A comparison between two health care delivery systems using a spatial competition model approach
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ABSTRACT
Regional mal-distribution of healthcare providers such as hospitals and clinics is conspicuous in Japan. This study analyses whether Japan’s fee-for-service reimbursement system (FFSRS) or its diagnosis procedure combination/per-diem payment system (DPC/PDPS) is the better solution for the problem, with reference to the Hotelling-style spatial competition model. Under FFSRS, we also consider two modes of competition: the Stackelberg case, in which providers can control the number of hospital visits, and the Nash case, in which providers cannot do so. Results indicate that competition under DPC/PDPS is the most intensive of the three modes of competition. To relieve the locational concentration of providers, we also find that DPC/PDPS has a better mechanism than FFSRS.

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INTRODUCTION
Regional mal-distribution of healthcare providers such as hospitals and clinics is evident in Japan. The Survey on No-doctor Districts by the Ministry of Health, Labour and Welfare (MHLW) defines no-doctor districts as areas which have no health care providers with a radius of about 4 km and more than 50 residents whose access to health care providers outside the district is poor. According to the survey in 2014, Hokkaido, one of Japan’s least populated prefectures, has 138 no-doctor districts, the worst situation in any district documented, whereas four heavily populated prefectures (Tokyo, Osaka, Kanagawa and Chiba) have no such districts. The map in Figure 1 illustrates the spatial dimension of the problem in Hokkaido. To reduce this gap in accessibility across regions, it is suggested that the Japanese government should set a higher fee for health care service in underpopulated regions than in urban ones to attract more health care providers. In all likelihood, however, only an extraordinarily large difference in fees would result in improvements.

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One potentially more successful proposal is to devise health care delivery systems. The Japanese government employs two main health care delivery systems: the fee-for-service reimbursement system (FFSRS) and the diagnosis procedure combination/per-diem payment system (DPC/PDPS). Under FFSRS, the government sets a unit fee for every medical treatment and each provider decides the quality and/or quantity of medical treatments required for each patient. Under this system, especially when the market is highly competitive, providers tend to administer excessive medical treatments to patients in order to differentiate themselves — a phenomenon known as the medical arms race (Cromwell & Mitchell, 1986; Fuchs, 1978; Gruber & Owings, 1996). In contrast, under DPC/PDPS, partially employed in Japanese hospitals dealing with acute diseases, the government sets the per-diem fee for medical treatments of each diagnosis-related group, regardless of the quantity of treatment supplied. This system is aimed at reducing total medical costs by motivating providers to cut the quantity and/or quality of medical treatments for a patient just to make a profit. See Appendix B for a brief explanation of the public health care system in Japan. Employing the spatial competition model developed by Hotelling (1929), this study analyses how differences in modes of competition influence the locational patterns of health care providers in a geographically defined competitive market.

Several studies of competitive health care markets use Hotelling-style spatial competition models. Ma and Burgess (1993), Barros and Martinez-Giralt (2002), Ma (2003), Nuscheler (2003), Montefiori (2003, 2005), Brekke, Nuscheler, and Straume (2006), Sanjo (2009), Aiura (2013), and Kuchinke and Zerth (2015) analyse the competitive health care market by using the Hotelling-style model with quality choice. All these studies assume that each patient visits a health care provider only once and consumes one unit of health care. Patients are also free to choose their health care providers, and their choices are assumed to be influenced by the distance from

**Figure 1.** Spatial distribution of no-doctor districts in Hokkaido prefecture from Survey on No-doctor Districts, The Ministry of Health, Labour and Welfare, Japan, 2014. The number of no-doctor districts at every administrative district in Hokkaido is distinguished by using different colors.
the provider as well as the quality of treatment. Tay (2003) empirically shows that both distance and quality substantially influence patients’ choice of health care providers.

However, the assumption of patients visiting only once is not applicable to health care services such as dental care, physical check-ups, etc. In the case of such a service, patients visit a provider several times, and each physician controls the number of visits for each patient and the quantity of health care for one hospital visit (henceforth the density of health care service). In such a situation, the density of health care can be discriminated according to a patient’s cost of visit. In underpopulated areas, where the cost of travel to a hospital is extremely high, the density of health care tends to be high because patients save on their visit cost by accessing several treatments on one visit. Noguchi (2010) empirically shows that distance can increase the density of health care and decrease the number of visits for outpatient care in the Nakatonbetsu area of Hokkaido. Discriminating the density is also practical because physicians can see each patient’s health insurance card to find out about the patient’s address and visit costs.

Nishida and Yoshida (2006) describe the discrimination of the density. We consider the competitive locational equilibrium of (dental) clinics under FFSRS. In our two-stage decision tree, clinics determine their locations in the first stage and the density of medical treatments they will provide in the second stage. Patients and clinics maximize their profits/utilities by controlling the number of visits and their density, respectively. In this setting, we consider two cases: first, clinics set the density first and patients choose the number of visits after observing the density presented (the Stackelberg case), and second, both clinics and patients simultaneously decide the density and the number of visits, respectively (the Nash case). The Stackelberg case describes the situation in which physicians have superior knowledge about the treatments needed by their patients and can choose the density by anticipating its impact on the number of visits. The Nash case describes the situation in which patients have sufficient knowledge about their treatments and physicians no longer play a leading role in the decision-making process. Comparing these two modes of competition enables us to analyse how adequate knowledge about treatments for patients influences the competitive health care market.

In this study, we modify the model in Nishida and Yoshida (2006) to explain DPC/PDPS and compare the two systems in terms of the competitive locational points as well as the spatial distribution of the density of health care. We analyse total medical spending under some scenarios because rising expenditures for hospital care are of great concern in many developed countries. We also analyse providers’ profits to help understand the intensity of competition under each mode.

THE MODEL

We consider a Hotelling-type linear market expressed by a line segment $L = [0, 1]$. In market features, there exist duopolistic health care providers ($i = 0, 1$) who provide homogeneous services in locations denoted, respectively, by $x_0$ and $x_1$. We assume that the location of provider 0 is fixed at the endpoint of the market $x = 0$, and that provider 1 is located at the endpoint of the market $x = 1$. Patients are uniformly distributed along $L$ and the population of the city is denoted as 1. Let $q_i$ denote the quantity (density) of medical treatments by provider $i$. Let $v$ denote the number of hospital visits from a patient to a provider. Under this standard setting, we consider two alternative health care delivery systems: FFSRS and DPC/PDPS.

The model under FFSRS

A patient living at $x \in L$ consumes health care services in amount $vq_i$ and composite goods in amount $\epsilon$ and confronts the following utility maximization problem:

$$
\max_{v, \epsilon} u(vq_i, \epsilon) = \alpha \ln(vq_i) + (1 - \alpha) \ln(\epsilon), \quad 0 \leq \alpha \leq 1,
$$

subject to $p v q_i + \epsilon \leq Y - \nu_t$,
where $p$ is the co-payment rate, $Y$ is the patient’s income, $\phi_F$ is the unit fee for medical treatments on average, $t_i$ is the distance from the patient at $x$ to provider $i$, written as $|x_i - x|$, $\gamma$ is the transportation cost per distance and $\alpha$ is the parameter in the utility function. In the budget constraint, the price of composite goods is normalized to 1.

The first-order condition of the problem yields,

$$v(q_i, t_i) = \alpha Y \frac{p \phi_F q_i + \gamma t_i}{\rho \phi_F q_i + \gamma t_i}. \quad (1)$$

Subsequently, we obtain the indirect utility function of a patient as

$$V(q_i) = \alpha \ln \left( \frac{\alpha Y q_i}{p \phi_F q_i + \gamma t_i} \right) + \text{Const.}$$

Past studies of Hotelling’s quality choice model in health care markets assume that each patient has inelastic demand and consumes one unit of health care. However, we assume that each patient decides the number of visits $v$. In fact, patients living in under-populated areas where the travel cost to a hospital/clinic is extremely high face the choice of $v$.

Provider $i$ chooses the density of treatments $q_i(t_i)$ for the patient living at $x$ and maximizes its local profit function,

$$\max_{q_i(t_i)} \pi_i(q_i(t_i)) = v \phi_F q_i(t_i) - \beta v q_i^2(t_i), \quad (2)$$

subject to $\pi_i(q_i(t_i)) \geq \pi_{\text{min}}$, \quad (3)

where $\beta$ represents a cost parameter for providing a health care service. The term $\pi_{\text{min}}$ in Equation (3) represents the providers reservation profit. For simplicity, we assume $\pi_{\text{min}} = 0$.

We assume in Equation (2) that the marginal cost to produce the health care service increases linearly in $q$. If we consider that physicians’ working time accounts for a large percentage of $q$, the cost to provide care is approximately interpreted as the disutility of physicians. Since the marginal disutility of labour generally increases with the time spent on work, the assumption of a quadratic cost function in $q$ is acceptable. It is well-known that health care goods are labour-intensive. Moreover, several empirical studies of hospital cost functions can be found in Troels, Kim, Jannie, and Kjeld (2008) for Denmark and Morikawa (2010) for Japan. Morikawa (2010) reports that hospitals’ productivity is greater when they are bigger, although he does not deny that the cost function features increasing returns to scale when the size is small. We also assume in Equation (2) that the cost function is linearly increasing in $v$ because we do not consider cases in which waiting periods for patients are several years.

The first-order condition of Equation (2) yields the following response function of the provider:

$$q_i(t_i) = \frac{\phi_F}{2 \beta}. \quad (4)$$

The provider’s break-even point is written as follows:

$$\bar{q}_i(t_i) = \frac{\phi_F}{\beta}. \quad (5)$$

Hence, we consider two cases, the Stackelberg case in which only the clinics know the reaction functions of each patient and the Nash case, in which both the clinics and patients know each other’s reaction functions.
**The Stackelberg case**

In the Stackelberg case, provider $i$ determines $q_i(t_i)$, subject to the patient’s response function (Equation (1)), to maximize its own local profit function (Equation (2)). This situation can be summarized as a sequential game in which a provider determines $q_i(t_i)$ as a leader and a patient determines $v$ as a follower, given that $q_i(t_i)$ is determined by the provider. The density of treatments $q_i^e(t_i)$ and the number of visits $v(q_i^e(t_i), t_i)$ in the Stackelberg case are, respectively, determined as follows:

$$ q_i^e(t_i) = \frac{\gamma}{p\Phi_F} \left[ \frac{p\Phi_F^2}{\beta_\gamma} t_i - t_i \right] $$

and

$$ v(q_i^e(t_i), t_i) = \frac{\alpha Y}{\gamma \sqrt{\frac{p\Phi_F^2}{\beta_\gamma} t_i}}. $$

Equation (6) is a monotone increasing function with respect to distance $t_i$. This result shows that the density of medical treatments per visit should be large enough to compensate, in terms of utility, patients whose travelling costs are high.

We consider the strategic behaviours of providers and patients in the market in equilibrium, given the providers’ locations. We define the entry–preventing density of treatments,

$$ \hat{q}_i(t_i) \equiv \frac{t_i}{t_{i-1}} \phi_F, $$

as the minimal density of treatments at which provider $i$ goes into the red and ceases competition, as long as provider $i$ supplies Equation (7) to the patient at $x$. Each provider strategically decides its density of treatment for each patient at $x$, like in the spatial price-discrimination model in Hoover (1937). Each patient chooses the provider that brings him/her the utility $V(q_i(t_i)) \geq V(q_{-i}(t_i))$. The following Proposition 1 encapsulates the strategic behaviours of providers and patients in equilibrium in the Stackelberg case, as expressed by the spatial distributions of $q_i(x)$ and $v(x)$.

**Proposition 1:** In the Stackelberg case under FFSRS, the density of medical treatments in equilibrium is given by the following:

$$ q_i^{eq}(x) = \begin{cases} q_i^e(x) & (0 \leq x \leq r_0) \\ \hat{q}_i(x) & (r_0 \leq x \leq \frac{1}{2}) \\ 0 & (\frac{1}{2} \leq x \leq r_1) \\ 0 & (r_1 \leq x \leq 1) \end{cases} \quad q_i^1(1-x) = \begin{cases} 0 & (0 \leq x \leq r_0) \\ 0 & (r_0 \leq x \leq \frac{1}{2}) \\ \hat{q}_i^1(1-x) & (\frac{1}{2} \leq x \leq r_1) \\ q_i^1(1-x) & (r_1 \leq x \leq 1) \end{cases} $$

where $r_0 = \frac{aY + \sqrt{aY^2 + 4p\phi_F^2u}}{2p\phi_F}$ and $r_1 = \frac{-aY + \sqrt{aY^2 - 4p\phi_F^2u}}{2p\phi_F}$. The number of visits in equilibrium is given by the following:

$$ v^{eq}(x) = \begin{cases} \frac{\alpha Y}{\gamma \sqrt{\frac{p\Phi_F^2}{\beta_\gamma} x}} & (0 \leq x \leq r_0) \\ \frac{\alpha Y}{\gamma \sqrt{\frac{p\Phi_F^2}{\beta_\gamma} x}} \cdot \frac{1-x}{x} & (r_0 \leq x \leq \frac{1}{2}) \\ \frac{\alpha Y}{\gamma \sqrt{\frac{p\Phi_F^2}{\beta_\gamma} x}} \cdot \frac{r_0}{x} & (\frac{1}{2} \leq x \leq r_1) \\ \frac{\alpha Y}{\gamma \sqrt{\frac{p\Phi_F^2}{\beta_\gamma} x}} \cdot \frac{r_1}{1-x} & (r_1 \leq x \leq 1) \end{cases} $$
The Nash case

In the Nash case, provider $i$ determines $q_i(t_i)$, independent of the patient’s response function (Equation (1)), and yields Equation (4). This situation can be summarized as a Nash game in which a provider determines $q_i(t_i)$ and a patient simultaneously determines $v$. The density of treatments $q_i^N(t_i)$ and the number of visits $v(q_i^N(t_i), t_i)$ in the Nash case are, respectively, determined as follows:

$$ q_i^N(t_i) = \frac{\phi_F}{2\mu}, $$

and

$$ v(q_i^N(t_i), t_i) = \frac{\alpha Y}{\frac{\phi F}{2\mu} + \gamma t_i}. $$

We derive the following proposition on the relationship between the Stackelberg and the Nash cases.

**Proposition 2:**

(i) The relationship $q_i^S(t_i) < q_i^N(t_i)$, $v(q_i^S(t_i), t_i) > v(q_i^N(t_i), t_i)$ always holds.

(ii) For every patient at $x$, the medical spending in the Nash case always exceeds the spending in the Stackelberg case, $\phi_F q_i^S(t_i) v(q_i^S(t_i), t_i) < \phi_F q_i^N(t_i) v(q_i^N(t_i), t_i)$.

**Proof:** (ii) At every $x$, the medical spending for each patient $\phi_F q_i(t_i) v(q_i(t_i), t_i)$ is expressed by the monotone increasing function with respect to $q_i(t_i)$, written as $\phi_F \alpha Y q_i(t_i)/\left(\phi_F q_i(t_i) + \gamma t_i\right)$. Since $q_i^S(t_i) < q_i^N(t_i)$ from (i), we obtain $\phi_F q_i^S(t_i) v(q_i^S(t_i), t_i) < \phi_F q_i^N(t_i) v(q_i^N(t_i), t_i)$. □

In health care markets where the patients do not have enough knowledge about medical services, total medical spending under FFSRS, defined as $\phi_F \int_{0}^{1} v(x) q(x) dx$, becomes comparatively smaller from Proposition 2(ii).

In the Nash case as well, the strategic behaviours of providers and patients in equilibrium are given by the following proposition.

**Proposition 3:** In the Nash case, the density of medical treatments in equilibrium is given by the following:

$$ q_0^N(x) = \begin{cases} 
q_0^N(x) & \left(0 \leq x \leq \frac{1}{3}\right) \\
\hat{q}_0(x) & \left(\frac{1}{3} \leq x \leq \frac{1}{2}\right) \\
0 & \left(\frac{1}{2} \leq x \leq \frac{2}{3}\right) \\
0 & \left(\frac{2}{3} \leq x \leq 1\right)
\end{cases}, \quad 
q_1^N(1-x) = \begin{cases} 
0 & \left(0 \leq x \leq \frac{1}{3}\right) \\
\hat{q}_1(1-x) & \left(\frac{1}{3} \leq x \leq \frac{1}{2}\right) \\
q_1^N(1-x) & \left(\frac{2}{3} \leq x \leq 1\right)
\end{cases}, \quad (10) $$

The number of visits in equilibrium is given by the following:

$$ v^N(x) = \begin{cases} 
\frac{\alpha Y}{\gamma + \frac{\phi F}{2\mu}} & \left(0 \leq x \leq \frac{1}{3}\right) \\
\frac{\alpha Y}{\gamma + \frac{\phi F}{2\mu}} + \frac{1-x}{x} & \left(\frac{1}{3} \leq x \leq \frac{1}{2}\right) \\
\frac{\alpha Y}{\gamma + \frac{\phi F}{2\mu}} + \frac{1-x}{1-x} & \left(\frac{1}{2} \leq x \leq \frac{2}{3}\right) \\
\frac{\alpha Y}{\gamma (1-x) + \frac{\phi F}{2\mu}} & \left(\frac{2}{3} \leq x \leq 1\right)
\end{cases}. \quad (11) $$

Proof: See Appendix A.
Proof: See Appendix A.

The model under DPC/PDPS

For the model under DPC/PDPS, let $\phi_D$ denote the per-diem fee for medical treatment for a diagnosis-related group. In practice, the fee for health care treatments calculated under DPC/PDS is the sum of the fees based on bundled payment and fee-for-service payment. The part on bundled payment is calculated by multiplying the per-diem fee for medical treatment of a diagnosis-related group, the number of days in hospital, and the coefficient representing each hospital’s efficiency. In our model, we simplify the system and assume that DPC/PDPS is employed in clinics as well.

The utility maximization problem of a patient at $x$ under DPC/PDPS is as follows:

$$\max_v u(vq_i, c) = a \ln(vq_i) + (1 - a) \ln(c), \quad 0 \leq a \leq 1,$$

subject to $p\phi_D v + c \leq Y - vq_i t_i$.

The first-order condition and the patient’s indirect utility function under DPC/PDPS are respectively given by the following equations:

$$v^D(q_i, t_i) = \frac{aY}{p\phi_D + \gamma t_i},$$

and

$$V^D(q_i) = \alpha \ln \left[ \frac{aYq_i}{p\phi_D + \gamma t_i} \right] + \text{Const.}$$

On the other hand, the provider $i$’s local profit function under DPC/PDPS is written as follows:

$$\max_{q_i(t_i)} \pi^D_i(q_i(t_i)) = \phi_D v - \beta vq_i^2(t_i)$$

subject to $\pi^D_i(q_i(t_i)) \geq \pi_{\text{min}} = 0$, $q_i(t_i) \geq q_{D\text{min}}$.

The cost function to produce care in Equation (13) is quadratic in $q_i$ to facilitate comparison with FFSRS. The term $q_{D\text{min}}$ represents the minimum density of treatments to maintain the service. For simplicity, we assume $q_{D\text{min}} = 0$. We then obtain the first-order condition of the provider’s local profit maximization problem,

$$q^D_i(t_i) = q_{D\text{min}} = 0,$$

and the provider’s break-even point,

$$\widetilde{q}^D_i(t_i) = \sqrt{\frac{\phi_D}{\beta}} \geq q_{D\text{min}} = 0.$$  (14)

Under DPC/PDPS, there is no difference between the Stackelberg and Nash modes of competition because the results coincide. This outcome arises directly from the assumption that the quantity of health care services does not appear in patients’ budget constraints in Equation (12).

Under DPC/PDPS as well, we consider the strategic behaviours of providers and patients in equilibrium, given the provider’s location. The entry-preventing density of treatments under DPC/PDPS can be defined as

$$\widehat{q}^D_i(t_i) = \frac{p\phi_D + \gamma t_i}{p\phi_D + \gamma t_i - \beta} \sqrt{\frac{\phi_D}{\beta}}.$$
The following proposition is the result of strategic behaviours of health care providers and patients under DPC/PDPS expressed by the spatial distribution of \( q(x) \) and \( v(x) \).

**Proposition 4:** Under DPC/PDPS, the density of medical treatments in equilibrium is given by the following:

\[
q_0^D(x) = \begin{cases} 
\frac{\hat{q}_0^D(x)}{\hat{q}_0^D(1-x)} & \left( 0 \leq x \leq \frac{1}{2} \right) \\
0 & \left( \frac{1}{2} \leq x \leq 1 \right)
\end{cases},
\]

\[
q_1^D(x) = \begin{cases} 
0 & \left( 0 \leq x \leq \frac{1}{2} \right) \\
\frac{\hat{q}_1^D(1-x)}{\hat{q}_1^D(1-x)} & \left( \frac{1}{2} \leq x \leq 1 \right)
\end{cases}.
\] (15)

The number of visits in equilibrium is given by the following:

\[
v_0^D(x) = \begin{cases} 
\frac{aY}{p\phi_D+x} & \left( 0 \leq x \leq \frac{1}{2} \right) \\
\frac{aY}{p\phi_D+y(1-x)} & \left( \frac{1}{2} \leq x \leq 1 \right)
\end{cases}.
\] (16)

**Proof:** See Appendix A. \(\square\)

**MODEL ANALYSIS**

We now present the policy implications of our extended Hotelling model. To focus on key variables such as \( \phi_F, \phi_D \) and \( p \), we set \( \beta = 1, \gamma = 1 \) in the following analysis. Setting \( \beta = 1 \) preserves the generality of the analysis because the relative magnitude between \( \beta \) and \( \phi_F, \phi_D \) matters.

**Proposition 5:** The sufficient condition under which total medical spending under DPC/PDPS exceeds spending under FFSRS is as follows:

\[ \sqrt{\phi_D} > \phi_F. \]

**Proof:** Using Proposition 2, we notice that the total spending in the Nash case always exceeds that in the Stackelberg case. In Appendix A, we derive the sufficient condition under which total medical spending under DPC/PDPS exceeds that in Nash. \(\square\)

DPC/PDPS was originally intended to reduce total medical spending. However, Proposition 5 states that the objective can be accomplished only when the per-diem fee for medical treatment of a diagnosis-related group is comparatively small.

Example 1 Let \( p = 0.3, aY = 200 \text{ (¥10,000)} \) and \( \phi_F = 3.0 \text{ (¥10,000 per unit)} \). The total medical spending in the Stackelberg case amounts to 542.689 (¥10,000) and to 579.989 (¥10,000) in the Nash case. Under DPC/PDPS, the total medical spending amounts to 611.637 (¥10,000) when \( \phi_D = 9 \text{ (¥10,000 per day)} \) exceeding the amount under Nash. Figure 2 plots the total medical spending at each value of \( \phi_D \) under the three modes of competition. From the figure, we can confirm that the total medical spending under DPC/PDPS goes below that under Stackelberg when \( \phi_D \) is smaller than 3.406 (¥10,000 per day).
The case of a market with several competitors
We look at the case of a competitive health care market with \( n \) providers in the linear market. We assume that the two providers are located at both endpoints of the linear market and the remaining \( n-2 \) providers are equally spaced. In this setting, the interval between every two providers is \( \frac{1}{n-1} \).

When the number of providers in the market is \( n \), the total medical spending in the Nash case and its limiting value are given by the following:

\[
TMS_N(n) \equiv (n - 1) \cdot 2\phi_F \left[ \int_0^{\frac{1}{n-1}} \nu(q_0(x), x) \bar{q}_0(x) dx + \int_{\frac{1}{n-1}}^{\frac{1}{2}} \nu(q_0^N(x), x) \bar{q}_0^N(x) dx \right] \rightarrow \frac{\alpha Y}{p}, \quad \text{as } n \text{ goes to infinity.}
\]

In the Stackelberg case, as \( n \) increases, the region where \( q_0^S(x) \) is provided vanishes. Thus, the entry-preventing density is provided almost everywhere in the market. Total medical spending in the Stackelberg case for a finitely large \( n \) and its limiting value are given by the following:

\[
TMS_S(n) \equiv (n - 1) \cdot 2\phi_F \left[ \int_0^{\frac{1}{2}} \nu(q_0^S(x), x) \bar{q}_0^S(x) dx \right] \rightarrow \frac{\alpha Y}{p}, \quad \text{as } n \text{ goes to infinity.}
\]

Under DPC/PDPS, the total medical spending and its limiting value are as follows:

\[
TMS_D(n) \equiv (n - 1) \cdot 2\phi_D \left[ \int_0^{\frac{1}{2}} \nu^D(x) dx \right] \rightarrow \frac{\alpha Y}{p}, \quad \text{as } n \text{ goes to infinity.}
\]

Comparing the three outcomes, we notice that the mode of competition does not influence the total medical spending in a market with many providers.

**Proposition 6:** When the number of health care providers in the market is infinitely large, we obtain the following relation on total medical spending in the market:

\[
TMD_\delta(n) = TMD_N(n) = TMD_D(n) = \frac{\alpha Y}{p}.
\]
We analyse the model with \( n \) providers in terms of total profit defined by \( \int_0^1 \pi(x)dx \). In the Stackelberg case, the total profit function and its limiting value are as follows:

\[
\Pi_S(n) \equiv (n - 1) \cdot 2 \left[ \int_0^{\frac{1}{n+1}} \pi_0(\hat{q}_0(x))dx \right] - \frac{aY}{p} (2 - \ln 4), \quad \text{as } n \text{ goes to infinity.}
\]

In the Nash case, the total profit function and its limiting value are as follows:

\[
\Pi_N(n) \equiv (n - 1) \cdot 2 \left[ \int_0^{\frac{1}{n+1}} \pi_0(\hat{q}_0^N(x))dx + \int_{\frac{1}{n+1}}^{\frac{1}{n-1}} \pi_0(\hat{q}_0(x))dx \right] \\
- \frac{aY}{p} \left( 1 - 2 \ln \frac{4}{3} \right), \quad \text{as } n \text{ goes to infinity.}
\]

Under DPC/PDPS, the total profit function and its limiting value are

\[
\Pi_D(n) \equiv (n - 1) \cdot 2 \left[ \int_0^{\frac{1}{n+1}} \pi_0^D(\hat{q}_0^D(x))dx \right] \to 0, \quad \text{as } n \text{ goes to infinity.}
\]

We then obtain Proposition 7 regarding total profits.

**Proposition 7:** When the number of providers in the market is sufficiently large, we have the following relation concerning provider’s total profits:

\[
\Pi_S(n) > \Pi_N(n) > \Pi_D(n) = 0.
\]

From Proposition 7, we note that the competition under DPC/PDPS is the most intense of the three. It is difficult for providers under DPC/PDPS to enter the market as followers, considering the sunk costs. In addition, we also note that the limiting values of profits are influenced by the co-payment rate \( p \) and the patient’s expenditure \( aY \) and not by either \( \phi_F \) or \( \phi_D \) in the three cases. If \( p \) is small or \( aY \) is large, the profits under FFSRS increase.

Example 2 Let \( p = 0.3 \) and \( aY = 200 \) (¥10,000). Then, for sufficiently large \( n \), we obtain \( \Pi_S(n) = 409.137 \) (¥10,000) and \( \Pi_N(n) = 283.091 \) (¥10,000). The profit in the Stackelberg is \( \Pi_S(n)/\Pi_N(n) = 1.4452 \) times larger than that in the Nash, which is not influenced by any one of the parameters \( p, \phi_F, \) and \( aY \).

**Comparison of competitive locational equilibrium**

Let us suppose that the two providers plan to enter the linear market simultaneously. In the two-stage decision tree, the providers decide their location in the first stage and then decide the quantity of health care services they will provide in the second stage. Both patients and clinics maximize their utilities by controlling the number of visits and the density of the services, respectively. We analyse the locational points in equilibrium under FFSRS and DPC/PDPS. The total profit functions of the providers are so complex that we conduct simulations with respect to the key parameters, \( \phi_F, \phi_D, p, \gamma \) and \( \beta \). Without loss of generality, we assume that \( x_0 \leq x_1 \). Figures 3 and 4 summarize the results under FFSRS and DPC/PDPS, respectively.

**The results under FFSRS**

In the upper panel of Figure 3, we set \( aY = 4, \beta = 1, \gamma = 1 \) and \( p = 0.3 \) and plot the locational points in equilibrium at every parameter value of \( \phi_F \) from 0 to 3.0. We observe that the locational points in the case of Stackelberg, \( x_0^{S,*} \) and \( x_1^{S,*} \), are concentrated in the centre of the market as \( \phi_F \) increases. The
loca\nal points in the case of Nash, \( x_{1,N}^* \) and \( x_{2,N}^* \), are also concentrated in the centre of the market as \( \phi_F \) increases. Additionally, we observe that \( x_{0,S}^* \leq x_{0,N}^* \) and \( x_{1,S}^* \geq x_{1,N}^* \) in the market.

In the middle panel of Figure 3, we set \( \alpha Y = 4, \beta = 1, \gamma = 1, \) and \( \phi_F = 1.5 \) and plot the locational points at every \( p \) from 0 to 1.0. We observe the locational concentration in both cases as \( p \) increases. We also observe that \( x_{0,S}^* \geq x_{0,N}^* \) and \( x_{1,S}^* \leq x_{1,N}^* \) in the market.

**Figure 3.** Plot of locational points in equilibrium (FFSRS).
In the lower panel of Figure 3, we set $\alpha Y = 4$, $\gamma = 1$, $p = 0.3$, and $\phi_k = 1.5$ and calculate the locational points in equilibrium at every $\beta$ from 0 to 3.0. When $\beta$ is small, we observe the concentration in both cases. As $\beta$ becomes large, the locational points in equilibrium approach $1/3$ and $2/3$ in both cases. We also observe the relation, $x_0^* \geq x_0^*$ and $x_1^* \leq x_1^*$ in the market.

Figure 4. Plot of locational points in equilibrium (DPC/PDPS).
The result that FFSRS can bring about locational concentration is worthy of attention in that it does not happen in the spatial price discrimination model as in Hoover (1937). We also note that FFSRS does not generate the locational points 1/4 and 3/4, which are the outcomes in Hoover (1937).

The physical relationship between \( x_i^{S,*} \) and \( x_i^{N,*} \) is also noteworthy. It is difficult to explain the mechanism causing the outcome because several effects are intricately mixed. The Nash case is generally more desirable for patients in welfare, so this outcome can indicate the more desirable location for patients.

**The results under DPC/PDPS**

In the upper panel of Figure 4, we set \( \alpha Y = 4, \beta = 1, \gamma = 1, \) and \( \rho = 0.1, 0.2, 0.3, 1.0 \) and plot the locational points in equilibrium \( x_{D,0} \) and \( x_{D,1} \) at every \( \phi_D \) from 0 to 3.0. We observe that the concentration does not occur at every \( \phi_D \). We also observe that, as \( \phi_D \) increases, \( x_{D,0} \) and \( x_{D,1} \) approach 0.25 and 0.75, respectively, but very slowly. When \( \rho \) increases from 0.0 to 1.0, \( x_{D,0} \) and \( x_{D,1} \) shift toward 0 and 1 respectively at every parameter value of \( \phi_D \).

In the middle panel of Figure 4, we set \( \alpha Y = 4, \beta = 1, \gamma = 1, \phi_D = 1.0, 5.0, 10.0, 50.0 \) and plot the locational points in equilibrium at every \( \rho \) from 0.0 to 1.0. In the lower panel of Figure 4, we set \( \alpha Y = 4, \gamma = 1, \phi_D = 1.0, \) and \( \rho = 0.1, 0.2, 0.3, 1.0 \) and plot the locational points in equilibrium at every parameter value of \( \beta \) from 0.0 to 3.0. In both of the panels, we observe the same results as in the upper panel of Figure 4.

It should be noted that the speed at which \( x_{D,0} \) and \( x_{D,1} \) approach 0.25 and 0.75, respectively, is very slow in all the panels of Figure 4. We also observe the cases where the providers concentrate on the market center under FFSRS but not under DPC/PDPS. This result reveals that DPC/PDPS has a better mechanism to relieve the concentration of clinics, compared with FFSRS. This outcome is brought about by the fact that competition under DPC/PDPS is more intense than FFSRS.

**DISCUSSION**

In Japan, DPC/PDPS was introduced in 1998, and the Japanese government has increased the percentage of providers employing DPC/PDPS in stages. As of 1 July 2010, 1,391 hospitals operated under DPC/PDPS, and the number of sick beds under DPC/PDPS was 0.91 million, 50.4% of the total sick beds in Japan (MHLW, 2011). A consequence of this increase in DPC/PDPS providers is that the competition as measured in provider’s profit has become more intense under DPC/PDPS than under FFSRS. If we equate total spending on medical care in the market with the welfare of patients, the three modes of competition become irrelevant in the face of more intense competition.

Our model offers insights into the mal-distribution of healthcare providers in Japan. We use simulation and observe the locational concentration only under FFSRS. Because competition under DPC/PDPS is more intense as indicated in Proposition 7, providers under DPC/PDPS are incentivized to avoid locating near competitors, and locational dispersion is brought about. This result shows DPC/PDPS can help relieve the concentration of providers. Therefore, policy-makers are motivated to allow the clinics to employ DPC/PDPS as well as to increase the percentage of hospitals employing DPC/PDPS. See Appendix B for definitions of hospitals and clinics in Japan.

We also find insights from the model regarding how patient knowledge about medical treatments affects the results in equilibrium. FFSRS has two modes of competition, Stackelberg and Nash, whereas DPC/PDPS does not have such a difference. This means that knowledge about medical treatments does not matter under DPC/PDPS. In contrast, the mode of competition under FFSRS apparently affects the results. Although the complexity of the model makes it
difficult to clearly explain how patient knowledge affects outcomes under FFSRS, we can say that the outcome can be a benchmark of desirable location of providers for patients because the Nash case is generally more desirable for patients on welfare.

A fundamental assumption of our model is that each provider sets a different density for patients and discriminates patients based on location. Leaving legal and moral issues aside, this assumption may come across as very strong for readers unfamiliar with the Japanese health care delivery system. Noguchi (2010) empirically shows that the assumption holds true for out-patient services in underpopulated areas where travel costs are extremely high. Noguchi (2010) notes that such discrimination results either from providers seeking to maximize their profits (Stackelberg) or from patients trying to save on their visit costs (Nash), although she does not reveal which of the two happens in the target area. We also expect that some clinical departments in Japan, such as dentistry and otolaryngology, can explain the assumption even in urban areas. In general, it is difficult to differentiate the qualities of services in dentistry, so patients can improve their utility if they receive a number of services on one hospital visit. We hope our study can help cross-institutionally explain why such spatial discrimination of the density occurs.

The limitation of our study is that the patient’s utility in our model is influenced by the quantity of health care service that the patients receive from a provider, not necessarily by the level of the patients’ health. The point is whether DPC/PDPS can assure the level of health although it has the better mechanism to relieve locational concentration of providers. For further study, we want to reflect the level of health in our model and reveal how it affects the results.

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**APPENDIX 1**

**Sketch of the proof : Proposition 1**

By symmetry of the model, we consider the behaviour of health care provider 0. When $I(q_0(x)) \geq I(q_1(1-x))$ is satisfied, the patient at $x$ chooses the provider 0. This condition is summarized as follows, along with the feasibility condition Equation (5),

$$R_0(q_1(1-x), q_0(x)) = \begin{cases} (q_1(1-x), q_0(x)) & \frac{\phi_0}{\beta} > q_0(x) \geq \frac{x}{1-x} q_1(1-x), \quad 0 < q_1(1-x) - \frac{\phi_0}{\beta} \end{cases} \quad (A1)$$

Provider 0 gains the patient at $x$ if the combination $(q_1(1-x), q_0(x))$ in Equation (A1) is selected. The locational point of patients who are indifferent between both providers is $x = 1/2$ by symmetry of the model. Then at every $x$ in $[0, 1/2]$, provider 0 faces either of the two cases illustrated in Figure A1. Case 1 represents the situation $\hat{q}_0^*(x) > \hat{q}_1^*(x)$. In this case, as long as provider 0 provides $\hat{q}_0^*(x)$, it gains patients and maximizes its profit, regardless of the density of competitor. Case 2 represents the situation $\hat{q}_0^*(x) < \hat{q}_0^*(x)$. In this case, if provider 0 provides $\hat{q}_0^*(x)$ smaller than $\hat{q}_0^*(x)$, it loses patients because its competitor can provide $[(1-x)/x] q_1(x) + e (e \to 0)$. As long as provider 0 provides $\hat{q}_0^*(x) + e (e \to 0)$, its competitor can never gain the patients. The boundary point $r_1$ separating the two cases is given by $x$ satisfying $\hat{q}_0^*(x) = \hat{q}_0^*(x)$. Summarizing the conditions, we obtain Equations (8) and (9). \[\square\]
Sketch of the proof: Proposition 3
In the same manner as Proposition 1, provider 0 faces either of the two cases illustrated in Figure A2 at every patient’s location \( x \) in \([0, 1/2]\). Case 1 represents the situation \( q_N^0(x) > q_0^0(x) \). In this case, as long as provider 0 provides \( q_N^0(x) \), it earns the maximum profit, regardless of the density of competitor. Case 2 represents the situation \( q_N^0(x) < q_0^0(x) \). In this case, as long as provider 0 provides \( q_0^0(x) + \epsilon (\epsilon \rightarrow 0) \), its competitor can never get patients. The boundary point \( \eta_0 \) separating the two cases is given by the \( x \) satisfying \( q_0^0(x) = q_N^0(x) \). Summarizing the conditions, we obtain Equations (10) and (11). ♦

Sketch of the proof: Proposition 4
When \( V_D(q_0(x)) \geq V_D(q_1(1-x)) \) is satisfied along with the feasibility condition Equation (14), we obtain the domain illustrated in Figure A3,

\[
R_0 = \left\{(q_1(1-x), q_0(x)) \mid \sqrt{\frac{\Phi_D}{\beta}} > q_0(x) > \frac{p\Phi_D + \gamma x}{p\Phi_D + \gamma (1-x)} q_1(1-x), \ 0 = \tilde{q}_D < q_0(x) < \sqrt{\frac{\phi_D}{\beta}} \right\}, \tag{A2}
\]

meaning that provider 0 obtains the patient at \( x \) if the combination \((q_1(1-x), q_0(x))\) in Equation (A2) is chosen. The locational point of patients who are indifferent between both providers is \( x = 1/2 \) by symmetry of the model. In this case, if provider 0 provides \( q_0(x) \) smaller than \( \hat{q}_D \), it

**Figure A1.** Cases 1 and 2 in the Stackelberg case at the given point of \( x \). If a combination \((q_1(1-x), q_0(x))\) in the shaded area is chosen, the provider 0 obtains the patients.

**Figure A2.** Cases 1 and 2 in the Nash case at the given point \( x \). If a combination \((q_1(1-x), q_0(x))\) in the shaded area is chosen, provider 0 gains the patients.
loses patients because its competitor can provide \( \frac{(\phi_D + \gamma(1-x))q_D(x) + \epsilon}{\phi_D + \gamma(1-x)} q_1(1-x) \). As long as provider 0 provides \( \frac{q_D(x) + \epsilon}{\phi_D + \gamma(1-x)} q_0(x) \), its competitor can never obtain patients. Summarizing the conditions, we obtain Equations (15) and (16). \( \square \)

**Proof of Proposition 5**

Without loss of generality, we assume \( aY = 1 \). To satisfy

\[
\phi_Dv(q_D(x), x) - \phi_Fv(q_F(x), x) q_F(x) = \frac{\phi_D}{p\phi_D + x} - \frac{\phi_F}{p\phi_F + 2x} > 0
\]

at every \( x \) in \( [0,s_0), \sqrt{2\phi_D} > \phi_F \) is required. In contrast, to satisfy

\[
\phi_Dv(q_D(x), x) - \phi_Fv(q_F(x), x) q_F(x) = \frac{\phi_D}{p\phi_D + x} - \frac{\phi_F}{p\phi_F + (1-x)} > 0
\]

at every \( x \) in \( [s_0, 1/2], \sqrt{\phi_D} > \phi_F \) is required. Hence, the sufficient condition is \( \sqrt{\phi_D} > \phi_F \). \( \square \)

**APPENDIX B**

**On the public health care system in Japan**

Health care providers in Japan are roughly classified into two categories, hospitals and clinics. A hospital refers to a provider having more than 20 sickbeds, while a clinic refers to one with less than 19 sickbeds. As for hospitals, the Japanese government supervises the gross number of sickbeds in a geographic division of medical services to avoid regional mal-distribution of medical facilities. Because of this regulation, hospitals cannot freely enter into the market in practice if the upper limit of sickbeds established by the government has been reached in a particular district. However, as for clinics, there are no such regulations to control the gross number of sickbeds. Therefore, the entry or exit of clinics into the market is free in Japan.

The Japanese government employs FFSRS for the entire health care delivery system. Under FFSRS, a unit fee for every health care service is fixed by the Central Social Insurance Medical Council, the institution of the MHLW. It determines and revises the medical fee schedule every two years in the
light of actual cost and marketplace. Every health care provider can freely decide the type or quantity of health care service for patients. It has been indicated that health care providers have incentives to provide excess treatment to obtain more profit under FFSRS.

To address this problem, the introduction of DPC/PDPS has been discussed in Japan. DPC/PDPS was first introduced in 1998, and the percentage of providers employing DPC/PDPS has been increased in stages. Under this system, the per-diem fee for medical treatments of each diagnosis-related group is fixed by the government. The introduction of this system is intended to reduce medical cost spending in Japan. One flaw with this system is that it could lead to a loss in quality for health care services because providers under this system would have an incentive to employ the most cost effective alternative, and may not be concerned with the quality of the treatment.

These delivery systems are supported by the universal health care system under which every citizen is obliged to join one of the public health insurance organizations. Every citizen pays a premium to the organization and they can receive health care services by paying a copayment of the total medical fee for the health care provider. The remainder is paid by the insurance organization. The copayment rate depends on a patient’s age and income in principle. Simultaneously, patients are free to choose any health care providers to see a doctor. The pattern diagram in Figure B1 illustrates the health care delivery system in Japan.