalence of planned early readmissions is regarded as a proxy for hospital's quality. We model a hospital as a profit-maximizing supplier of volume and quality (Hodgkin and McGuire 1994; Ellis and McGuire 1996; Ma 1998; Grabowski et al. 2011). Hospital chooses the intensity of treatment in response to price incentives of a prospective payment system (McClellan 1997). The model ignores competition among hospitals. For simplicity we consider a hospital which treats patients with a given diagnosis (DPC).

Let $L = L(I, D)$, I are inputs that increase the LOS, $I \in [0, \infty)$ and D are inputs that decrease the LOS, $D \in [0, \bar{D}]$. Owing to the medical constraints on the minimal value of LOS for a given diagnosis, we set an upper limit for the value of D, so that LOS could not be infinitely decreased.

Having I does not imply that they these inputs are necessarily wasteful. Indeed, increasing the LOS is not bad per se, since it might involve higher quality, some appropriate precautionary treatment and follow-up tests.

Cost is assumed to equal $\gamma g(L)$, where g is an increasing convex function of the LOS and γ is an exogenous parameter, that reflects hospital's technology or tightness of hospital's financial incentives. Essentially, γ is the source for heterogeneity of hospital's costs. It should be noted that γ is analogous to Laffont's and Tirole's (1993) technological parameter, related to hospital's efficiency.

3.1 Hospital volume

3.1.1 Fee-for-service system

The maximization problem is

$$\max p_D D + p_I I - \gamma g(L);$$

and so from the FOC $D^* = \bar{D}$. Intuitively, higher D gives revenue $p_D D$ and it decreases the cost associated with LOS. Thus, it is optimal to set D as high as possible. The FOC to determine I^* is

$$p_I = \gamma g'(L) L'_I. \tag{1}$$

Applying the implicit function theorem we obtain

$$\frac{\partial I^*}{\partial \gamma} = \frac{g'(L) \cdot L'_I}{-\gamma [g''(L) L'_I + g'(L) L'_{II}]} < 0.$$

The denominator is the second derivative of the objective function in (1) and is, therefore, negative at the optimum. The numerator is positive since $g(\cdot)$ is convex and $L'_I > 0$. Intuitively, when keeping patients is costlier, hospitals would prefer to use lower amounts of I.

Denote the optimal length of stay as $L_{FFS} = L(I^*, \bar{D})$, in which case the average payment per day for a given hospital is

$$d = \frac{p_D \bar{D} + p_I I^*}{L_{FFS}},$$

where recall that I^* depends on γ.

3.1.2 Per diem prospective payment system

Per-diem rate introduced by the reform is based on the average per-diem payments to hospitals. Taking the average over all hospitals with respect to γ we get

$$\bar{d} = E_\gamma \left[\frac{p_D \bar{D} + p_I I^*}{L_{FFS}} \right].$$

The maximization problem under the per diem PPS (hereafter PD) is

$$\max \bar{d} L(I, D) - \gamma g(L(I, D)),$$

and the FOC that determines the LOS is

$$E_{\gamma}\left[\frac{p_D\bar{D}+p_I I^*}{L_{FFS}}\right]-\gamma g'(L_{PD})=0. \tag{2}$$

To compare L_{FFS} and L_{PD} note that the latter satisfies the FOC (1):

$$p_I-\gamma g'(L_{FFS})\cdot(L_{FFS})'_I=0.$$

Given the convexity of $g(\cdot)$ inequality $\bar{d}-\gamma g'(L_{FFS})>0$ would imply $L_{FFS}<L_{PD}$ and vice versa. From (1) we have that

$$g'(L_{FFS})=\frac{p_I}{\gamma(L_{FFS})'_I},$$

and plugging it into (2) we have

$$E_{\gamma}\left[\frac{p_D\bar{D}+p_I I^*}{L_{FFS}}\right]-\gamma g'(L_{FFS})=E_{\gamma}\left[\frac{p_D\bar{D}+p_I I^*}{L_{FFS}}\right]-\frac{p_I}{(L_{FFS})'_I}. \tag{3}$$

Note that the first term does not depend on γ. As for the second term, its derivative with respect to γ equals to

$$\left[-\frac{p_I}{(L_{FFS})'_I}\right]'_{\gamma}=\frac{p_I(L_{FFS})''\cdot(\partial I^*/\partial\gamma)}{[L'_{FFS}]^2}. \tag{4}$$

Since $\partial I^*/\partial\gamma<0$ the sign of (4) is determined by convexity or concavity $L(\cdot)$. When $L(\cdot)$ is concave then (3) is an increasing function of γ and therefore is positive for sufficiently high values of γ, i.e. $L_{FFS}<L_{PD}$, and negative for sufficiently low values of γ, i.e. $L_{FFS}>L_{PD}$. The inequalities are reversed if $L(\cdot)$ is convex.

The results may be summarized in the following table:

	low γ	high γ
L is concave	$L_{FFS}>L_{PD}$	$L_{FFS}<L_{PD}$
L is convex	$L_{FFS}<L_{PD}$	$L_{FFS}>L_{PD}$

Regardless of whether $L(\cdot)$ is concave or convex, which will be tested in the empirical section, one can see that hospitals response is non-uniform. For some hospitals the length of stay increases after the reform and for some it drops. We should expect the difference to be most pronounced when comparing hospitals with low ALOS to hospitals with high ALOS.

3.1.3 Per diem prospective payment system with a stepdown rate

Denote the per-diem prospective payment system with a stepdown rate as PDSD. Let $\bar{L}$ denote the the average LOS under the FFS system. We model a PDSD system with two per diem rates: a higher per-diem rate, $q\bar{d}$, during the initial $\alpha\bar{L}$ days, where $q>1$ and $\alpha\leq 1$, and a regular per diem rate, $\bar{d}$, afterwards. In Section 7 we discuss the predictions of our theoretical model when it is expanded into a model with three per diem rates (i.e. an exact analogue of Japanese per diem

PPS with thresholds a, c, and d, as is shown on Fig.1). The reader might think about $q\bar{d}$ as the average rate over the periods I and II in the Japanese per diem PPS.

The hospital's profit thus consists of two functions:

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

Let $L_1^*(\gamma)$ denote the unconstrained maximum of the first function and $L_2^*(\gamma)$ denote the unconstrained maximum of the second function. Since $(q\bar{d})\alpha\bar{L}$ is constant that does not depend on L, $L_2^*(\gamma)$ is equal to $L_{PD}(\gamma)$.

It immediately follows from convexity of g 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 $\gamma_2 < \gamma_1$.

Next we study hospital's response to the change from the PD system, i.e. the one with per-diem rate being $\bar{d}$ regardless of the LOS, and the PDSD system. The response is fully determined by how hospital's γ is related to γ_1 and γ_2. Three cases are possible:

i) when $\gamma < \gamma_2$ then $L_{PD}(\gamma) = L_2^*(\gamma) > \alpha\bar{L}$. This is because if $\gamma < \gamma_2$ then $L_1^*(\gamma) > L_2^*(\gamma) > L_2^*(\gamma_2) = \alpha\bar{L}$. In other words the optimum of the second part is reached at point L_2^* such that $L_2^* > \alpha\bar{L}$. When γ is low then introducing higher premium for shorter stay will not affect hospital's behavior compared to the PD system. Intuitively, the cost of LOS is so low compared to the extra benefits from shorter stay that it's not worth it to reduce the LOS.

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 and the second function is decreasing 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 $L_1^*(\gamma) < \alpha\bar{L}$. For high values of γ, hospitals will try to discharge the patients before less favorable per-diem rate is being paid. Importantly, as compared to the PD case the LOS of stay goes up. The main reason being that the marginal benefit for longer stay is higher, due to factor q, but the marginal cost is the same.

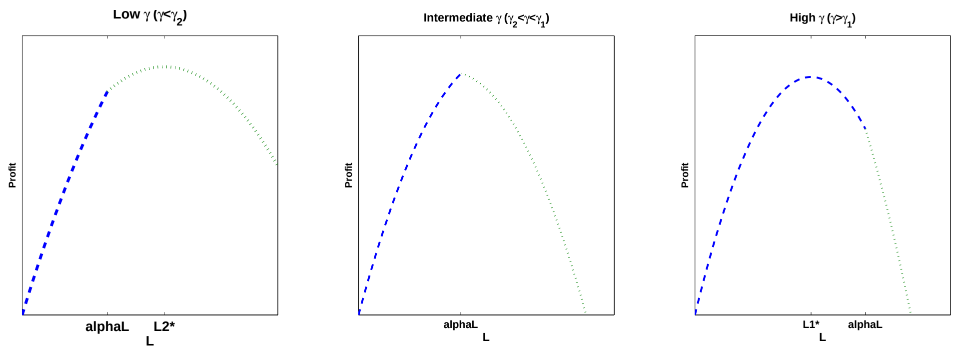

Figure 2: Graphical representation of hospital's profit function for three different ranges of γ.

As the analysis above show the move from the PD system to the PDSD system with a premium rate during the beginning of the stay has either no effect or an effect on the LOS. We summarize it in the Table below:

	$\gamma < \gamma_2$	$\gamma_2 < \gamma < \gamma_1$	$\gamma > \gamma_1$
Effect on LOS	no change	$L^* \uparrow$	$L^* \uparrow$

Recall that the reform changed the reimbursement system from the pre-reform FFS to the post-reform PDSD system. The simple per-diem system, PD, was not actually implemented and it was used in our analysis as a convenient intermediary. Now that we analyzed the effects of FFS→PD change and PD→PDPS change we can combine the two in the following table.

	low γ	high γ
L is concave	$L^* \downarrow$	$L^* \uparrow$
L is convex	$L^* \uparrow$	ambiguous

The overall effect of moving from FFS to a per-diem prospective system with a stepdown rate PDSD depends on concavity of L as a function of I. If L is concave then less efficient hospitals, those with low γ, will unambiguously decrease the LOS and more efficient, those with higher γ, will unambiguously increase the LOS. This is because both transitions (FFS→PD and PD→PDSD) have the same effect on LOS. If L is convex then for hospitals with low γ there will be unambiguous increase in L and for hospitals with higher γ the total effect cannot be determined. The transition from FFS to PD decreases the LOS but then introduction of the piecewise tariff works in the opposite direction.

3.2 Hospital quality

The section studies the effect of PPS on planned readmission rate, which is regarded as a proxy for hospital's quality. We analyze how the choice of planned readmission varies with parameter γ.

Assume that a hospital has to decide whether to treat with planned readmission or not. There might be two aspects of the decision: medical and financial. We consider medical reasons to be exogenous. That is if for medical reasons planned readmission is needed then it is used. There are also financial reasons, however. It could be that it is more or less profitable to treat the patient with planned readmission. In what follows we focus on the impact of different reimbursement schemes on financial incentives.

We assume that if a hospital uses two hospitalizations, then its cost is $\gamma g(L_1 + L_2)^2$, where L_1 is the duration of the first admission and L_2 is the duration of the readmission. Furthermore, we suppose that the readmission incurs fixed cost $F \geq 0$ which is a random variable distributed with cdf $\Phi(\cdot)$.

As before the duration of stay is determined by function $L = L(I, D)$, where D are inputs that decrease the duration of stay and $D_1, D_2 \in [0, \bar{D}]$. However, the result will remain the same. Also it will be convenient to introduce an inverse function $I = I(L, D)$. For fixed D this is a convex function of L, since L is assumed to be a concave function of I.

3.2.1 Fee-for-service system

Recall that it is optimal to use decreasing inputs as much as possible, because they increase reimbursement received by the hospital and decrease the cost by reducing the length of stay. Thus, we will simply focus on increasing inputs.

The hostpital's profit with readmission is

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

and without is

$$\max_{L_1} p_D \bar{D} + p_I I(L, \bar{D}) - \gamma g(L).$$

As the next proposition shows there is no financial incentives to use planned readmission.

Proposition 1 *If $F \geq 0$ then planned readmission is suboptimal.*

Note that for an alternative specification, where reimbursement is $p_I \cdot I(L_1 + L_2)$, same result would hold. In that case, only the maximization problem determines only $L_1 + L_2$ and they are the same with and without readmissions. Thus when $F = 0$ the hospital is indifferent. However, when $F > 0$ the hospital strictly prefers to treat without readmissions.

3.2.2 Per diem prospective payment system with a stepdown rate

This part studies financial incentives of hospital to use readmissions. Recall that per diem payment during initial $\alpha\bar{L}$ days is higher by factor of q than the payment for the remaining days (5). The profit for planned readmission consists of two parts. First, as before there is a fixed cost F, which is a random variable distributed with cdf $\Phi(\cdot)$. Second, there is a per diem payment to hospital minus cost which is

$$\pi^2(L_1, L_2) = \begin{cases} q\bar{d}(L_1 + L_2) - \gamma g(L_1 + L_2) & \text{if } L_1, L_2 \leq \alpha\bar{L} \\ q\bar{d}L_j + (q\bar{d}) \cdot \alpha\bar{L} + \bar{d}(L_i - \alpha\bar{L}) - \gamma g(L_i + L_j) & \text{if } L_i > \alpha\bar{L} > L_j \\ 2(q\bar{d}) \cdot \alpha\bar{L} + \bar{d}(L_1 + L_2 - 2\alpha\bar{L}) - \gamma g(L_1 + L_2) & \text{if } L_1, L_2 \geq \alpha\bar{L} \end{cases} \tag{6}$$

Expression (6) is based on how planned readmission are actually reimbursed, which is that each admission is treated a separate admission. In particular, the initial phases of both stays, up to $\alpha\bar{L}$, are compensated under higher rate $q\bar{d}$ and stays longer than that are compensated with per diem rate $\bar{d}$. Thus, in the expression above the first line corresponds to the profit the hospital get when the length of both admission is short and it receives higher premium $q\bar{d}$. The last line corresponds to the case when both admissions are longer than $\alpha\bar{L}$ and end up receiving daily payment $\bar{d}$. Finally, the second line is when one admission is long[2] and another is short.

From financial perspective, using planend readmission is more profitable if $\pi^2 - \pi^1 > F$, in other words gain in profit is higher than the cost of the second admission. Thus, for a given hospital the

[2] In what follows "long" implies that the LOS is greater than $\alpha\bar{L}$ and "short" means that the LOS is less than $\alpha\bar{L}$.

likelihood of readmission is $\Phi(\pi^2 - \pi^1)$. Note that the likelihood of readmission is a readmission rate, which is observable in the MHLW's administrative database.

The next statement is the main result of this section. It consists of two parts. The first part shows that $\pi^2 - \pi^1$ is a decreasing function of γ. In other words, the gains from using readmission are lower for hospital with high γ. The immediate corollary of this result is that compared to the FFS case, the readmission rates of hospitals with lower γ will be higher. Indeed, medical reasons to use planned readmission are not affected by the reimbursement scheme and there are no financial reasons under FFS to use the second admission. We test this prediction using our data in later chapters of the paper. The second part, concerns the length of stay. Recall that the piecewise tariff containts perverse incentives for shorterning the ALOS. This is because the marginal benefit for extra day is increased by factor q during initial $\alpha\bar{L}$ days. However, as we show next with the planned readmission hospitals can split treatment between two stays, thereby reducing the ALOS.

Proposition 2 *Let L^* be the optimal LOS without readmission and L_1^* and L_2^* two LOS with planned readmission. Then*

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

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

The table below summarizes the proposition above for each of the γ-intervals. Cases with lower numbers correspond to *higher* γ's. The second column shows how the ALOS is changed compared to the no readmission case. The third column shows how the total number of days per case changes compared to the no readmission case.

	$(L_1^* + L_2^*)/2 - L^*$	$L_1^* + L_2^* - L^*$	Planned Readmission
Case 1 (highest γ)	$=$	$=$	No
Case 2	$\downarrow$	$\uparrow$	Yes
Case 3	$=$	$\uparrow$	Yes
Case 3'	$\downarrow$	$\uparrow$	Yes
Case 4	$\downarrow$	$\uparrow$	Yes
Case 5 (lowest γ)	$\downarrow$	$=$	Yes

Given that in the data we only observe ALOS we have the strong declining effect in ALOS, however, it comes at the expense of readmissions as the total number of days devoted to a given patient goes up.

3.3 Profit

This section compares profits under FFS and PDPPS. As for the change from FFS to the per dim payment system (PDPS) with a stepdown tariff, the profits increase for any type of hospital, since $q > 1$.

In what follows it will be convenient to use a function $I(L)$ which is the inverse function of $L(I)$ so that under FFS the maximization problem turns into

$$\max_L p_I I(L) - \gamma g(L),$$

and if $L(\cdot)$ was convex function then $I(L)$ is concave and vice versa. Furthermore, let $d(L)$ be defined as $\frac{p_I I(L)}{L}$, that is, effectively $d(L)$ is the average per day payment that the hospital would receive under FFS given L. Thus we can re-write the FS maximization problem as

$$\max_L d(L)L - \gamma g(L).$$

And recall that the PDPPS maximization problem is

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

The similarity of the two expression leads to an immediate result

Proposition 3 *Let L^*_{PDPPS} denote the LOS in some hospital under PDPPS and L^*_{FFS} denote the LOS under FFS.*

i) if $d(L^*_{PDPPS}) > \bar{d}$ then $\pi_{FFS} > \pi_{PDPPS}$, i.e. $\pi \downarrow$;

ii) if $d(L^*_{FFS}) < \bar{d}$ then $\pi_{FFS} < \pi_{PDPPS}$, i.e. $\pi \uparrow$;

iii) if $d(L^*_{PDPPS}) > \bar{d}$ then $d(L^*_{FFS}) > \bar{d}$.

Useful observation: Proposition 3 holds as stated even if hospitals maximize the average profit, i.e. π/L. Since the profit over fixed time frame is what we have in the data, plus it is most likely to be a hospital objective anyway, it is definitely good to know that the proof goes through.

The first case states that if the avarage daily payment for the LOS in a given hospital under PDPPS is greater than $\bar{d}$, then the change from FFS to PDPPS decreases profitability. The interpretation of this result for the second case is straightforward. If the average payment received by a hospital under FFS is less than $\bar{d}$, such hospital would gain from the reform as its profit would increase.

In order to show a more meaningful interpretation, especially if we want to use immediately observable variables such as LOS we should look at the function $d(\cdot)$. If we ignore the term with p_D then

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

and

$$d'(L) = p_I \frac{I'(L)L - I}{L^2}.$$

If we assume that $I(0) = 0$, or in other words no treatment no LOS, then the sign of $d'(L)$ is fully determined by the concavity of $I(\cdot)$. Specifically, when $I(\cdot)$ is concave then $d'(\cdot) < 0$ and then $I(\cdot)$ is convex then $d'(L) > 0$. Importantly, $d(L)$ is a monotone function of L. Thus when $I(\cdot)$ is convex ($L(\cdot)$ is concave) then from Proposition 1 follows that hospitals with low LOS (efficient) will gain and hospitals with high LOS (inefficient) will suffer. When $I(\cdot)$ is concave ($L(\cdot)$ is convex) then hospitals with high LOS (inefficient) will gain and hospitals with low LOS (efficient) will suffer.

More generally, if $p_D > 0$ and $L(0) > 0$ then sign of the derivative of d with respect to I is

$$\operatorname{sgn}\left(\frac{p_D\bar{D} + p_I I}{L(0) + \tilde{L}(I)}\right)'_I = \operatorname{sgn}\left[p_I(L(0) + \tilde{L}(I)) - (p_D\bar{D} + p_I I)L'(I)\right],$$

where $\tilde{L}(I) = L(I) - L(0)$, so that $\tilde{L}(0) = 0$. Re-arranging the terms we get

$$p_I\left[\tilde{L}(I) - I \cdot L'(I)\right] + p_I L(0) - p_D\bar{D}L'(I).$$

The expression in brackets is negative for convex L and positive for concave L. In particular, for concave $L(I)$ it is possible that $d(L)$ is initially decreasing, for example when $L(I) = I^\alpha$ with $\alpha < 1$. And thus for concave functions it is still possible to get that efficient hospitals will suffer. Importantly, since for concave functions $L'(\cdot)$ is a decreasing function then the negative impact of $p_D\bar{D}L'(I)$ will diminish and eventually $d(L)$ will become increasing. In this case then we have that most efficient and most inefficient hospitals will suffer.[3]

Other testable hypothesis are as follows. With increase of $L(0)$ the share of efficient hospitals which gain in terms of profitability goes up. When the compensation for D is higher then more efficient hospitals are more likely to suffer. Using the financial data for the sample of local public hospitals we could test it.[4]

For convex $L(\cdot)$ we have that unless term $p_I L(0)$ is huge, which is unlikely, then the sign of d' is negative which means that it is a monotone decreasing function. Thus only hospitals with low LOS will suffer.

Useful observation: If γ has support $[0, \infty)$ then $L^*_{PDPPS}(\gamma)$ also has support $[0, \infty)$ and therefore its broader or equal than the support of L^*_{FFS}. By construction of $\bar{d}$ there exist γ such that $d(L^*_{FFS}(\gamma)) > \bar{d}$ which implies that there exist γ's for which $d(L^*_{PDPPS}(\gamma)) > \bar{d}$ This is because, since the support of L^*_{PDPPS} is broader, whatever we can get with L^*_{FFS} we can also get with L^*_{PDPPS}, though potentially with different set of γ's. Importantly that means that there will be hospitals that lose profit and these hospitals are among those with high $d(L^*_{FFS})$.

3.4 Summary

Section 3.1.3 compares the change in ALOS due to the shift from FFS to per diem PPS with a stepdown tariff and absence of readmissions. The result is duplicated here in the table below.

	low γ	high γ
L is concave	$L^* \downarrow$	$L^* \uparrow$
L is convex	$L^* \uparrow$	ambiguous

[3] Recall that as far as LOS goes, concave $L(\cdot)$ is consistent with the data.

[4] I think it is just caused by moves of $d(\cdot)$ curve. When it goes up it means that less hospitals will suffer because only hospitals with very high d will lose profit as a result of the reforms.

When L is a concave function of I , and accordingly, the inverse function is convex, hospitals do not have planned readmissions under FFS. So we can think of the table above as a move from FFS with planned readmissions to a piecewise per diem payment system without readmission. The last step, which is to go from a piecewise per diem PPS without readmission to a piecewise per diem PPS with readmission is done in the previous subsection.

Most importantly we see that for concave L it is still holds that hospital with highest γ will increase their ALOS and other hospital have strong incentives to decrease the ALOS at the cost of readmission.

Finally, it follows that hospitals with low γ will have planned readmission with probability 1. This would, of course, contradict the real data. However, note that the fixed cost of each readmission can be thought of as a random variable. For example, some patients plainly cannot be discharged, which implies high F. When we think of F as random, then monotonicity of $\Delta\pi$ would precisely imply that hospitals with lower γ are *more likely to use planned readmission.*

4 Data

4.1 Sample

We employ an administrative database from Japan's Ministry of Health, Labor, and Welfare on hospitals participating in the Japanese PPS reform or planning to join the reform in the nearest future. The database contains annual aggregated information for hospital's patients, discharged in July-December of each corresponding year. There is a one-two year trial period, when hospitals submit their data to the database but do not yet join the PPS. The annual files allow us retrieve the full (i.e. two year) pre-PPS information only for hospitals, which joined the PPS in 2009.[5] Merging MHLW's annual files by hospital name (checking for the change of name due to restructuring, mergers, and closures), we constructed a balanced panel of 684 hospitals, which submitted the data to MHLW since 2007. 566 hospitals introduced PPS in 2009, another 33 hospitals – in 2010, and 14 more hospitals – in 2011. The rest remained in the FFS system. Note that 13 FFS hospitals left the database in 2010 and another 2 hospitals – in 2011.

The data on hospital characteristics (the binary variables for rural, emergency, and university hospitals, the number of hospital departments and the presence of MRI and CT scanners) come from the 2011 online version of the Handbook of Japanese Hospitals. Using the data from Japan Council For Quality Health Care (2012) we construct a binary variable, which equals unity of the hospital is given accreditation by the beginning of the corresponding financial year. The data for designated local public hospitals (MHLW 2012b) are employed for creating a similar time-varying binary variable for designated hospitals. We use financial data on hospital's costs from the Ministry of Internal Affairs (The Yearbook of Local Government Enterprises, Hospitals, Vol.47-56,

[5]Although the one-year pre-PPS data is available for 82 specific function hospitals, as well as for 358 hospitals that joined the PPS in 2008, we do not include them in the analysis. Indeed, the former produce specific type of health care services. As for the latter group, the database does not report hospital names in the first year, when they started to submit their information to the MHLW.

Variable	Definition	Obs	Mean	St Dev	Min	Max
PPS	=1 if joined PPS by correspondning financial year	3388	0.52	0.50	0	1
beds	total number of beds	3388	294	169	30	1196
departments	total number of departments	3388	15	6	1	33
urban	=1 if urban hospital	3388	0.89	0.31	0	1
public	=1 if public hospital	3388	0.28	0.45	0	1
designated	=1 if granted the status of designated local public hospital by correspondning financial year	3388	0.08	0.27	0	1
accredited	=1 if given independent accreditation by Japan Council for Quality Healthcare	3388	0.62	0.49	0	1
emergency	=1 if emergency hospital	3388	0.84	0.37	0	1
university	=1 if university hospital	3388	0.02	0.13	0	1
mri_ct	=1 if has MRI or CT scanner	3388	0.93	0, 25	0	1

Table 1: Descriptive statistics for the unbalanced panel in 2007-2011.
NOTE: Prefecture grants the status to a public hospital, which satisfies the following requirements: 1) has over 200 beds; 2) the share of patients referred from other facilities is over 60(e.g. MRI, CT scanner) with other hospitals; 4) educates local health care officials; 5) has an emergency status. Designated local hospitals receive a support of 10,000 yen per each admission.

1999-2009). Since ownership is shown to be a significant determinant of LOS (Kuwabara et al. 2006) and efficiency (Motohashi 2009), we construct a binary variable for public hospitals, using hospital names.

4.2 Variables

Since the database does not provide the hospital volume and quality by each DPC, we use the aggregation at the level of Major Diagnostic Categories (MDCs). The Japanese MDCs are constructed on the basis of ICD, with occasional aggregation of certain diagnoses (Appendix). It should be noted that there were 16 MDCs in Japan before 2008. The 16th MDC, which encompassed all unclassified diseases, was subdivided into three categories in 2008: "Trauma, burns, poison" (new MDC 16); "Mental diseases and disorders" (new MDC 17), and "Others" (new MDC 18). Therefore, to analyze the MDC-level data in 2007-2011 we use only 15 MDCs.

The variables of our interest are the number of discharges, average length of stay and the number of planned early readmissions (i.e., readmissions within 42 days after discharge). The database separates early readmissions into readmissions with the same or different diagnosis. It further divides each of the two categories into planned, anticipated and unplanned readmission. Planned readmissions are subdivided into groups according to the reason for readmission. However, the MDC-level data is available only for the following groups: "Operation after preliminary tests", “Planned operation or treatment”, and “Chemical and radioactive treatment”.[6] We impute the total number of planned readmission for each MDC assuming that the share of these reasons in planned readmissions is constant across all MDCs and equals to the hospital-level share.

[6] In total these reasons account for 50-75 percent of all planned readmissions.

MDC number as of 2008	Definition	ALOS					planned readmission rate					total cases				
		2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
MDC 1	Nervous system	21.3	20.7	20.5	21.2	21.5	0.051	0.065	0.056	0.077	0.084	80574	81337	83787	85523	128476
MDC 2	Eye	6.5	6.3	5.5	5.3	5.0	0.075	0.083	0.082	0.128	0.031	47409	47820	50548	52583	79791
MDC 3	Ear, nose, mouth and throat	8.2	8.2	7.6	7.3	7.4	0.026	0.020	0.017	0.018	0.014	48170	47942	44328	47044	66523
MDC 4	Respiratory system	18.3	18.2	17.7	18.1	17.9	0.235	0.210	0.206	0.251	0.257	151782	152751	157279	161992	257537
MDC 5	Circulatory system	15.7	15.7	14.8	15.0	15.1	0.195	0.204	0.214	0.294	0.294	117130	121699	126731	128625	201674
MDC 6	Alimentary, liver, biliary-tree, and pancreas	15.5	15.0	13.8	13.7	13.2	1.000	1.000	1.000	1.000	1.000	284884	301330	307847	311295	457503
MDC 7	Musculoskeletal system	21.5	21.0	19.8	20.0	20.0	0.135	0.141	0.129	0.160	0.230	60679	64347	65715	62099	90784
MDC 8	Skin and subcutaneous tissue	12.5	12.5	11.9	13.2	14.0	0.001	0.003	0.002	0.016	0.007	13409	13714	13088	18068	26553
MDC 9	Breast	14.3	12.9	11.6	11.9	11.7	0.093	0.090	0.082	0.087	0.083	14221	14342	14468	14421	20494
MDC 10	Endocrine, nutritional and metabolic system	17.7	17.2	16.5	16.1	16.2	0.020	0.019	0.014	0.012	0.013	38575	38226	36930	39978	56995
MDC 11	Kidney and urinary tract and male reproductive system	15.5	15.6	14.7	14.7	14.6	0.204	0.179	0.175	0.249	0.192	92332	94784	95955	99673	145604
MDC 12	Female reproductive system and puerperal diseases, abnormal pregnancy, and abnormal labor	12.3	11.5	11.0	11.0	10.8	0.196	0.188	0.159	0.174	0.171	75637	77857	76984	79182	115559
MDC 13	Blood and blood forming organs and immunological disorders	24.6	23.7	23.5	23.3	23.2	0.085	0.076	0.087	0.101	0.099	20935	22239	25651	26814	40644
MDC 14	New born and other neonates, congenital anomalies	11.4	10.6	10.7	10.4	10.2	0.010	0.009	0.011	0.012	0.012	23835	24921	24709	26107	38720
MDC 15	Pediatric diseases	7.8	8.1	8.0	7.7	7.7	0.001	0.0003	0.001	0.001	0.001	27695	24880	18428	22927	34820
MDC 16	Trauma, burns, poison		19.3	18.5	18.4	18.9		0.031	0.055	0.041	0.042		87445	88390	94220	145001
MDC 17	Mental diseases and disorders		12.8	12.0	10.8	8.6		0.000	0.000	0.000	0.000		2298	1730	1443	2341
MDC 18	Other	18.9	17.6	22.2	22.2	23.3	0.089	0.018	0.019	0.015	0.012	109221	18104	20344	22692	34509

Table 2: ALOS and readmission rate for each MDC in hospitals which implemented PPS in 2009.

NOTE: The numbers of MDCs are given as of 2008. Consequently, in 2007 the values for MDC 16 (other) are given in the row, corresponding to new MDC 19.

5 Empirical specification

Using the panel data on Japanese local public hospitals, we estimate a panel data fixed effect model with logarithm of LOS as a function of several hospital inputs: numbers of doctors, nurses, hospital beds, amount of medical materials (measured in yen), and examinations per patient. Hospital inputs are taken in logs. the results reveal that the sum of coefficients for inputs that increase LOS is less than unity. Consequently, we conclude that LOS is a *concave* function of increasing inputs. Given the concavity of the LOS, our theoretical model yields the following testable hypotheses.

5.1 Hypotheses

H1: The change from a FFS to a per diem PPS with a stepdown tariff increases the LOS in more efficient hospitals and reduces LOS in less efficient hospitals.

H2: The change from a FFS to a per diem PPS with a stepdown tariff decreases the prevalence of planned readmissions in more efficient hospitals and increases planned readmission rate in less efficient hospitals.

5.2 Dynamic panel data model

We assume that there is an "attraction point" μ, so that the effect of the PPS reform for hospitals with the pre-reform values of LOS larger than μ monotonically approaches the effect for hospitals with the LOS equal to μ "from above". Similarly, the effect of the PPS reform for hospitals with the pre-reform values of LOS smaller than μ monotonically approaches the effect for hospitals with the LOS equal to μ "from below". Let

$$y_{it} - \mu = \alpha_1(y_{i,t-1} - \mu) + \alpha_2(y_{i,t-1} - \mu) \cdot PPS_{it} + \delta \mathbf{X}_{it} + \nu_i + \varepsilon_{it}, \tag{7}$$

where y_{it} is ALOS of hospital i in year t, PPS_{it} is the reform dummy which equals unity if hospital introduced PPS in year t, $\mathbf{X}_{it}$ are hospital control variables, ν_i are fixed effects, ε_{it} are i.i.d. with zero mean. For convenience we estimate an equivalent specification

$$y_{it} = \alpha_0 + \alpha_1 y_{i,t-1} + \alpha_2 y_{i,t-1} \cdot PPS_{it} + \alpha_3 PPS_{it} + \delta \mathbf{X}_{it} + \nu_i + \varepsilon_{it}, \tag{8}$$

where $\alpha_0 = \mu(1 - \alpha_1)$ and $\mu = -\alpha_3/\alpha_2$. An identification condition for the "attraction point" (i.e. an AR(1) process) is $0 < \alpha_1 < 1$. Given identification condition holds, the significance of μ implies the presence of an "attraction point" which might be contrasted to the actual values of the thresholds of a piece-wise tariff in the DPC component. If an additional condition $0 < \alpha_1 + \alpha_2 < 1$ holds, then the "attraction point" does not change with time.

Since $y_{i,t-1}$ is a factor of the cross-term $(y_{i,t-1} \cdot PPS_{it})$, we treat the cross-term as a predetermined variable. Given voluntary participation in the PPS reform, we assume that a hospital decides about introducing PPS, taking into consideration the value of hospital's ALOS in the pre-reform year. Consequntly, PPS_{it} must be regarded as a predetermined variable, too. The time-varying hospital controls $\mathbf{X}_{it}$ are accreditation dummy and designated hospital dummy. Equation (8) is estimated using Arellano–Bover (1995)/Blundell–Bond (1998) estimator,[7] with robust variance-covariance matrix (Windmeijer 2005). Lagged levels and lagged differences of y_{it} , PPS_{it} and $(y_{i,t-1} \cdot PPS_{it})$ are taken as instruments for the differenced equation. Arellano-Bond (1991) test does not reject the hypothesis about the absence of serial correlation at order two in the first differenced errors.

We run regressions (8) for each Major Diagnostic Category.If the dynamic panel data model (8) is correctly specified, the average treatment effect (ATE) of the PPS reform, implemented in year t+1, is a function of the pre-reform value mean value of $y_{i,t}$ and estimated coefficients α_2 and α_3: $ATE = [(y_{i,t+1}|PPS_{i,t+1} = 1) - [(y_{i,t+1}|PPS_{i,t+1} = 0) = \alpha_2\overline{y}_{i,t} + \alpha_3$. [8] We assume that hospital's efficiency is directly related to ALOS, and calculate ATE for percentiles of ALOS. Smaller values of the average treatment effect in lower percentiles might be interpreted as a proof of H1, since H1 predicts smaller change in ALOS in more efficient hospitals.

To conduct a formal test of H1, we assume that efficiency parameter γ is inversely related to ALOS. Accordingly, we divide hospitals into quartiles of ALOS in 2007, so that the quartile with the lowest ALOS proxies the group of hospitals with the highest γ. Running regressions in (8) for each quartile of ALOS we examine the coefficient of the average treatment effect of the PPS reform. If hypothesis 1 holds, ATE should be higher for lower quartiles of ALOS.

To test H2 we estimate (8) for each quartile of ALOS, with the dependent variable y_{it} being planned readmission rate of hospital i in year t. The proof of H2 may be revealed from the lower values of α_2 for lower quartiles of ALOS.

Since $y_{i,t-1}$ is a factor of the cross-term $(y_{i,t-1} \cdot PPS_{it})$, we treat the cross-term as a predetermined variable. Given voluntary participation in the PPS reform, we assume that a hospital decides about introducing PPS, taking into consideration the value of hospital's ALOS in the pre-reform year. Consequntly, PPS_{it} must be regarded as a predetermined variable, too. The time-varying hospital controls $\mathbf{X}_{it}$ are accreditation dummy and designated hospital dummy. Equation (8) is estimated using Arellano–Bover (1995)/Blundell–Bond (1998) estimator,[9] with robust variance-covariance matrix (Windmeijer 2005). Lagged levels and lagged differences of y_{it} , PPS_{it} and $(y_{i,t-1} \cdot PPS_{it})$ are taken as instruments for the differenced equation. Arellano-Bond (1991) test does not reject the hypothesis about the absence of serial correlation at order two in the first differenced errors.

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[7] Which is more efficient than Arellano–Bond (1991) estimator.

[8] The difference-in-difference between the treated and the controls (in years t+1 and t) is: $[(y_{i,t+1}|PPS_{i,t+1} = 1) - (y_{i,t}|PPS_{i,t+1} = 1)] - [(y_{i,t+1}|PPS_{i,t+1} = 0) - (y_{i,t}|PPS_{i,t+1} = 0)]$, where the terms $(y_{i,t}|PPS_{i,t+1} = 1)$ and $(y_{i,t}|PPS_{i,t+1} = 0)$ can not be identified.

[9] Which is more efficient than Arellano–Bond (1991) estimator.

6 Results

The results of our estimations reveal that identification conditions for dynamic panel data hold: α_1 is significant at 0.01 level and belongs to the interval (0,1) for all MDCs, with an exception of MDC4, for which $\alpha_1 = 1.087$. The "attraction point" exists for each MDC. The sum $\alpha_1+\alpha_2$ belongs to the interval (0,1) and is statistically significant for eleven MDCs out of fifteen.[10] Arguably, for four MDCs the "attraction point" varies over time.

ATE of the PPS reform is significant for 11 MDCs out of 15, with negative significance for 9 MDCs. The result reveals that overall the Japanese PPS resulted in a decrease of the average length of stay. According to the values of ATE in quartiles of ALOS, H1 about differential response of hospitals to PPS is not rejected for 12 MDCs out of fifteen. The exceptions are MDC1, MDC8 and MDC12 where ATE is insignificant for all quartiles. In case of MDC14 the ATE of the PPS reform is positive, yet, its absolute value in quartile 4 is smaller than in quartile 3, which may also be treated as the proof of H1 (i.e. larger rise in ALOS in more efficient hospitals). In the remaining MDCs the ATE of the PPS reform is negative and is generally significant in most quartiles. The absolute values of the ATE coefficients in lower quartiles are smaller than in higher quartiles, which implies than PPS resulted in smaller falls in ALOS of more efficient hospitals.

For each MDC columns 1 and 2 give the results with regressions for the whole sample of hospitals. Column 1 presents the value of "concentration point" and column 2 gives the coefficient for the average treatment effect (estimated in 2009). Columns 3 through 6 present the cofficients of the average treatment effect in regressions, when hospitals are divided into 4 groups according to the quartile of ALOS for the corresponding MDC in 2007, where group 1 indicates hospitals with the lowest ALOS. The average treatment effect of PPS reform in regression for the subsample of hospitals in quartile j is denoted $\text{ATE}_{,j}$. It should be noted that Arellano-Bond (1991) test rejected the hypothesis about the absence of second order serial correlation in regressions with MDC14, first quartile of MDC 3 and third quartile of MDC 15. Given the total number of our regressions equal to 60, the failures of model specification produce the value of the first order error equal to 0.04.

7 Discussion

A number of theoretical approaches forecast heterogeneity in hospital's volume owing to the introduction of a mixed (per diem) PPS. Grabowski et al.'s (2011) theoretical model predicts that the shift from FFS to per diem PPS for skilled nursing facilities may lead to ambigous dynamics of ALOS in the US. Yasunaga et al. (2006) argue that although the Japanese inpatient PPS decreases the mean LOS for all participating hospitals, the reduction in LOS occurs only in large hospitals, which deal primarily with surgical patients. Moreover, Kuwabara et al. (2006) demonstrate that surgical procedures explain a large variation in resourse use. A hint at explaining heterogeneous response of hospital's volume to per diem PPS may be found in Frank's and Lave's (1989; 1986)

[10]Statistical insignificance is found for MDCs 8, 9, 10 and 15.

hypothesis about longer LOS as a result of per diem rates set above marginal costs.

In this paper we presented a theoretical model, which explicitly incorporated the essential features of the per diem PPS in Japan. The empirical analysis with the data for the reformed and non-reformed hospitals confirmed the predictions of the model about heterogeneous hospital response to the per diem PPS. As we already mentioned earlier, the actual reimbursement system employed in Japan has three per-diem rates. The highest rate is paid during the first quartile of the average LOS, where the average for a given MDC is taken over all hospitals. The second per diem rate is being paid until the length of stay reaches the average LOS, after which hospitals are reimbursed with the lowest per diem rate. This, however, is not going to affect our results. According to our model the LOS should increase for most hospitals, because of the premium coefficient q, which is greater than 1. This coefficient increases the marginal benefit of a longer stay while keeping the marginal cost unaffected. Whether a hospital uses planned readmission or not, it has more incentives to take advantage of the higher initial per diem rate. Having two premiums $q_1 > q_2 > 1$, will lead to a quantitatively similar results.

8 Conclusion

The paper presents a theoretical model, which explains heterogeneous dynamics of hospital's volume and quality in a mixed prospective payment system with per diem payments and a length-of-stay dependent PPS tariff. The novelty of the model is that it incorporates hospital's heterogeneity through an explicit parameter of hospital's cost efficiency. The model predicts different directions of the change in ALOS for efficient and inefficient hospitals. Moreover, the decline in ALOS is shown to be associated with a rise in the rate for planned early readmissions.

Using an administrative database for 684 Japanese PPS hospitals in 2007-2011, we conduct avearge treatment effect estimations with dynamic panel data and find an empirical support for the predictions of the theoretical model. The results of our empirical analysis reveal that ALOS increases in more efficient hospitals and decreases in less efficient hospitals. Our theoretical model demonstrates that the reason for such heterogeneity is the LOS dependent stepdown tariff, which is based on the empirical distribution of hospitals with respect to their ALOS.

In 2012, Japan introduced a modification of the reimbursement schedule: regardless of hospital's position in the empirical distribution of ALOS, no more than 50% of days for each hospital stay may be reimbursed according to the highest rates. Based on our model, we predict that this change should have no effect on less efficient hospitals. As for more efficient hospitals hospitals, the effect should be benefitial for a social planner, since hospital's incentives to keep patients longer will be reduced.

9 Appendix

Proof of Proposition 1: *If* $F \geq 0$ *then planned readmission is suboptimal.*

Proof. Intuitively, this is because the benefit, $I(L, \bar{D}$ is the convex function of L and therefore it is suboptimal to split it into two admissions. Indeed, take $(L_1, L_2) > 0$ and assume that it is optimal. First, assume that $L_1 \geq L_2$. Then for a small ε $p_I I(L_1+\varepsilon, \bar{D})+p_I I(L_2-\varepsilon)-\gamma g(L_1+\varepsilon+L_2-\varepsilon)-F > p_I I(L_1) + p_I I(L_2) - \gamma g(L_1 + L_2) - F$, which is a contradiction. Similar logic is applicable when $L_2 > L_1$. Thus the two strict optima are $(L^*, 0)$ and $(0, L^*)$, both of which involve one admission. ■

Proof of proposition 2: *Let L^* be the optimal LOS without readmission and L_1^* and L_2^* two LOS with planned readmission. Then*

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

ii) $(L_1^* + L_2^*)/2 \leq L^* \leq L_1^* + L_2^*$.

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 requires a careful considerations of five intervals with γ values. However, the intuition is straightforward. For hospitals with high γ the LOS has to be so short that with or without the planned readmission the daily rate will be $q\bar{d}$ thus there is not much to gain by using the planned readmission. For hospitals with low γ on the other hand the gain can be substantial as a long LOS can be split in two, thus doubling the number of days for which hospitals will be compensated under the higher rate $q\bar{d}$.

Proof. First, it follows from (6) that it is never optimal to have one admission short and another admission long, that is $L_i > \alpha\bar{L} > L_j$. Given that daily payment on admission j are higher than on i it is strictly optimal to decrease L_i and increase L_j by the same amount. Thus, we can ignore the second line of (6) and focus on the cases where both admissions are long or both are short. In the former case, if the optimum is interior then it is reached when $q\bar{d} = \gamma g'(L_1 + L_2)$. In the latter case, if the optimum is interior it is reached when $\bar{d} = \gamma g'(L_1 + L_2)$.

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

1. γ is such that $\gamma g'(2\alpha\bar{L}) > \gamma g'(\alpha\bar{L}) > q\bar{d}$. For these parameter values the profit with readmission has the global maximum at point where $\gamma g'(L_1^* + L_2^*) = q\bar{d}$, and the profit with readmission has the global maximum at point $\gamma g'(L^*) = q\bar{d}$. This means that even without readmission the hospital can ensure the daily payment at a premium rate, $q\bar{d}$, which effectively means that unless $F = 0$, hospitals with such high γ have no financial incentives to use planned readmission.

2. γ is such that $\gamma g'(2\alpha\bar{L}) > q\bar{d} > \gamma g'(\alpha\bar{L}) > \bar{d}$. The first inequality means that if a hospital to use planned readmission it is optimal to use two planned readmissions. In particular, $L_1^* + L_2^* < 2\alpha\bar{L}$. The last two inequliaties mean that without readmission the optimal LOS is $\alpha\bar{L}$. In particular, $L_1^* + L_2^* > \alpha\bar{L}$ since otherwise the optimal solution without readmission would be less than $\alpha\bar{L}$. This shows that the ALOS drops when the readmission is used, but the total number of days for a given patient goes up.

   Next we look at the profit difference.

Lemma 1 *The profit difference with and without readmission is positive and is a strictly decreasing function of γ.*

Proof. The profit difference is

$$\Delta\pi = \left[q\bar{d}(L_1^* + L_2^*) - \gamma g(L_1^* + L_2^*)\right] - \left[q\bar{d}\alpha\bar{L} - \gamma g(\alpha\bar{L})\right] > 0.$$

By the envelope theorem the derivative of the first term with respect to γ is $-g(L_1^* + L_2^*)$. Since $\alpha\bar{L}$ is a constant that does not depend on γ the derivative of the second term is $-g(\alpha\bar{L})$. For the highest γ in our range, which is when $\gamma g'(\alpha\bar{L}) = q\bar{d}$ it is the case that $L_1^* + L_2^* = \alpha\bar{L}$ and so $\Delta\pi = 0$. For lower values of γ we have $L_1^* + L_2^* > \alpha\bar{L}$ and so the derivative of the profit difference with respect to γ is

$$-g(L_1^* + L_2^*) + g(\alpha\bar{L}) < 0$$

In other words $\Delta\pi$ is a strictly decreasing function of γ which is equal to 0 at the upper limit of the interval and therefore is positive on the remaining part of the interval. ■

As we continue to decrease γ two cases are possible. Either, $\gamma g'(\alpha\bar{L})$ becomes equal to $\bar{d}$ first, or $\gamma g'(2\alpha\bar{L})$ becomes equal to $q\bar{d}$ first. We consider each of these two cases separately.

3. γ is such that $q\bar{d} > \gamma g'(2\alpha\bar{L}) > \gamma g'(\alpha\bar{L}) > \bar{d}$. Then the optimal solution with the readmission is to have $L_1^* = L_2^* = \alpha\bar{L}$. The optimal solution without the readmission is as before, that is $L^* = \alpha\bar{L}$. In thi case the ALOS is the same, but $L_1^* + L_2^* > L^*$.

   The profit difference is

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

   and it is positive. The reason is that by continuity the value of $\Delta\pi$ at the upper bound (that is for γ such that $q\bar{d} = \gamma g'(2\alpha\bar{L})$) the value of the profit difference should be the same as its value at the lower bound for the previous case, which is positive. Given that $\Delta\pi$ is decreasing with γ it will remain positive as γ decreases.

3' Alternatively we consider the case when γ is such that $\gamma g'(2\alpha\bar{L}) > q\bar{d} > \bar{d} > \gamma g'(\alpha\bar{L})$. In this case without readmission hospitals would go for long admission and with, the hospital would go for two short admissions. By the same logic as in case 2 we conclude that $2\alpha\bar{L} > L_1^* + L_2^* > \alpha\bar{L}$. Furthermore, $L_1^* + L_2^* > L^*$ as $\gamma g'(L^*) = \bar{d} < q\bar{d} = \gamma g'(L_1^* + L_2^*)$. Thus, the ALOS will decrease and the total number of days per case goes up. As for profit difference,

$$\Delta\pi = \left[q\bar{d}(L_1^* + L_2^*) - \gamma g(L_1^* + L_2^*)\right] - \left[q\bar{d}\alpha\bar{L} + \bar{d}(L^* - \alpha\bar{L}) - \gamma g(L^*)\right]$$

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

4. γ is such that $q\bar{d} > \gamma g'(2\alpha\bar{L}) > \bar{d} > \gamma g'(\alpha\bar{L})$. The solution with the readmission is $L_1^* = L_2^* = \alpha\bar{L}$ and without is such that $\gamma g'(L^*) = \bar{d}$, where $\alpha\bar{L} < L^* < 2\alpha\bar{L}$. Thus, the ALOS declines and the total stay goes up. Profit difference is

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

and its derivative is $-g(2\alpha\bar{L}) + g(L^*) < 0$ and thus as before we can conclude that $\Delta\pi > 0$ and is a decreasing function of γ.

5. γ is such that $\bar{d} > \gamma g'(2\alpha\bar{L}) > \gamma g'(\alpha\bar{L})$. In this case $\gamma g'(L_1^* + L_2^*) = \gamma g'(L^*) = \bar{d}$ and so $L_1^* + L_2^* = L^*$. The profit difference is

$$\left[q\bar{d}(2\alpha\bar{L}) + \bar{d}(L_1^* + L_2^* - 2\alpha\bar{L}) - \gamma g(L_1^* + L_2^*)\right] - \left[q\bar{d}\alpha\bar{L} + \bar{d}(L^* - \alpha\bar{L}) - \gamma g(L^*)\right] = (q-1)\bar{d}\alpha\bar{L}$$

It does not depend on γ and is positive. While the *total* LOS does not change, the average LOS does. This is because it is worth to receive the premium payment $q\bar{d}$ twice rather than once and so hospitals have incentives to use planned readmission.

This concludes the proof of the Proposition. ■

Proof of proposition 3: *Let L^*_{PDPPS} denote the LOS in some hospital under PDPPS and L^*_{FFS} denote the LOS under FFS.*
i) if $d(L^*_{PDPPS}) > \bar{d}$ then $\pi_{FFS} > \pi_{PDPPS}$, i.e. $\pi \downarrow$;
ii) if $d(L^*_{FFS}) < \bar{d}$ then $\pi_{FFS} < \pi_{PDPPS}$, i.e. $\pi \uparrow$;
iii) if $d(L^*_{PDPPS}) > \bar{d}$ then $d(L^*_{FFS}) > \bar{d}$.
Proof. Consider the first case:

$$\pi_{PDPPS} = \bar{d}L^*_{PDPPS} - \gamma g(L^*_{PDPPS}) < d(L^*_{PDPPS})L^*_{PDPPS} - \gamma g(L^*_{PDPPS}) \leq \pi_{FFS}.$$

The first equality comes from the fact that L^*_{PDPPS} is optimal LOS under PDPPS. The next inequality comes from the fact that $d(L^*_{PDPPS}) > \bar{d}$ and the last inequality comes from the fact that the highest profit under FS has to be greater or equal than the profit the hospital can achieve using L^*_{PDPPS}. For the second case

$$\pi_{FFS} = d(L^*_{FFS})L^*_{FFS} - \gamma g(L^*_{FFS}) < \bar{d}L^*_{FFS} - \gamma g(L^*_{FFS}) \leq \pi_{FFS},$$

which is similar to the first case.

Finally, part iii) follows from parts i) and ii). Indeed, $d(L^*_{PDPPS}) > \bar{d}$ means that the profit would drop and therefore it cannot be the case that $d(L^*_{FFS}) < \bar{d}$. ■

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