Heterogeneous hospital response to per diem prospective payment system

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Abstract

The paper provides theoretical analysis for hospitals’ heterogeneity in the response to the change from the the fee-for-service (FFS) system to a per diem prospective payment system with a length-of-stay dependent step-down rate (SDR): hospitals with shorter (longer) average length of stay under FFS have longer (shorter) average length of stay under SDR. We also show that for FFS hospitals with longer average length of stay the planned readmission rate is to increase under the SDR. Using a recent administrative database for 684 Japanese hospitals in 2007-2011, we conduct estimations with dynamic panel data and find an empirical support for the predictions of our theoretical model. The results suggest that step-down rate contributes to differential hospital’s response to a per diem prospective payment system and might lead to insufficient cost containment.
1 Introduction

Health care is an example of an industry in which providers have a strong influence on consumers’ choice of medical services (Christianson and Conrad 2011; Mayes 2007). Combined with the volume-based fee-for-service (FFS) reimbursement, the power of health care providers leads to supplier-induced demand, overuse of resources, and overspending. Although providers may take initiative in exerting cost-reducing efforts and raising efficiency of medical treatment (Borghans et al 2012), cost-reducing efforts are not immediately verifiable. Therefore, the task of devising a reimbursement mechanism that encourages efficiency falls on the governments, who act as social planners concerned over welfare issues (Chalkley and Malcomson 2000; Holmstrom and Milgrom 1991).

A particularly significant example of such reimbursement mechanism is the one based on the diagnosis-related groups (DRGs) which were developed in the U.S. in the 1960s. DRGs is a classification of diseases into medically justified groups with a stable distribution of resources required to treat patients in each group (Thompson et al. 1979). Providers receive a fixed reimbursement amount for each episode of medical care to a patient with a given DRG. This system is called prospective payment system (PPS) and it promotes cost efficiency since hospitals start bearing the financial burden of excessive medical treatment.

Countries which are not yet ready to introduce the genuine version of PPS (e.g., owing to high variation of medical practices, historical differences in hospital reimbursement or lack of standardized data on patient cases) might favor a per diem PPS as the system that contains certain incentives for cost containment. Under the per-diem PPS hospitals have incentives to limit the daily resource use; however, their incentives with regards to the length of hospital stay and total cost are not directly affected. Such per diem PPS may be regarded as a cost-sharing system, which allows for an appropriate balance between cost-efficiency and quality (Laffont and Tirole 1993). Among the developed countries, Germany and Japan employ the per diem system. Furthermore, the Japanese version on the inpatient PPS contains explicit incentives to 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. While Germany exploited per diem PPS in 1996–2003 as a transitory system to the prospective reimbursement, Japan keeps preserving the per diem character of its PPS.

Originally introduced in 2003, the Japanese PPS immediately resulted in the decline of the ALOS at the hospital and at the national levels (MHLW 2005). Since ALOS is often treated as a proxy for hospital efficiency (Lopes et al., 2004; Rapoport et al., 2003; Heggestad, 2002), one could argue that a fall in the ALOS was, in fact, associated with increased efficiency (Kuabara 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 hospitals costs is ambiguous (Nishioka 2010; Yasunaga et al. 2006; Yasunaga et al. 2005). Notably, the effect of the PPS introduction on ALOS was not uniform and for some hospitals the ALOS has increased (Nawata and Kawabuchi, 2012).

The Japanese PPS also resulted in quality deterioration reflected in the rise of early readmission
rate (by Japanese definition - readmissions within 42 days after discharge, Hamada et al. 2012; Yasunaga et al. 2005a), as well as in the growing prevalence of "remission" report and the decreasing prevalence of "healing" report[1] to the discharged patients (Besstremyannaya, 2010). The major reason for the rise in early readmission rate is the increase in planned readmissions (Besstremyannaya 2010; Okamura et al. 2005)[2] which was, in turn, caused by the LOS-dependent stepdown per diem PPS tariff (Kondo and Kawabuchi 2012).

Motivated by the Japanese PPS reform and prior evidence regarding its effect, in this paper we provide a theoretical and empirical analysis of how the reform affected hospitals’ financial incentives and its impact on the ALOS and planned readmission rates. In the theoretical part, we develop a model to compare the outcomes under the fee-for-service reimbursement scheme, FFS, and a per diem PPS with a LOS-dependend step-down rate, SDR. The former corresponds to the pre-reform system and the latter corresponds to the post-reform system. To separate the effect of the per diem system per se from the effect of LOS-dependent per diem rates we also study an intermediate reimbursement system with the flat per diem rate, PD.

In our model we assume that heterogeneity among hospitals results in a variation in the hospital-level ALOS, which is consistent with the data. We show that a change from the FFS to the per diem system has a differential effect, depending on hospital’s ALOS under the FFS system. Specifically, we demonstrate that hospitals with shorter ALOS have incentives to prolong the ALOS, and hospitals with longer ALOS prefer to decrease their ALOS under PD. Adding LOS-dependent reimbursement rates such that initial stay is reimbursed under higher tariff, as in SDR, has unambiguously perverse incentives on hospitals. Higher initial tariff increases hospitals’ marginal benefit from longer stay while does not affect marginal cost. Effectively, all hospitals, except for those with the longest ALOS, find it profitable to treat patients longer.

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. We specifically focus on financial incentives to use planned readmission, as we assume that medical reasons for readmissions remain unaffected by the

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1The following categories of outcomes are specified in the MHLW (2009) “Explanatory materials for the 2008 survey on the Effect of DPC introduction”: 1) Healing (Chiyu): There is no need in outpatient treatment after discharge. 2) Improvement (Keikai): Improvement was achieved in the course of treatment. In principle, there is a need for continuous outpatient care after discharge. 3) Remission (Kankai): Radical treatment (e.g., as in case of blood diseases) was applied during hospital stay, and there is temporary improvement; yet, there is a chance of disease reoccurrence. 4) No change (Fuhen): No improvement was reached in the course of the relevant treatment in hospital. 5) Worsening (Dzouaku): Worsening was noticed in the course of the relevant treatment in hospital.

2According 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 QOL; 4) Discharged due to patient’s desire during previous hospital stay; 5) Other.

The reasons for planned readmissions are: 1) operation after preliminary tests; 2) planned operation or procedures; 3) chemical or radioactive treatment; 4) planned examinations/tests; 5) examination/operation was stopped during previous treatment, and patient was discharged; 6) patient was sent home to recover before the operation

The reasons for unplanned readmissions are: 1) Non-anticipated worsening of medical condition; 2) Non-anticipated worsening of co-morbidity; 3) Emergence of other acute medical condition; 4) Other.
reform. We show that from the financial point of view, hospitals with longer ALOS under the FFS have stronger incentives to treat patients using planned readmission. Since each admission is reimbursed separately, planned readmission enables hospitals to benefit twice from higher initial rates under the SDR system. 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 readmissions to decrease the reported ALOS, even though the full treatment takes longer.

In the second part of the paper we empirically test the predictions of our model. We use a recently released administrative database for 684 Japanese hospitals in 2007-2011, with most hospitals gradually joining the PPS reform in 2009-2011. The data come from the Japanese Ministry of Health, Labor, and Welfare’s (MHLW) database on PPS hospitals. We supplement it with the data on hospitals’ characteristics taken from the Handbook of Hospitals, and financial characteristics used from the Ministry of Internal Affairs’s database. The empirical analysis is conducted for each Major Diagnostic Category (MDC). The Japanese MDCs aggregate groups of certain diagnoses (e.g., circulatory system diseases) and are constructed on the basis of the International Classification of Diseases (ICD) with minor modifications. In addition, we estimate the model for the pooled data without the separation by MDCs. We find strong evidence supporting heterogeneity in hospitals’ response. In each of 15 MDCs, as well as in the pooled data, we observe that hospitals with the shortest ALOS (in the first quartile, when ordered by ALOS) significantly increase their ALOS after the introduction of the SDR, whereas hospitals with the longest ALOS (those in the fourth quartile) significantly decrease it. Regarding the planned readmission rate, only for two MDCs out of fifteen we observe a drop in planned readmission rates in hospitals with the longest ALOS, as compared to ten MDCs for which the readmission rate significantly goes up as predicted by the model.

A certain amount of empirical literature pays attention to a differential response of hospital’s ALOS to the change from FFS to PPS (Sood et al. 2008; Ellis and McGuire 1996; Gold et al. 1993; Coulam and Gaumer 1991) and per diem PPS (Grabowski et al. 2011). Yet, a 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, to the best of our knowledge, the only attempts to theoretically exploit the potential sources for heterogeneity in the dynamics of ALOS.

The findings of our analysis may be relevant not only for the country-level, but also for the medical specialty level generalizations. Indeed, along with the experience of Germany and Japan, prospective per diem PPS is currently employed in Medicare’s psychiatric hospitals, skilled nursing facilities and hospices, as well as in Medicaid’s psychiatric inpatient facilities.

The remainder of the paper is structured as follows. Section 2 provides a description of the major features of 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. Section 4 describes

\[ \text{MDC3 } "\text{Ear, nose, and throat}" \text{ and MDC12 } "\text{Female reproductive system}".]
the data, and Section 5 provides specifications for the empirical analysis. Section 6 presents the results of the estimations, and the follow-up discussion is given in Section 7.

2 Japanese inpatient prospective payment system

The issue of cost containment became on the agenda of Japanese health care policy makers in 1970s, when the rate of health care expenditure growth started to exceed the rate of growth in GDP (Fujii and Reich 1988). The main factors causing soaring costs of the Japanese health care system are aging population, decrease of the labor force, and the physician-induced demand combined with the development of medical technologies. In fact, the Japanese social health insurance system has always been highly subsidized. In 2012, for example, central government financed 25.3% of health care expenditure (MHLW 2012c), which contributed to 10.2 % of the government’s budget (Ministry of Finance, 2012). 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 (Ikegami 2009). Consequently, the Ministry of Health, Labor, and Welfare 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 in Japan was implemented in 1990, when inclusive per diem rates were introduced in 50% of geriatric hospitals (MHLW 2012a; Ikegami 2005; Okamura et al. 2005). Then, inpatient PPS was piloted in 10 acute care national hospitals in 1998. Finally, in 2003 the PPS was introduced 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, voluntarily 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 step-down 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 calculated for all hospitals submitting the data to MHLW, period 2 contains the rest of the ALOS, and period 3 encloses 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, 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 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 are gradually increasing since 2003, and as of 2012 there are 2927 groups of diagnoses and 2241 DPCs.\footnote{The initial rates were set on the basis of 267,000 claim data on patients discharged from 82 targeted hospitals in July-October 2002.}
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. We conducted a thorough investigation of potential administrative tools and found that there was no pressure. 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. There are several eligibility criteria: a hospital has to meet the threshold value of MHLW nurse staffing ratio of 2 inpatients per nurse; has to follow the methodology for accounting inpatient expenditure; and has to collect standardized data on prescribed drugs. In particular, the methodology for accounting inpatient expenditure implies employment of special administrative staff, detailed book keeping, ICD-10 coding, and data processing (Sato 2007).

The Japanese PPS resulted in the decrease of the ALOS in participating hospitals (MHLW 2012). Case studies demonstrate that the Japanese hospitals use the classic measures of reducing ALOS through raising efficiency of medical treatment (Borghans et al. 2012), which include shortening the diagnostic and tests procedures (Suwabe, 2004). However, a combination of a retrospective and a prospective fee might not have shorted the ALOS in certain cases (Yasunaga et al. 2006).
3 Theoretical model

The section develops a theoretical framework to analyze hospitals’ incentives in response to the introduction of a per diem PPS. We consider three reimbursement systems: the 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 stepdown rate (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.

In this section we restrict our attention to the treatment of a patient with a given diagnosis (DPC). We assume that there is a variety of medical procedures and input combinations that could be used to treat a given condition, and it is up to a hospital or a physician to choose a particular input combination. Since the major goal of this paper is to understand the effect of reforms on the ALOS, it is natural to classify inputs and procedures based on their impact on the LOS for a given patient. Inputs that decrease the LOS are labeled $D$, and inputs that increase the LOS are labeled $I$. Owing to the medical constraints on the minimal value of the LOS for a given diagnosis, we set an upper limit for the value of $D$ by assuming that $D \in [0, \bar{D}]$. As for increasing inputs, we assume that $I \in [0, \infty)$. Note that $I$ are not necessarily wasteful in terms of patient’s health. For example, such inputs could include appropriate precautionary treatments and follow-up tests.

Given levels of $I$ and $D$, we define a function $L(I, D)$ that determines the length of stay. As hospitals deal with many cases of a given diagnosis, we can think of $L(I, D)$ as the average length of stay for the diagnosis in a hospital. Hospital’s cost is given by a function $g(L)$, where $g$ is strictly increasing and convex. We assume that different hospitals have different $\gamma$, so that the cost (and marginal cost) is higher for hospitals with higher $\gamma$. The heterogeneity parameter $\gamma$ may reflect the difference in equipment costs, human capital, or opportunity costs due to personnel availability or bed occupancy rates. Alternatively, heterogeneity could be introduced through the production function $L(I, D, \gamma)$ as long as heterogeneity parameter, $\gamma$, ranks hospitals in terms of their costs and marginal costs (the required technical conditions are $L' > 0$ and $L'' > 0$).

The model is based on the following theoretical approaches in the literature on hospital economics, regulation and provider incentives. First, we model a hospital as a profit-maximizing supplier of health care and quality (Hodgkin and McGuire 1994; Ellis and McGuire 1996; Ma 1998; Grabowski et al. 2011). Second, we focus on the intensity of treatment (McClellan 1996; McClellan 1997; Grabowski et al. 2011), which is particularly relevant for a per diem PPS with the two-part tariff, where procedures are given a special emphasis (MHLW 2004; Busse and Schwartz 1997). Finally, the existence of the heterogeneity parameter in the cost function is analogous to Laffont’s and Tirole’s (1993) technological parameter, reflecting hospital’s efficiency.

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5 The assumption that $g$ is a strictly increasing function of $L$ is not innocuous one because one can imagine that a faster treatment can 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 neither the FFS nor the PD systems will lead to a choice of $L$ at the interval where $g$ declines.
3.1 Length of stay

3.1.1 Fee-for-service system

We model the fee-for-service system, which reimburses a given predetermined price for each unit of input. Denote the price of decreasing inputs as $p_D$ and the price of increasing inputs as $p_I$. The maximization problem is

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

and so it follows that $D^* = \tilde{D}$. Intuitively, higher $D$ raises revenues, $p_D D$, and decreases the costs because of lower LOS. The optimal level of $I$ is determined from the FOC and satisfies:

$$p_I = \gamma g'(L)L_I.$$  \hspace{1cm} (1)

An immediate property of $I^*$ to be used later is that it is a decreasing function of $\gamma$. The implicit function theorem applied to (1) produces:

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

Here, the denominator is the second derivative of the objective function in (1) and, by the second-order condition, is negative at the optimum. The numerator is positive since $g(\cdot)$ is convex and $L'_I > 0$ by assumption. The intuition is straightforward: for hospitals that incur higher cost for a given $L$ it is optimal to use lower amount of inputs that increase $L$.

3.1.2 Per diem prospective payment system

The maximization problem under the per diem PPS is

$$\text{max } \tilde{d}L(I, D) - \gamma g(L(I, D));$$

where $\tilde{d}$ is a per diem rate received by the provider. In Japan, the value of $\tilde{d}$ is determined according to the average per diem reimbursement under the pre-reform fee-for-service system. Specifically, for a given hospital denote the optimal LOS under the fee-for-service system $L_{FFS} = L(I^*, \tilde{D})$. Then the average per diem reimbursement is

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

where $I^*$ depends on $\gamma$. Taking the average over all hospitals we get the expression for $\tilde{d}$:

$$\tilde{d} = E_\gamma \left[ \frac{p_D \tilde{D} + p_I I^*}{L_{FFS}} \right].$$  \hspace{1cm} (3)

The FOC for the maximization problem (2) is

$$\tilde{d} - \gamma g'(L_{PD}) = 0,$$

and, in particular, it implies that higher values of $\tilde{d}$, ceteris paribus, lead to longer LOS.
To compare $L_{FFS}$ and $L_{PD}$ recall that from (1)
\[
\gamma g'(L_{FFS}) = \frac{p_I}{(L_{FFS})_I^2},
\]
and, therefore,
\[
L_{FFS} \leq L_{PD} \quad \text{if and only if} \quad \frac{p_I}{(L_{FFS})_I^2} \leq \bar{d}.
\]
The term $\bar{d}$ on the right-hand side does not depend on $\gamma$. As for the fraction term on the left-hand side, its derivative with respect to $\gamma$ is
\[
\left[ \frac{p_I}{(L_{FFS})_I^2} \right]'_{\gamma} = -\frac{p_I(L_{FFS})'' \cdot (\partial I^*/\partial \gamma)}{(L_{FFS})_I^2}. \tag{5}
\]
Since $\partial I^*/\partial \gamma < 0$ the monotonicity of (5) as a function of $\gamma$ is determined by the convexity of $L(\cdot, \bar{D})$. When $L(\cdot, \bar{D})$ is concave it is a decreasing function of $\gamma$ and when $L(\cdot, \bar{D})$ is convex it is an increasing function.

Thus three options are possible. If $\frac{p_I}{(L_{FFS})_I^2}$ is greater (less) than $\bar{d}$ for every $\gamma$, then for all hospitals the LOS will decrease (increase) after the reform. Clearly, if the per diem rate is too low, all hospitals find it profitable to discharge patients earlier; on the other hand, if the per diem rate is too high, all hospitals prefer to keep patients for as long as possible. The most interesting case arises for intermediate values of $\bar{d}$, when there exists $\gamma_0$ such that $\frac{p_I}{(L_{FFS})_I^2}_{|\gamma=\gamma_0} = \bar{d}$. Then the hospital’s response depends on $\gamma$ and convexity of $L$ as summarized in the Table below:

<table>
<thead>
<tr>
<th>$L$ is concave</th>
<th>$\gamma &lt; \gamma_0$</th>
<th>$\gamma &gt; \gamma_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{FFS}$</td>
<td>$&gt; L_{PD}$</td>
<td>$&lt; L_{PD}$</td>
</tr>
<tr>
<td>$L$ is convex</td>
<td>$&lt; L_{FFS}$</td>
<td>$&gt; L_{FFS}$</td>
</tr>
</tbody>
</table>

The intuition is as follows. Consider, for example, the case when $L(\cdot, \bar{D})$ is a convex function. Look at a hospital with high $\gamma$ so that $L$ and, by convexity, $L'_I$ are low. Under the PD system, the marginal cost should always equal to $\bar{d}$ which is the marginal revenue. Under the FFS the marginal cost is $\gamma g'(L)L'_I$. If a hospital decides to choose the $L_{PD}$ under the FFS then its marginal cost is $\bar{d}L'_I$ and because of convexity of $L$ it is low. Therefore, under the FFS for hospitals with higher $\gamma$ it is optimal to choose $L$ greater than $L_{PD}$ because the marginal cost, $\bar{d}L'_I$, is lower and the marginal benefit, $p_I$ is the same.

**Proposition 1** When the reimbursement rule changes from the fee-for-service to the per-diem PPS it will have the following impact on the LOS. If per diem rate is too low (high) all hospitals will decrease (increase) the length of treatments. For intermediate values of the per diem rate the response will be heterogeneous. When the LOS is a concave function of increasing inputs then hospitals with high pre-reform LOS (and low $\gamma$) will decrease the LOS as the results of the reform; hospitals with low pre-reform LOS will increase the LOS.
In the empirical section we establish that hospitals’ response is heterogeneous and is consistent with $L$ being a concave function of $I$: the average length of stay increases for hospitals with lower pre-reform ALOS and increases for hospitals with higher ALOS.

We illustrate Proposition 1 with the following stylized example. Let $\gamma \sim U[1, 3]$, $g(L) = L^4$ and $L(I, D) = \sqrt{I - D + 1}$, so that $L$ is a concave function of $I$. Assume that $p_I = 2$ and $p_D = 1$ and that $\bar{D} = 1$. Then the cost function under the FFS system is

$$2I + D - \gamma \cdot (I - D + 1)^2.$$ 

The optimal level of $D$-inputs equals to $\bar{D}$ which is 1. The optimal level of $I$-inputs is given from the FOC, $I = \frac{1}{\gamma}$, and $LOS_{FFS} = \frac{1}{\sqrt{\gamma}}$. The average daily payment to a hospital with a given $\gamma$ is

$$\frac{p_DD + p_I I}{L(I, D)} = \frac{1 + 2 \cdot \frac{1}{\gamma}}{\frac{1}{\sqrt{\gamma}}},$$

and taking the average over all hospitals we get that $\bar{d} \approx 3.39$.

Under the PD system the maximization problem is

$$\bar{d}L - \gamma L^4.$$ 

From the first order condition we get that $L_{PD} = \sqrt[4]{\frac{\bar{d}}{4\gamma}}$. Figure 2 shows the lengths of stay under the FFS and the PD systems. As proved in Proposition 1 hospitals with longer LOS under the FFS decrease the LOS, whereas the effect is opposite for hospitals with shorter LOS.
3.1.3 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, which employs the step-down per diem rate (SDR).

Let \( \bar{L} \) denote the the average LOS under the FFS system. We assume that there are two per diem rates under SDR: 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.

The hospital’s profit function under the SDR is:

\[
\pi(L) = \begin{cases} 
q\bar{d}L - \gamma g(L) & \text{if } L \leq \alpha \bar{L} \\
(q\bar{d}) \cdot \alpha \bar{L} + \bar{d}(L - \alpha \bar{L}) - \gamma g(L) & \text{if } L > \alpha \bar{L}
\end{cases}
\] (6)

From (6), \( \pi(L) \) is a continuous function of \( L \), however, it has a kink at point \( L = \alpha \bar{L} \). 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 (6) and and \( L^*_2(\gamma) \) denote the unconstrained maximum of the second part of (6). Formally, \( L^*_1(\gamma) \) satisfies \( q\bar{d} = \gamma g'(L) \) and \( L^*_2(\gamma) \) satisfies \( \bar{d} = \gamma g'(L) \). Note that since \( (q\bar{d})\alpha \bar{L} \) does not depend on \( L \), \( L^*_2(\gamma) \) is equal to \( L_{PD}(\gamma) \) from the previous section.

It follows from the convexity of \( g \) that \( L^*_1(\gamma) > L^*_2(\gamma) \), and that both are decreasing functions of \( \gamma \). Let \( \gamma_2 \) be such that \( L^*_2(\gamma_2) = \alpha \bar{L} \) and \( \gamma_1 \) be such that \( L^*_1(\gamma_1) = \alpha \bar{L} \). Since \( L^*_i(\gamma) \) are decreasing functions we have that \( \gamma_2 < \gamma_1 \). Depending on the value of \( \gamma \) three cases are possible (see Figure 3):

i) when \( \gamma < \gamma_2 \) then \( L_{PD}(\gamma) = L^*_2(\gamma) > \alpha \bar{L} \). This is because if \( \gamma < \gamma_2 \) then \( L^*_1(\gamma) > L^*_2(\gamma) > L^*_2(\gamma_2) = \alpha \bar{L} \). The optimum of the second part is reached at point \( L^*_2 \) such that \( L^*_2 > \alpha \bar{L} \). It is the

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Figure 3: Graphical representation of hospital’s profit function for low, intermediate and high values of \( \gamma \).

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6In Section 7 we discuss the predictions of our theoretical model when it is expanded into a model with three per diem rates which is an exact analogue of Japanese per diem PPS with thresholds a, c, and d, as is shown on Figure 1.
global optimum because $\pi(L)$ is an increasing function for $L < \alpha L$. When $\gamma$ is low, introducing higher premium for shorter stay does not affect hospital’s behavior compared to the PD system. Intuitively, with low $\gamma$ the cost associated with LOS is small so that extra benefits from shorter stay are not sufficient to affect hospital’s behavior.

ii) when $\gamma_2 < \gamma < \gamma_1$ then the optimum is reached at $\alpha L$. For this range of $\gamma$’s the first function in $\{6\}$ is increasing and the second function is decreasing on their respective domains. Compared to the PD system, the LOS goes up, since $L^*_2(\gamma) < \alpha L$. For intermediate values of $\gamma$ 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.

iii) when $\gamma > \gamma_1$ then the maximum is reached at point $L^*_1(\gamma) < \alpha L$. For high values of $\gamma$, hospitals will try to discharge the patients before less favorable per-diem rate is being paid. The difference with previous case is that $\gamma$ is too high and is not worthwhile to keep patients until $\alpha L$ is reached. Importantly, as compared to the PD case the LOS still goes up. The main reason being that the marginal benefit for longer stay is higher, due to premium $q$, but the marginal cost is the same as under the PD.

The analysis above shows that the effect of introducing step-down rate, where initial per diem rate has a premium, has actually perverse incentives on hospitals as in almost all cases the LOS increases instead of going down. The Table below summarizes the effect of the change from PD to SDR reimbursement systems.

<table>
<thead>
<tr>
<th>Effect on LOS</th>
<th>$\gamma &lt; \gamma_2$</th>
<th>$\gamma_2 &lt; \gamma &lt; \gamma_1$</th>
<th>$\gamma &gt; \gamma_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{PD} = L_{SDR}$</td>
<td>$L_{PD} &lt; L_{SDR}$</td>
<td>$L_{PD} &lt; L_{SDR}$</td>
<td>$L_{PD} &lt; L_{SDR}$</td>
</tr>
</tbody>
</table>

It is well-documented that in Japan the ALOS is the highest among developed countries, which is why one of the reform’s goals was to provide incentives for quicker discharges. An important policy insight from our analysis is that having a higher per diem rate, whether for the entire stay or for some initial period, has an unambiguously opposite effect. Longer stays are more profitable for all hospitals.

The combined effect of the change from FFS to SDR reimbursement systems depends on the sizes of $FFS \rightarrow PD$ and $PD \rightarrow SDR$ effects, as well as on relation between $\gamma_0, \gamma_1$ and $\gamma_2$. To highlight the incentives that the $FFS \rightarrow SDR$ change generates for hospitals we look at the extreme cases of hospitals with very low and very high values of $\gamma$’s. For such hospitals the combined effect is summarized in the table below.

<table>
<thead>
<tr>
<th>$L$ is concave</th>
<th>low $\gamma$</th>
<th>high $\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{FFS} &gt; L_{SDR}$</td>
<td>$L_{FFS} &lt; L_{SDR}$</td>
<td>ambiguous</td>
</tr>
<tr>
<td>$L$ is convex</td>
<td>$L_{FFS} &lt; L_{SDR}$</td>
<td>$L_{FFS} &lt; L_{SDR}$</td>
</tr>
</tbody>
</table>

For example, consider a hospital with low $\gamma$, where low means $\gamma < \min\{\gamma_2, \gamma_0\}$, and assume $L$ is concave. The change to the PD system will decrease the LOS and introducing the premium with the SDR system will not affect it. Thus, the total change in LOS is negative and $L_{FFS} > L_{SDR}$.
On the other hand when \( \gamma \) is high so that \( \gamma > \max\{\gamma_1, \gamma_0\} \) then both a change to the \( PD \) system and the premium on the per diem rate as prescribed by \( SDR \) will lead to an increase in LOS. The total effect is, therefore, positive.

3.2 Quality

Although there is still a large inconsistency in economic research about 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 \textit{planned} readmission rate, assuming that there are strong personal relations and high degree of trust between doctor and patient (Muramatsu and Liang, 1996). Therefore, the patient would tolerate being discharged sick at the decision of the hospital. Moreover, the patient would seek the continuation of the inpatient care at the same hospital.

Planned readmission rate is in direct relation to the ALOS. Hospitals can use planned readmission to shorten the average length of stay since each readmission, even if the same patient is readmitted with the same diagnosis, is recorded and reimbursed as a separate instance. Needless to say, most common reasons for planned readmission are of medical nature. Nonetheless, we think it is important to understand hospital’s financial incentives regarding planned readmission and how the \( FFS \) and the \( SDR \) reimbursement systems affect these incentives.

The possibility of readmission changes 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 one would be the planned readmission. For simplicity, we assume that the decision regarding the a number of admissions is made in the beginning of the treatment.

If a hospital chooses to treat a patient with one admission its cost is \( \gamma g(L) \). If a hospital chooses to treat a patient with planned readmission and \( L_1 \) is the LOS during the first admission and \( L_2 \) is the LOS during the planned readmission, then hospital’s cost is \( \gamma g(L_1 + L_2) + F \). Here \( F \geq 0 \) is the fixed cost 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 we observe 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. Both \( L_1 \) and \( L_2 \) are functions of input combinations used by hospitals that is \( L_1 = L(I_1, D_1) \) and \( L_2 = L(I_2, D_2) \). Finally, in this section we restrict our attention to the case of \( L \) being a concave function of \( I \) which is consistent with the evidence from our data.

3.2.1 Fee-for-service system

First, we look at hospitals’ financial incentives to use planned readmission under the \( FFS \) system. Having the possibility of a readmission does not change the fact that it is strictly optimal for the
hospital to use as much $D$-inputs as possible. This is because under the FFS systems $D$-inputs reduce hospital’s cost associated with the duration(s) of stay, and, accordingly, increase hospital’s revenue. In what follows it will be convenient also to introduce inverse function $I(L, D)$ which is a convex function of $L$. Hospital’s profit then is

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

if a planned readmission is used. Without the readmission the profit is

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

The next proposition shows that under the FFS there are no financial incentives to use planned readmission. It immediately follows from the convexity of $I(L, \bar{D})$.

**Proposition 2** If $F \geq 0$ then planned readmission is suboptimal.

**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 $L_1 \geq L_2$. For a small $\epsilon \geq 0$ then $p_I(L_1 + \epsilon, \bar{D}) + p_I(L_2 - \epsilon) - \gamma g(L_1 + \epsilon + L_2 - \epsilon) - F > p_I(L_1) + p_I(L_2) - \gamma g(L_1 + L_2) - F$, which is a contradiction to $L_1$ and $L_2$ being optimal. The inequality follows from the convexity of $I(\cdot)$. Thus the two strict optima are $(L^*, 0)$ and $(0, L^*)$, and therefore to avoid cost $F$ it is optimal to use one readmission. \qed

### 3.2.2 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. Recall that under the step-down rate the reimbursement is as follows. There is a basic per diem rate $d$ which is augmented by factor $q > 1$ during initial $\alpha \bar{L}$ days. Without the planned readmission the profit is given by (6) and with the planned readmission it is

$$- F + \left\{ \begin{array}{ll}
q \bar{d} (L_1 + L_2) - \gamma g(L_1 + L_2) & \text{if } L_1, L_2 \leq \alpha \bar{L} \\
2(q \bar{d} + \alpha \bar{L} + \bar{d} (L_1 + L_2 - 2 \alpha \bar{L}) - \gamma g(L_1 + L_2) & \text{if } L_1, L_2 \geq \alpha \bar{L} \\
q \bar{d} L_j + (q \bar{d} + \alpha \bar{L} + \bar{d} (L_i - \alpha \bar{L}) - \gamma g(L_i + L_j) & \text{if } L_i > \alpha \bar{L} > L_j
\end{array} \right.$$  \hspace{1cm} (7)

Profit (7) is calculated under the assumption that the two admissions are treated and reimbursed independently of each other. That is, 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 $\bar{d}$. The first line in (7) corresponds to the profit when the length of both admission is short so that the hospital is reimbursed under the premium per-diem rate $q \bar{d}$. The second line corresponds to the case when both admissions are longer than $\alpha \bar{L}$ and end up receiving daily payment $\bar{d}$. The last line is hospital’s profit when one admission is long and another is short.

Let $\pi^1$ denote the optimal profit without the readmission and $\pi^2$ is the optimal profit with the readmission without the fixed cost $F$. Planned readmission is more profitable if and only if

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*In what follows “long” is a label for the LOS greater than $\alpha \bar{L}$ and “short” for the LOS shorter than $\alpha \bar{L}$.}
\( \pi^2 - \pi^1 > F \), 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 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 \( \gamma \), which means that hospitals with low \( \gamma \) have stronger incentives to use planned readmission than with high \( \gamma \). The immediate and testable corollary of this result is that hospitals with higher LOS, are more likely to start using planned readmission. 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 \( \alpha L \) days. However, as we show with the planned readmission hospitals can split treatment between two stays, thereby reducing the LOS per admission.

**Proposition 3** Let \( L^* \) be the optimal LOS without readmission and \( L_1^* \) and \( L_2^* \) be two LOS with planned readmission. Then

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

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

The proof of the proposition is somewhat technical and is given in the Appendix. The intuition, however, is straightforward. For hospitals with high \( \gamma \), the LOS has to be so short that with or without the planned readmission the per diem rate is \( q \bar{d} \) and thus there is no gain from using the planned readmission. For hospitals with low \( \gamma \), on the other hand, the gain is substantial as a long LOS can be split in two, thus doubling the number of days for which hospitals is compensated under the higher rate \( q \bar{d} \).

In the proof of Proposition 3 we consider five different cases, depending on the value of \( \gamma \). While the exact conditions that determine each \( \gamma \) range are specified in the Appendix; the Table below summarizes the effect on the LOS for each \( \gamma \)-range. Cases with lowers numbers correspond to higher values of \( \gamma \). The second column is the difference between the average length of stay with and without planned readmissions. Note that since each admission is considered and reported separately, the average length of stay will be the average of \( L_1^* \) and \( L_2^* \). The third column shows the difference in actual number of days that a patient would have to stay in the hospital.

<table>
<thead>
<tr>
<th>Case 1 (highest ( \gamma ))</th>
<th>( (L_1^* + L_2^<em>)/2 ) vs. ( L^</em> )</th>
<th>( L_1^* + L_2^* ) vs. ( L^* )</th>
<th>Planned Readmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 2</td>
<td>&lt;</td>
<td>&gt;</td>
<td>Yes</td>
</tr>
<tr>
<td>Case 3</td>
<td>=</td>
<td>&gt;</td>
<td>Yes</td>
</tr>
<tr>
<td>Case 3′</td>
<td>&lt;</td>
<td>&gt;</td>
<td>Yes</td>
</tr>
<tr>
<td>Case 4</td>
<td>&lt;</td>
<td>&gt;</td>
<td>Yes</td>
</tr>
<tr>
<td>Case 5 (lowest ( \gamma ))</td>
<td>&lt;</td>
<td>=</td>
<td>Yes</td>
</tr>
</tbody>
</table>

As one can see from the Table above, apart from a few exceptions, the financial incentives related to the planned readmission have undesirable effects. With exception of hospitals with the
highest $\gamma$ (and, therefore, shortest LOS), all hospitals prefer to use planned readmission. If planned readmission is used as a response to financial incentives, then for all but most extreme cases the total number of days the patient spends in a hospital goes up even though the recorded LOS, i.e. LOS per admission, declines. All these negative effects arise owing to the premium per diem rate during the initial stay, as hospitals have strong financial incentive to double the number of days for which they receive the premium rate.

### 3.3 Profit

We conclude the theoretical part of the paper with a simple comparison of hospital’s profitability under different reimbursement systems. First of all, for every $\gamma$ hospitals are better off under the SDR system than under the PD system. This is because the initial period under the SDR is reimbursed with a premium rate $q > 1$ and therefore $\pi_{\text{SDR}}(L) > \pi_{\text{PD}}(L)$ for every $L$. A possibility of using the planned readmission increases hospitals’ profit even further. This is because the planned readmission would be used by a hospital only if it is more profitable. Thus the only non-trivial comparison is between FFS and PD systems. Recall that under the PD system the per diem rate is determined based on the average daily payments under the FFS system, that is

$$d = E_\gamma \left( \frac{p_{PD}D + p_{I}I}{L(I, D)} \right).$$

Let $d(L)$ be the average daily payment that a given hospital receives under the FFS:

$$d(L) = \frac{p_{PD}D + p_{I}I}{L(I, D)}.$$

Thus we can rewrite the FFS maximization problem as

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

and the PD maximization problem is as before

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

Owing to the similarity of the two expressions above, we obtain the following result:

**Proposition 4** Let $L^*_{PD}$ denote the LOS in a given hospital under PD and $L^*_\text{FFS}$ denote the LOS in the same hospital under FFS.

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

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

**Proof.** Consider the first case:

$$\pi_{PD} = \tilde{d}L^*_{PD} - \gamma g(L^*_P) < d(L^*_{PD})L^*_{PD} - \gamma g(L^*_{PD}) \leq \pi_{\text{FFS}}.$$
profit under FFS has to be greater or equal than the profit the hospital can achieve using $L_{PD}^*$. For the second case

$$\pi_{FFS} = d(L_{FFS}^*)L_{FFS}^* - \gamma g(L_{FFS}^*) < dL_{FFS}^* - \gamma g(L_{FFS}^*) \leq \pi_{FFS},$$

which is similar to the first case.

As one could expect, the value of the average daily payment under the FFS relative to $d$ determines, whether the profit is higher under the PD or FFS. In particular, if the average daily payment under the FFS is less than $d$, a hospital benefits from the switch to the PD system.

Finally, we examine whether it is hospitals with low or high $\gamma$ that are likely to benefit from the PD. It follows from the Proposition above that the answer to this question depends on the function $d(\cdot)$ and, in particular its monotonicity as a function of $\gamma$. For instance, if $d(\cdot)$ is a decreasing function of $\gamma$, then it is hospitals with high $\gamma$ that are likely to suffer from the reform.

Taking the derivative of $d(L)$ with respect to $\gamma$ and looking at its sign, we obtain that

$$\text{sgn} \left( \frac{p_D\bar{D} + p_I I}{L(D, I)} \right) = \text{sgn} \left( \frac{p_D\bar{D} + p_I I}{L(D, I)} \right) \frac{\partial L^*}{\partial \gamma} = -\text{sgn} \left[ p_I(L(D, I)) - (p_D\bar{D} + p_I I)L'_{I} \right].$$

Re-arranging the terms we get

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

The expression in brackets is positive for concave $L$ and, therefore the sign of (8) depends on relative values of the first two positive terms and the third negative term. For example, when $L(\bar{D}, I) = I^*$ then the sign of (8) is negative at $I$ close to zero (corresponds to high $\gamma$ values) and positive for large $I$. This means that $d(L)$ is non-monotone and takes higher value at extremes, i.e. when $\gamma$’s are low or high, thereby implying that it is the hospitals with longest and the shortest ALOS that would suffer from the reform. More generally, in the case of concave $L(\bar{D}, \cdot)$ term $L'_{I}$ declines with $I$ and therefore (8) is likely to be positive for high values of $I$ (low values of $\gamma$), so that hospitals with the longest ALOS are likely to be hurt by the switch to the PD system.

4 Data

4.1 Sample

We employ a recently released administrative database from Japan’s Ministry of Health, Labor, and Welfare (Aug 16, 2012) on annual aggregated information for hospital’s patients, discharged in July-December of each corresponding year 2002-2011. The data are voluntarily sent to MHLW by hospitals, which plan to join the PPS reform. Hospitals may join the PPS reform after the trial

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footnote text

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period (normally after one or two years), may postpone the decision and continue submitting the data to the MHLW, or may choose to never join the reform and stop sending their data.

The annual files allow us to retrieve the full (i.e. two year) pre-PPS information only for hospitals, which joined the PPS in the year 2009.\(^9\) Merging MHLW’s annual files by hospital name (checking for the change of name due to restructuring, mergers, and closures), we construct an unbalanced panel of 684 such hospitals, which submit the data to MHLW since 2007. 566 hospitals introduced PPS in 2009, 33 hospitals – in 2010, and 14 hospitals – in 2011. The rest remained in the FFS system. Note that 14 FFS hospitals left the database in 2010 and 2 hospitals – in 2011.\(^{10}\)

Hospital characteristics (the binary variables for rural, emergency, 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 if the hospital is given accreditation by the beginning of the corresponding financial year.\(^{11}\) The MHLW (2012b) data are employed to create a binary variable, with unity value for hospitals, which received the status of designated hospital by the beginning of the financial year.\(^{12}\) We use financial data on hospital’s costs from the Ministry of Internal Affairs (The Yearbook of Local Government Enterprises, Hospitals, Vol.47-56, 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.\(^{13}\)

As the MHLW’s database does not provide the hospital ALOS and quality by each DPC, we use the aggregation at the level of MDCs. The Japanese MDCs are constructed on the basis of International Classification of Diseases (ICD), with occasional aggregation or disaggregation of certain diagnoses as explained in Table 2.\(^{14}\)

It should be noted that there were 16 MDCs in Japan before 2008. The 16th MDC, which

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\(^9\) 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 produces 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.

\(^{10}\) The distributions of ALOS for FFS hospitals that left the database and remained in the database are similar.

\(^{11}\) Since 1997, Japanese hospitals are given a third-party accreditation if they fulfill seven standards: 1) mission, policy, organisation and planning; 2) community needs; 3) medical care and medical care support systems; 4) nursing care; 5) patient satisfaction and safety; 6) administration; 7) specific standard for rehabilitation and psychiatric hospitals (Hirose et al. 2003).

\(^{12}\) Prefecture grants the status of a designated hospital to a local public hospital if it satisfies the following requirements: 1) has over 200 beds; 2) the share of patients referred from other facilities is over 60%; 3) shares its beds and expensive equipment (e.g. MRI, CT scanner) with other hospitals; 4) educates local health care officials; 5) has an emergency status. Designated local public hospitals receive a support of 10,000 yen per each admission.

\(^{13}\) Public hospitals in our sample include national (kokuritsu), prefectural (kenritsu, douritsu, furitsu), city (shimin, shiritsu), town (chouritsu), village (sonritsu), municipal (kouritsu) hospitals, as well as hospitals within the system of National Health Insurance (kucho) and the system for health care of workers (roudoushakenfukushikikou).

\(^{14}\) The Japanese MDC6 encompasses MDC6 and MDC7 in ICD, MDC11 incorporates MDC11 and MDC12 in ICD, MDC12 combines MDC13 and MDC14 in ICD, MDC13 includes MDC16 and MDC17 in ICD. At the same time, MDC9 in ICD is disaggregated into the Japanese MDC8 and MDC9.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Obs</th>
<th>Mean</th>
<th>St Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPS</td>
<td>=1 if joined PPS by corresponding financial year</td>
<td>3388</td>
<td>0.52</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
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<tr>
<td>beds</td>
<td>total number of beds</td>
<td>3388</td>
<td>294</td>
<td>169</td>
<td>30</td>
<td>1196</td>
</tr>
<tr>
<td>departments</td>
<td>total number of departments</td>
<td>3388</td>
<td>15</td>
<td>6</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>urban</td>
<td>=1 if urban hospital</td>
<td>3388</td>
<td>0.89</td>
<td>0.31</td>
<td>0</td>
<td>1</td>
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<tr>
<td>public</td>
<td>=1 if public hospital</td>
<td>3388</td>
<td>0.28</td>
<td>0.45</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>designated</td>
<td>=1 if granted the status of designated local public hospital by corresponding financial year</td>
<td>3388</td>
<td>0.08</td>
<td>0.27</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>accredited</td>
<td>=1 if given independent accreditation by Japan Council for Quality Healthcare</td>
<td>3388</td>
<td>0.62</td>
<td>0.49</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>emergency</td>
<td>=1 if emergency hospital</td>
<td>3388</td>
<td>0.84</td>
<td>0.37</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>university</td>
<td>=1 if university hospital</td>
<td>3388</td>
<td>0.02</td>
<td>0.13</td>
<td>0</td>
<td>1</td>
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<tr>
<td>mri_ct</td>
<td>=1 if has MRI or CT scanner</td>
<td>3388</td>
<td>0.93</td>
<td>0.25</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1: Descriptive statistics for the unbalanced panel in 2007-2011.

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 average length of stay and the number of planned readmissions (i.e., planned readmissions within 42 days after discharge). While the values of ALOS are available at the MDC-level, the database reports the prevalence of planned readmissions only at the hospital level. The MDC-level data are available only for three major reasons of planned readmissions: “Operation after preliminary tests”, “Planned operation or treatment”, and “Chemical and radioactive treatment”, which account for 72-82 percent of all planned readmissions. We impute the total number of planned readmissions for each MDC assuming that the share of these three reasons for planned readmissions is constant across all MDCs and equals to the hospital-level share.
Table 2: ALOS and readmission rate for each MDC in hospitals which implemented PPS in 2009.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MDC 1</td>
<td>Nervous system</td>
<td>21.3, 20.7, 20.5, 21.2, 21.5</td>
<td>0.069, 0.070, 0.073, 0.079, 0.088</td>
<td>80574, 81337, 83767, 85523, 128476</td>
</tr>
<tr>
<td>MDC 2</td>
<td>Eye</td>
<td>6.5, 6.3, 5.5, 5.3, 5.0</td>
<td>0.112, 0.112, 0.131, 0.057, 0.035</td>
<td>47409, 47820, 50548, 52583, 79781</td>
</tr>
<tr>
<td>MDC 3</td>
<td>Ear, nose, mouth and throat</td>
<td>8.2, 8.2, 7.6, 7.3, 7.4</td>
<td>0.024, 0.020, 0.016, 0.018, 0.012</td>
<td>48170, 47942, 44328, 47044, 66523</td>
</tr>
<tr>
<td>MDC 4</td>
<td>Respiratory system</td>
<td>18.3, 18.2, 17.7, 18.1, 17.9</td>
<td>0.206, 0.181, 0.182, 0.215, 0.211</td>
<td>151782, 152751, 157279, 161992, 257537</td>
</tr>
<tr>
<td>MDC 5</td>
<td>Circulatory system</td>
<td>15.7, 15.7, 14.8, 15.0, 15.1</td>
<td>0.201, 0.193, 0.212, 0.263, 0.264</td>
<td>117130, 121699, 126731, 128625, 201674</td>
</tr>
<tr>
<td>MDC 6</td>
<td>Alimentary, liver, biliary-tree, and pancreas</td>
<td>15.5, 15.0, 13.8, 13.7, 13.2</td>
<td>0.757, 0.778, 0.778, 0.837, 0.830</td>
<td>284884, 301330, 307847, 311295, 457503</td>
</tr>
<tr>
<td>MDC 7</td>
<td>Musculoskeletal system</td>
<td>21.5, 21.0, 19.8, 20.0, 20.0</td>
<td>0.141, 0.146, 0.143, 0.158, 0.158</td>
<td>60679, 64347, 65715, 62099, 90784</td>
</tr>
<tr>
<td>MDC 8</td>
<td>Skin and subcutaneous tissue</td>
<td>12.5, 12.5, 11.9, 13.2, 14.0</td>
<td>0.001, 0.003, 0.003, 0.010, 0.006</td>
<td>13409, 13714, 13088, 16068, 26553</td>
</tr>
<tr>
<td>MDC 9</td>
<td>Breast</td>
<td>14.3, 12.9, 11.6, 11.9, 11.7</td>
<td>0.110, 0.120, 0.106, 0.114, 0.103</td>
<td>14221, 14342, 14468, 14421, 20494</td>
</tr>
<tr>
<td>MDC 10</td>
<td>Endocrine, nutritional and metabolic system</td>
<td>17.7, 17.2, 16.5, 16.1, 16.2</td>
<td>0.014, 0.016, 0.014, 0.011, 0.012</td>
<td>38575, 38226, 36930, 39978, 56995</td>
</tr>
<tr>
<td>MDC 11</td>
<td>Kidney and urinary tract and male reproductive system</td>
<td>15.5, 15.6, 14.7, 14.7, 14.6</td>
<td>0.178, 0.168, 0.160, 0.175, 0.160</td>
<td>92332, 94784, 95955, 99673, 145604</td>
</tr>
<tr>
<td>MDC 12</td>
<td>Female reproductive system and puerperal diseases, abnormal pregnancy, and abnormal labor</td>
<td>12.3, 11.5, 11.0, 11.0, 10.8</td>
<td>0.295, 0.293, 0.254, 0.271, 0.246</td>
<td>75637, 77857, 76984, 79182, 115559</td>
</tr>
<tr>
<td>MDC 13</td>
<td>Blood and blood forming organs and immunological disorders</td>
<td>24.6, 23.7, 23.5, 23.3, 23.2</td>
<td>0.085, 0.079, 0.095, 0.098, 0.091</td>
<td>20935, 22239, 25651, 26814, 40644</td>
</tr>
<tr>
<td>MDC 14</td>
<td>Newborn and other neonates, congenital anomalies</td>
<td>11.4, 10.6, 10.7, 10.4, 10.2</td>
<td>0.018, 0.018, 0.020, 0.021, 0.020</td>
<td>23835, 24921, 24709, 26107, 38720</td>
</tr>
<tr>
<td>MDC 15</td>
<td>Pediatric diseases</td>
<td>7.8, 8.1, 8.0, 7.7, 7.7</td>
<td>0.001, 0.0003, 0.001, 0.001, 0.0002</td>
<td>27695, 24880, 18428, 22927, 34820</td>
</tr>
<tr>
<td>MDC 16</td>
<td>Trauma, burns, poison</td>
<td>19.3, 18.5, 18.4, 18.9</td>
<td>0.031, 0.031, 0.039, 0.039</td>
<td>87445, 88390, 94220, 145001</td>
</tr>
<tr>
<td>MDC 17</td>
<td>Mental diseases and disorders</td>
<td>12.8, 12.0, 10.8, 8.6</td>
<td>0.0004, 0.0003, 0.0001, 0.00002</td>
<td>2298, 1730, 1443, 2341</td>
</tr>
<tr>
<td>MDC 18</td>
<td>Other</td>
<td>18.9, 17.6, 22.2, 22.2, 23.3</td>
<td>0.066, 0.018, 0.019, 0.015, 0.012</td>
<td>109221, 18104, 20344, 22692, 34509</td>
</tr>
</tbody>
</table>

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 18.
5 Empirical specification

Our theoretical model gives predictions about length of stay for a patient with a given DPC. Given data availability, the empirical analysis deals with the hospital-level data, and therefore, the testable hypotheses are formulated in terms of the average length of stay.

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

5.1 Hypotheses

H1: The change from a fee-for-service (FFS) to a per diem PPS with a step-down tariff (SDR), increases the ALOS in more efficient hospitals and reduces ALOS in less efficient hospitals.

H2: The change from a fee-for-service (FFS) to a per diem PPS with a step-down tariff (SDR), increases the prevalence of planned readmissions in hospitals with longer ALOS.

5.2 Dynamic panel data model

In our analysis we estimate two models, both based on the following specification:

\[ y_{it} = \alpha_0 + \alpha_1 y_{i,t-1} + \alpha_2 y_{i,t-1} \cdot PPS_{it} + \alpha_3 PPS_{it} + \delta X_{it} + \nu_i + \varepsilon_{it}, \]  

(9)

Here, \( PPS_{it} \) is the reform dummy which equals unity if hospital introduced PPS in year \( t \), \( X_{it} \) are hospital control variables, \( \nu_i \) are fixed effects, \( \varepsilon_{it} \) are i.i.d. with zero mean. The dependent variable, \( y_{it} \), is ALOS of hospital \( i \) in period \( t \) for the first specification, and planned readmission rate of hospital \( i \) in period \( t \) for the second specification. We assume that there is “attraction point” \( \mu \) so that the effect of the PPS reform depends on whether \( y_{it} \) is greater than \( \mu \) or not. In other words, the effect of the PPS reform for hospitals with the pre-reform value of \( y_{it} \) greater (smaller) than \( \mu \) monotonically approaches the effect for hospitals with \( y_{it} \) equal to \( \mu \) “from above” (“from below”).

For convenience we estimate an equivalent specification

\[ y_{it} = \alpha_0 + \alpha_1 y_{i,t-1} + \alpha_2 y_{i,t-1} \cdot PPS_{it} + \alpha_3 PPS_{it} + \delta X_{it} + \nu_i + \varepsilon_{it}, \]  

(10)

where \( \alpha_0 = \mu(1 - \alpha_1) \) and \( \mu = -\alpha_3/\alpha_2 \). The identification condition for the existence of the attraction point (i.e., the fact that \( y_{it} \) follows an AR(1) process) is \( 0 < \alpha_1 < 1 \). Given the identification condition holds, the significance of \( \mu \) implies the presence of an attraction point. In particular, in case of the specification with ALOS, the estimated value of \( \mu \) may be contrasted to
the actual values of the thresholds of a piece-wise tariff. If an additional condition \(0 < \alpha_1 + \alpha_2 < 1\) holds, then the attraction point does not change with time (i.e. in the pre-PPS and post-PPS period).

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. Consequently, \(PPS_{it}\) must be regarded as a predetermined variable, too. The time-varying hospital controls in \(X_{it}\) are accreditation dummy and designated hospital dummy. Equation (10) is estimated using Arellano–Bover (1995)/Blundell–Bond (1998) estimator 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. When included in (10), annual dummies proved to be insignificant for most MDCs. Therefore, we do not use time dummies as regressors in our empirical analysis.

We estimate model (10) for each MDC with \(y\) being equal to ALOS or planned readmission rate. Recall that the theoretical parameter of heterogeneity \(\gamma\) is inversely related to ALOS (i.e., hospitals with the shortest ALOS proxy hospitals with the highest \(\gamma\)). Therefore, to test for heterogeneity of hospitals’ response we divide all hospitals into four quartiles based on their ALOS in the pre-reform year (2008). We study the changes in the fitted values of the dependent variable in the \(k\) post-reform years and the pre-reform year. More precisely, for each \(k = 1, \ldots, 3\) let \(D_{y_{i,k}} = \sum_{s=1}^{k} \hat{y}_{i,t+s} - \hat{y}_{i,t}\), where \(\hat{y}\) is the fitted value of the corresponding dependent variable, \(y\), i.e. ALOS or planned readmission rate, estimated in (10) and \(t = 2008\). If \(H1\) holds, \(D_{ALOS_{i,k}}\) is positive for the lower quartiles of ALOS and negative for the upper quartiles of ALOS. If \(H2\) holds, \(D_{planned\ readmission\ rate,i,k}\) is positive for the highest quartile of ALOS.

To check robustness of the analysis with the panel data in assessing \(H1\) and \(H2\), we measure \(D_{ALOS_{i,k}}\) and \(D_{planned\ readmission\ rate,i,k}\) by estimating cross-section analogues of equations (10) for each \(t = 2009, 2010, 2011\). The cross-section specification enables incorporating time-invariant hospital characteristics in \(X_{it}\), which are differenced out in the estimations with dynamic panel data.

6 Results

6.1 Average length of stay

The results of our estimations reveal that the identification condition for dynamic panel data analysis holds for the specification when \(y\) is the average length of stay: \(\alpha_1\) belongs to the interval \(15\) Which is more efficient than Arellano–Bond (1991) estimator.

\(16\) Except for MDC6 in case of the regression with planned readmission rate.

\(17\) In case of the hospital-level analysis (the analysis for the average of all MDCs) and for MDC 4 we estimate the dynamic panel with the first differences of ALOS. Therefore, the fitted value of the dependent variable in 2008 is undefined. Consequently, we construct the quartiles based on the actual values of ALOS in 2008.

22
Table 3: Dynamic panel data estimations with ALOS as the dependent variable.

Note: In case of all MDCs and MDC4 the table reports the results of the estimations for the first differences of \( y_{i,t} \) and \( y_{i,t-1} \), since the process in levels proved to be non-stationary.

(0, 1) for fourteen MDCs out of fifteen. Furthermore, it is significant at 0.01 level for thirteen MDCs, which means that the attraction point, \( \mu \), exists for each of those MDCs. The sum \( \alpha_1 + \alpha_2 \) belongs to the interval (0, 1) and is statistically significant for eleven MDCs out of fifteen. Arguably, for the remaining four MDCs the "attraction point" varies over time. Estimated values for \( \alpha_1 \), \( \alpha_2 \) as well as of the attraction point \( \mu \) are given in Table 3.

Table 4 reports estimated changes in ALOS for hospitals that introduced PPS in 2009. As mentioned earlier, hospitals are sorted based on their ALOS in 2008 so that hospitals in quartile 1 are those with the shortest ALOS. For each MDC and for the average of all MDCs the values of \( D_{ALOS,i,k} \) are positive in the lower quartiles of ALOS and negative in the upper quartiles. This is consistent with \( H1 \) regarding a differential response of hospitals to the introduction of the PPS reform. The results indicate that the values of \( D_{ALOS,i,k} \) are higher in the lower quartiles of ALOS and lower in the upper quartiles for the average of all MDCs and for each MDC, which is consistent with \( H1 \) regarding heterogeneity in the change of hospital’s ALOS. As for the robustness check, we conducted cross-section calculations and discovered that the values of \( D_{ALOS,i,k} \) are positive in the lower quartiles of ALOS for 10 out of 15 MDCs; and are negative in the highest quartile for each MDC as well as for the average of all MDCs. Therefore, the results of the cross-section analysis correspond to the predictions of \( H1 \).

It should be noted that our result with the aggregated data (MDC-level data) corresponds to the finding about larger reduction in ALOS in hospitals with larger pre-reform ALOS with the data for patients with the same diagnosis (Nawata and Kawabuchi 2012).

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18 Statistical insignificance is found for MDCs 8, 9, 10 and 15.
19 Statistical significance is found for MDCs 1, 3, 4, 5, 7, 8, 9, 13, 14 and 15.
Table 4: Changes in ALOS for hospitals that introduced PPS in 2009. Hospitals are sorted based on their ALOS in 2008. Quartile 1 corresponds to the shortest ALOS and quartile 4 to the longest.
6.2 Planned readmission rate

The estimations of (10) with planned readmission rate as the dependent variable (Table 5) indicate that the identification condition for dynamic panel data analysis holds for the average of all MDCs as well as for ten MDCs out of fifteen. The attraction point, \( \mu \), exists for the average of all MDCs and for eight MDCs out of fifteen. Finally, the sum \( \alpha_1 + \alpha_2 \) belongs to the interval \((0, 1)\) and is statistically significant for the average of all MDCs and eight MDCs out of fifteen.

<table>
<thead>
<tr>
<th>Hospitals</th>
<th>( \alpha_1 )</th>
<th>( \alpha_2 )</th>
<th>( \alpha_1 + \alpha_2 )</th>
<th>( \mu )</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDC 1</td>
<td>0.308*** (0.081)</td>
<td>-0.031 (0.076)</td>
<td>0.277*** (0.077)</td>
<td>0.237 (0.525)</td>
</tr>
<tr>
<td>MDC 2</td>
<td>0.302** (0.120)</td>
<td>-0.281*** (0.101)</td>
<td>0.021 (0.062)</td>
<td>0.115*** (0.041)</td>
</tr>
<tr>
<td>MDC 3</td>
<td>0.275*** (0.089)</td>
<td>-0.416*** (0.093)</td>
<td>-0.142 (0.037)</td>
<td>0.013*** (0.007)</td>
</tr>
<tr>
<td>MDC 4</td>
<td>0.069 (0.055)</td>
<td>0.026 (0.059)</td>
<td>0.095** (0.053)</td>
<td>0.136 (0.371)</td>
</tr>
<tr>
<td>MDC 5</td>
<td>0.296*** (0.052)</td>
<td>-0.030 (0.048)</td>
<td>0.266*** (0.043)</td>
<td>1.373 (2.051)</td>
</tr>
<tr>
<td>MDC 6</td>
<td>0.553*** (0.070)</td>
<td>-0.426*** (0.070)</td>
<td>0.127*** (0.047)</td>
<td>0.804*** (0.029)</td>
</tr>
<tr>
<td>MDC 7</td>
<td>0.122** (0.061)</td>
<td>-0.100 (0.070)</td>
<td>0.022 (0.054)</td>
<td>0.262** (0.125)</td>
</tr>
<tr>
<td>MDC 8</td>
<td>-0.002 (0.003)</td>
<td>0.196 (0.282)</td>
<td>0.194 (0.283)</td>
<td>-0.020 (0.033)</td>
</tr>
<tr>
<td>MDC 9</td>
<td>0.579*** (0.138)</td>
<td>-0.405*** (0.149)</td>
<td>0.174** (0.082)</td>
<td>0.069*** (0.019)</td>
</tr>
<tr>
<td>MDC 10</td>
<td>0.003 (0.044)</td>
<td>-0.165* (0.092)</td>
<td>-0.161 (0.082)</td>
<td>0.013 (0.015)</td>
</tr>
<tr>
<td>MDC 11</td>
<td>0.113* (0.067)</td>
<td>-0.158** (0.073)</td>
<td>-0.045 (0.045)</td>
<td>0.178*** (0.060)</td>
</tr>
<tr>
<td>MDC 12</td>
<td>0.316*** (0.050)</td>
<td>-0.179*** (0.060)</td>
<td>0.137*** (0.049)</td>
<td>0.098 (0.091)</td>
</tr>
<tr>
<td>MDC 13</td>
<td>0.167* (0.094)</td>
<td>-0.049 (0.100)</td>
<td>0.118** (0.070)</td>
<td>0.435 (0.799)</td>
</tr>
<tr>
<td>MDC 14</td>
<td>0.097 (0.162)</td>
<td>0.377** (0.160)</td>
<td>0.474*** (0.100)</td>
<td>0.031** (0.018)</td>
</tr>
<tr>
<td>MDC 15</td>
<td>0.005 (0.004)</td>
<td>-0.363*** (0.021)</td>
<td>-0.359*** (0.020)</td>
<td>0.002** (0.001)</td>
</tr>
<tr>
<td>all MDCs</td>
<td>0.878*** (0.051)</td>
<td>-0.250** (0.099)</td>
<td>0.628 (0.068)</td>
<td>0.051*** (0.004)</td>
</tr>
</tbody>
</table>

Table 5: Dynamic panel data estimations with planned readmission rate as the dependent variable. \( D_{\text{planned readmission rate},\, i,k} \) is positive in the highest quartile of ALOS in case of the average of all MDCs as well as for thirteen out of fifteen MDCs (exceptions are MDCs 3 and 12). We observe a significantly positive increase for the average of all MDCs in 2009-2011; for nine MDCs in 2009, ten MDCs in 2010, and eleven MDCs in 2011. This may be interpreted as the proof of \( H2 \). The results of cross-section estimations similarly indicate that \( H2 \) holds for the average of all MDCs and for most MDCs.

Note that the MDC-level estimations with the planned readmission rate are based on the assumption that the share of the three reasons for planned readmission is the same for all MDCs. The assumption is justified exclusively by the desire to conduct reasonable approximation in the absence of available data. In particular, the assumption is likely to be questionable for MDC 12 "Female reproductive system, abnormal pregnancy", which would not have many planned readmissions, and they should not be for chemical and radioactive treatment. Overall, since we can not quantitatively assess the assumption, the MDC-level results with planned readmission rate may be treated only as tentative findings.

\[20\] Exceptions are MDC4, MDC8, MDC10, MDC14, and MDC15.
Table 5: Changes in the planned readmission rate for hospitals that introduced PPS in 2009.

<table>
<thead>
<tr>
<th></th>
<th>quartile 1</th>
<th>quartile 2</th>
<th>quartile 3</th>
<th>quartile 4</th>
<th>quartile 1</th>
<th>quartile 2</th>
<th>quartile 3</th>
<th>quartile 4</th>
<th>quartile 1</th>
<th>quartile 2</th>
<th>quartile 3</th>
<th>quartile 4</th>
<th>quartile 1</th>
<th>quartile 2</th>
<th>quartile 3</th>
<th>quartile 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>all</strong></td>
<td>0.0024***</td>
<td>0.0040***</td>
<td>0.0031***</td>
<td>0.0012**</td>
<td>0.0037**</td>
<td>0.0013***</td>
<td>0.0064***</td>
<td>0.0013**</td>
<td>0.0047***</td>
<td>0.0012**</td>
<td>0.0056***</td>
<td>0.0015**</td>
<td>0.0037***</td>
<td>0.0013**</td>
<td>0.0069***</td>
<td>0.0014**</td>
</tr>
<tr>
<td><strong>MDC1</strong></td>
<td>0.0031</td>
<td>0.0032</td>
<td>0.0083**</td>
<td>0.0030**</td>
<td>0.0003</td>
<td>0.0035**</td>
<td>0.0048</td>
<td>0.0044**</td>
<td>0.0033</td>
<td>0.0032**</td>
<td>0.0041**</td>
<td>0.0003**</td>
<td>0.0027</td>
<td>0.0044**</td>
<td>0.0003**</td>
<td>0.0049**</td>
</tr>
<tr>
<td><strong>MDC2</strong></td>
<td>-0.0160**</td>
<td>-0.0160**</td>
<td>-0.0023</td>
<td>-0.0066**</td>
<td>0.0023</td>
<td>0.0058**</td>
<td>-0.0154**</td>
<td>-0.0007**</td>
<td>-0.0172**</td>
<td>-0.0079**</td>
<td>0.0055**</td>
<td>0.0007**</td>
<td>0.0025</td>
<td>0.0061**</td>
<td>0.0008**</td>
<td>0.0175**</td>
</tr>
<tr>
<td><strong>MDC3</strong></td>
<td>-0.0307**</td>
<td>-0.0307**</td>
<td>-0.0055**</td>
<td>-0.0010**</td>
<td>0.0083**</td>
<td>0.0019**</td>
<td>-0.0295**</td>
<td>-0.0002**</td>
<td>-0.0029**</td>
<td>-0.0015**</td>
<td>0.0059**</td>
<td>0.0018**</td>
<td>0.0097**</td>
<td>0.0016**</td>
<td>0.0043**</td>
<td></td>
</tr>
<tr>
<td><strong>MDC4</strong></td>
<td>0.0038**</td>
<td>0.0058**</td>
<td>0.0007</td>
<td>0.0024**</td>
<td>0.0005</td>
<td>0.0027**</td>
<td>0.0098**</td>
<td>0.0024**</td>
<td>0.0072**</td>
<td>0.0027**</td>
<td>0.0049**</td>
<td>0.0020**</td>
<td>0.0244**</td>
<td>0.0028**</td>
<td>0.0248**</td>
<td></td>
</tr>
<tr>
<td><strong>MDC5</strong></td>
<td>0.0036**</td>
<td>0.0036**</td>
<td>0.0015**</td>
<td>0.0006**</td>
<td>0.0030**</td>
<td>0.0054**</td>
<td>0.0478**</td>
<td>0.0056**</td>
<td>0.0372**</td>
<td>0.0011**</td>
<td>0.0432**</td>
<td>0.0075**</td>
<td>0.0264**</td>
<td>0.0047**</td>
<td>0.0531**</td>
<td></td>
</tr>
<tr>
<td><strong>MDC6</strong></td>
<td>0.0002**</td>
<td>0.0002**</td>
<td>0.0012**</td>
<td>0.0006**</td>
<td>0.0008**</td>
<td>0.0013**</td>
<td>0.0064</td>
<td>0.0015**</td>
<td>-0.0064**</td>
<td>0.0012**</td>
<td>0.0265**</td>
<td>0.0012**</td>
<td>0.0428**</td>
<td>0.0010**</td>
<td>0.0656**</td>
<td></td>
</tr>
<tr>
<td><strong>MDC7</strong></td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0027**</td>
<td>0.0022**</td>
<td>0.0121**</td>
<td>0.0021**</td>
<td>0.0191**</td>
<td>0.0013**</td>
<td>0.0104**</td>
<td>0.0022**</td>
<td>0.0117**</td>
<td>0.0022**</td>
<td>0.0189**</td>
<td>0.0013**</td>
<td>0.0004</td>
<td></td>
</tr>
<tr>
<td><strong>MDC8</strong></td>
<td>0.0039**</td>
<td>0.0042**</td>
<td>0.0000**</td>
<td>0.0006**</td>
<td>0.0032**</td>
<td>0.0009**</td>
<td>0.0040**</td>
<td>0.0004**</td>
<td>0.0043**</td>
<td>0.0004**</td>
<td>0.0041**</td>
<td>0.0007**</td>
<td>0.0026**</td>
<td>0.0008**</td>
<td>0.0052**</td>
<td></td>
</tr>
<tr>
<td><strong>MDC9</strong></td>
<td>0.0024**</td>
<td>0.0011**</td>
<td>0.0018**</td>
<td>0.0083**</td>
<td>0.0045</td>
<td>0.0071**</td>
<td>0.0189**</td>
<td>0.0088**</td>
<td>0.0010**</td>
<td>0.0030**</td>
<td>0.0086**</td>
<td>0.0045</td>
<td>0.0026**</td>
<td>0.0086**</td>
<td>0.0045**</td>
<td>0.0066**</td>
</tr>
<tr>
<td><strong>MDC10</strong></td>
<td>-0.0162**</td>
<td>-0.0016**</td>
<td>-0.0012</td>
<td>-0.0010**</td>
<td>0.0013**</td>
<td>0.0004**</td>
<td>0.0028**</td>
<td>0.0010**</td>
<td>-0.0018**</td>
<td>0.0009**</td>
<td>0.0014**</td>
<td>0.0000**</td>
<td>0.0012**</td>
<td>0.0004**</td>
<td>0.0032**</td>
<td></td>
</tr>
<tr>
<td><strong>MDC11</strong></td>
<td>-0.0129**</td>
<td>-0.0023**</td>
<td>-0.0052**</td>
<td>-0.0025**</td>
<td>0.0006**</td>
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Table 5: Changes in the planned readmission rate for hospitals that introduced PPS in 2009.
7 Discussion

A number of theoretical approaches forecasts potential heterogeneity in hospital’s length of stay owing to the introduction of a per diem PPS. Yasunaga et al. (2006) argue that although the Japanese inpatient PPS decreases the mean ALOS for all participating hospitals, the reduction in ALOS occurs only in large hospitals, which deal primarily with surgical patients. A hint at explaining heterogeneous response of hospital’s ALOS to per diem PPS may be found in the hypothesis about longer LOS as a result of per diem rates set above marginal costs (Lave 2003; Frank and Lave 1989; Frank and Lave 1986). As for heterogeneity in hospital’s quality, Kondo and Kawabuchi (2012) suggest that key issues are the step-down tariff and the composition of diagnoses in a hospital. In particular, patients which require long treatment (e.g. rehabilitation after surgery owing to hip fractures) are opt to premature discharges owing to the incentives within the step-down per-diem inclusive payment. Consequently, the quality of care for such DPCs is likely to deteriorate.

In this paper we present a theoretical model, which explicitly incorporates the essential features of the per diem PPS with LOS-dependent step-down tariff, as implemented Japan. The empirical analysis confirms the predictions of the model about heterogeneous response of hospital’s ALOS and quality to the per diem PPS. Our results indicate that the average length of stay increases for more efficient hospitals and declines for less efficient hospitals, owing to change from a fee-for-service reimbursement to a per diem PPS. As for the planned readmission rate, it becomes more prevalent in the least efficient hospitals.

It should be noted that establishing diminishing rates with due incentives is a subtle task for a per diem PPS (Monrad Aas 1995). Using a simplified case of a per diem PPS with two steps and a degressive rate, we demonstrate that it contains incentives for an increase in ALOS in more efficient hospitals. Indeed, the marginal benefit of treating a patient in the first period (with the highest per diem rate) is larger than the marginal benefit in the potential case with a flat per diem rate in both periods. Therefore, the Japanese inpatient PPS makes hospitals raise their ALOS up till the end of the first period. Our finding is similar to Okamura et al.’s (2005) conclusion about a disincentive for a sharp decline in ALOS within the Japanese per diem tariff. In this regard, the average outcomes of Japanese inpatient PPS may be contrasted to those of the German PPS in late 1990s, where per diem rate is 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 to 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 to such case.

In 2012 in an attempt to fine-tune the step-down per diem rates, 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

\[21\] In this regard, Kuwabara et al. (2006) demonstrate that surgical procedures explain a large variation in resource use.
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 become beneficial for a social planner.

As we mentioned earlier, the actual reimbursement system in Japan has three per diem rates. The highest rate is paid during the first quartile of the ALOS, where the average for a given DPC is taken over all hospitals. The second per diem rate is paid until the length of stay reaches the ALOS, after which hospitals are reimbursed with the lowest per diem rate. The extension of our model from a two-step to a three-step per diem rate does not affect our results. According to the model, the LOS increases for most hospitals, owing to the premium coefficient \( q \), which is greater than 1. This coefficient raises the marginal benefit of a longer stay while the marginal cost is unaffected. Whether a hospital uses planned readmission or not, it has more incentives to take advantage of the higher initial per diem rate and, therefore, two premia \( q_1 > q_2 > 1 \) lead to a qualitatively similar results.

Finally, we should note the limitations of our analysis. First, we employ the MDC-level data and therefore, implicitly assume that the composition of DPCs within each MDC is the same in all analyzed hospitals. Second, our estimations with the MDC level planned readmission rate are based on an approximation and therefore, may be used only for tentative conclusions. Third, unavailability of the long time series data for the pre-reform years does not enable us to introduce time-trends in the estimations with dynamic panel data. Lastly, the fact that the Japanese DPC database contains the data only for those FFS hospitals which plan to employ PPS in the nearest future introduces a selection bias in the estimations. Therefore, our analysis of the effect for the quartiles of the reformed hospitals is based on an assumption that the bias is the same in each quartile.

8 Conclusion

The paper presents a theoretical model to compare hospital’s incentives 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; 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 patient’s stay. Our main focus is two-fold. First, we compare the hospital’s efficiency, proxied by the average length of stay. Second, we study hospital’s financial incentives to use a planned readmission as a response to different reimbursement rules and, in particular, as a way to reduce the hospital’s ALOS.

Our main results are as follows. We show that the introduction of any form of the per diem PPS (either with a flat or with a length-of stay dependent tariff), leads to a heterogeneity in hospital’s response. Under some technical assumptions specified in the paper, hospitals with the shortest ALOS under the FFS lengthen patients’ treatment under the PPS, and hospitals with the longest ALOS under the FFS reduce the length of treatment under the PPS. Contrary to the expectations,
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 the shorter ALOS under the SDR system, hospitals have incentives to use planned readmission to shorten the reported length of stay. This can be done, since each admission, whether repeated or not, is reimbursed on a separate basis. Most importantly, we show that it is hospitals with the longer ALOS under the FFS system have the strongest incentives to treat patients with planned readmissions.

Using a recently released administrative database for 684 Japanese hospitals in 2007-2011, we conduct estimations with dynamic panel data and find an empirical support for the predictions of the theoretical model. The majority of the 684 hospitals from our data joined the PPS reform in 2009-2011, which involved a change from the FFS to the SDR reimbursement systems. The results of the empirical analysis confirm theoretical predictions. We show that ALOS increases in more efficient hospitals (with shorter pre-reform ALOS), and decreases in less efficient hospitals (with longer pre-reform ALOS). Furthermore, planned readmission rate rises, particularly for hospitals with a longer pre-reform ALOS.

9 Appendix

Proof of proposition 3. 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 $\gamma$;

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

The former inequality is strict for hospitals with low $\gamma$. The latter inequality is strict for hospitals with intermediate values of $\gamma$.

Proof. First, it follows from (7) 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 only need to consider cases on the cases where either 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 $\gamma$. We start with hospitals with the highest $\gamma$.

1. $\gamma$ 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 $\gamma$ have no financial incentives to use planned readmission.
2. \( \gamma \) 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 inequalities mean that without readmission the optimal LOS is \( \alpha \bar{L} \) and \( L_1^* + L_2^* > \alpha \bar{L} \) since otherwise the optimal solution without readmission would be less than \( \alpha \bar{L} \). This shows that the LOS 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** When \( \gamma g' (2 \alpha \bar{L}) > q \bar{d} > \gamma g' (\alpha \bar{L}) > \bar{d} \) the profit difference with and without readmission is positive and is a strictly decreasing function of \( \gamma \).

**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 \( \gamma \) is \(- g (L_1^* + L_2^*)\). Since \( \alpha \bar{L} \) is a constant and does not depend on \( \gamma \) the derivative of the second term is \(- g (\alpha \bar{L})\). For the highest \( \gamma \) 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 \( \gamma \) we have \( L_1^* + L_2^* > \alpha \bar{L} \) and so \( \partial \Delta \pi / \partial \gamma \) is

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

Thus, \( \Delta \pi \) is a strictly decreasing function of \( \gamma \) which is equal to 0 at the upper limit of the interval and therefore is positive on the remaining part of the interval. ■

For lower values of \( \gamma \) two cases are possible. When we move away from Case 2 by decreasing \( \gamma \) either it \( \gamma g' (\alpha \bar{L}) \) 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. \( \gamma \) 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 this case the LOS is the same and equal to \( \bar{d} \bar{L} \), 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 \( \gamma \) 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 in the previous case, which is positive. Given that \( \Delta \pi \) is decreasing with \( \gamma \) it will remain positive as \( \gamma \) decreases.

3' Alternatively we consider the case when \( \gamma \) 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 readmission the
hospital would go for two short admissions. By the same logic as in case 2 we conclude that 

\[ 2\alpha L > L_1^* + L_2^* > \alpha L. \]

Furthermore, \( L_1^* + L_2^* > L^* \) because \( \gamma g'(L^*) = d < q\tilde{d} = \gamma g'(L_1^* + L_2^*) \). Thus, the LOS will decrease and the total number of days per case goes up. As for profit difference,

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

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

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

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

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

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

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

It does not depend on \( \gamma \) 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 \( q\tilde{d} \) twice rather than once and so hospitals have incentives to use planned readmission.

This concludes the proof of the Proposition. ■

References


