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1 Introduction

In Japan, the uneven distribution of medical care facilities such as hospitals and clinics has been a major problem. This maldistribution of medical care facilities causes loss of welfare. In areas where the density of medical care facilities is less than that of patients, patients incur large transportation costs. However, in areas where the density of medical care facilities is greater than that of patients, competition between clinics becomes so fierce under a fee-for-service reimbursement system (FFSRS) that medical arms races between clinics occur. It is said that a medical arms race tends to generate more medical treatment than is necessary (e.g., Gruber and Owings 1996; Fuchs 1978; Cromwell and Mitchell 1986).

The Japanese government employs FFSRS as its medical delivery system. In an FFSRS, a unit fee for every medical treatment is fixed by the Japanese government and each clinic decides the quantity of medical treatments for each patient. Under this system, particularly when competition among clinics is fierce, clinics tend to have an incentive to supply more medical treatments per patient than is necessary from a medical perspective to secure profits. In contrast, the diagnosis procedure combination / per diem payment system (DPC/PDPS) is also partially employed in Japan. In this system, the fee for medical treatment per-diem is fixed by the Japanese government with respect to each diagnosis-related group. In principle, under this system, the fee for medical treatment per diem does not depend on the quantity of medical treatments supplied. This system helps to reduce the total medical costs because clinics tend to have an incentive to cut medical treatments for a patient, e.g., medical checkups, medicines and so on, to secure their profits. These two systems are totally different from each other in terms of their mechanisms for delivering medical care services.

To analyze the distribution of clinics in the market and welfare, Nishida and Yoshida (2006) consider the competitive locational equilibrium of (dental) clinics under FFSRS using an extended spatial competition model developed by Hotelling (1929) and d'Aspremont et al. (1979). In our two-stage decision tree, the clinics select their location in the first stage and then select the quantity of medical care services they will provide in the second stage. Both consumers and clinics maximize their utilities by controlling for the number of visits and the density of the services, respectively. We consider two cases, one in which only the clinics know the reaction function of consumers, namely, the Stackelberg case, and the other in which both clinics and patients know each others functions, namely, the Nash case. We conduct simulations with respect to the key parameters of utility functions and find that clinics not only concentrate at the center of the market but also locate at symmetrically separated points from the center of the market for both the Stackelberg and the Nash cases. We also find a case in which increasing the unit fee for service enhances consumer utility. This model is characteristic in that the consumers (patients) have elastic demand as in Smithies (1941), and the suppliers (clinics) quote a discriminating price to each consumer as in Kats (1987).

However, the model in Nishida and Yoshida (2006) addresses FFSRS and we have not found any model research that compares FFSRS to DPC/PDPS with respect to clinic locations. In this paper, we modify the spatial model in Nishida and Yoshida (2006) and consider DPC/PDPS as well as FFSRS to analyze how the two systems influence the distribution of clinics and patient and clinic welfare. We also analyze the fee for medical service discriminated between the populated and underpopulated areas to induce the location of clinics in the underpopulated area.

This paper is organized as follows. In Section 2, we present the spatial competitive model under FFSRS in Nishida and Yoshida (2006). In Section 3, we present the counter model to analyze DPC/PDPS. In Section 4, we make a comparison between FFSRS and DPC/PDPS with respect to location and welfare. In Section 5, we modify the models and analyze the discriminated fee for medical service to induce the new entry of clinics into the unpopulated area under both systems. In Section 6, we provide a discussion of the findings.

2 The model under FFSRS

We consider a Hotelling-type linear city expressed by a line segment $L = [0, 1]$. In the city, there exist duopolistic clinics ($i = 1, 2$) that provide homogeneous medical care service, and their locations are denoted by x_1 and x_2 ($x_1 < x_2$) without loss of generality. Patients are uniformly distributed on L and the population of the city is denoted as 1. Let q denote the amount of medical care services consumed by a patient. Let n denote the number of visits to a clinic by a patient.

A patient living at $x \in L$ consumes medical care services of the amount nq and composite goods of the amount c [1] and confronts the following utility maximization problem,

$$\begin{aligned} \max_{n} \ u(nq, c) \ &= \ \alpha \ln(nq) + (1-\alpha)\ln(c), \quad 0 \le \alpha \le 1, \\ \text{subject to} \quad & p\phi nq + c \le Y - n\gamma t_i, \end{aligned} \tag{1}$$

where p is the co-payment rate; Y is the patients income; ϕ is the unit fee for medical care service on average; t_i is the distance between the patient at x and the clinic i, written

[1] Assume that both q and c are measurable and continuous goods.

as $|x_i - x|$; γ is the transportation cost per distance and α is the parameter of the utility function. In the budget constraint, the price of the composite good is normalized to 1. The first order condition of the problem yields

$$n(q, t_i) = \frac{\alpha Y}{p\phi q + \gamma t_i}. \tag{2}$$

Subsequently, we obtain the indirect utility function of a patient

$$V(q) = \alpha \ln \left[\frac{\alpha Y q}{p\phi q + \gamma t_i}\right] + \text{Const}. \tag{3}$$

The clinic i chooses the density of medical care service $q(t_i)$ for the patient at x and maximizes its local profit function,

$$\begin{aligned} \max_{q(t_i)} \ \pi_i(q(t_i)) &= n\phi q(t_i) - \beta n q^2(t_i), \\ \text{subject to} \quad & \pi_i(q(t_i)) \geq \underline{\pi}, \end{aligned} \tag{4}$$

where β represents a cost parameter to provide medical care service. The term $\underline{\pi}$ in (4) represents the clinic's reservation utility. For the sake of simplicity, we assume $\underline{\pi} = 0$. The first order condition of the problem (4) yields the following response function of the clinic

$$q(t_i) = \frac{\phi}{2\beta}. \tag{5}$$

The break-even point of the clinic for the patient x is written as

$$\bar{q}(t_i) = \frac{\phi}{\beta}. \tag{6}$$

We consider two cases, one in which only the clinics know the reaction function of patients, namely, the case of "Stackelberg", and the other in which both clinics and patients know each others functions, namely, the case of "Nash".

In the Stackelberg case, the clinic determines $q(t_i)$, subject to the patient's response function (2), to maximize its own local profit function (4). This situation can be summarized as a sequential game, where a clinic determines $q(t_i)$ as a leader and a patient determines n as a follower, given the $q(t_i)$ determined by the clinic. Then, the density of medical care service in the Stackelberg case $q^S(t_i)$ and the number of visits in the Stackelberg case $n(q^S(t_i), t_i)$ are determined as

$$q^S(t_i) = \frac{\gamma}{p\phi}\left[\sqrt{t_i^2 + \frac{p\phi^2}{\beta\gamma}t_i} - t_i\right], \tag{7}$$

and,

$$n(q^S(t_i), t_i) = \frac{\alpha Y}{\gamma\sqrt{t_i^2 + \frac{p\phi^2}{\beta\gamma}t_i}}. \tag{8}$$

In the case of "Nash", the clinic determines $q(t_i)$, independent of the patient's responce function (2), and yields (5). This situation can be summarized as Nash game, where a clinic determines $q(t_i)$ and a patient simultaneously determines n. Then, the density of medical care service in the case of Nash $q^N(t_i)$ and the number of visits in the case of Nash $n(q^N(t_i), t_i)$ are respectively determined as,

$$q^N(t_i) = \frac{\phi}{2\beta}, \tag{9}$$

and,

$$n(q^N(t_i), t_i) = \frac{\alpha Y}{\frac{p\phi^2}{2\beta} + \gamma t_i}. \tag{10}$$

In both the Stackelberg and Nash cases, the duopolistic clinics simultaneously select their location x_i in the first stage of the game. In the second stage, the clinics simultaneously select their density of medical care services $q_i(t_i)$ for each patient. It should be noted that $q_i(t_i)$ depends on the distance $t_i = |x_i - x|$, so that the clinic chooses a different q_i for each patient. The game is solved by backward induction.

2.1 Spatial competition of clinics under FFSRS

We consider the spatial competition of clinics under FFSRS. In the second stage, when $V(q_i(t_i)) \geq V(q_{-i}(t_{-i}))$ is satisfied, the patient at x chooses the clinic i. This condition is summarized as follows, along with the feasibility condition (6),

$$R_i(q_2, q_1) = \left\{ (q_2, q_1) \middle| q_i(t_i) \geq \frac{t_i}{t_{-i}} q_{-i}(t_{-i}), \quad 0 < q_i(t_i), q_{-i}(t_{-i}) < \frac{\phi}{\beta} \right\}, \tag{11}$$

meaning that the clinic i obtains the patient at x if the combination (q_1, q_2) in (11) is chosen. We can also define the "entry-preventing" density of medical care treatment,

$$\widehat{q}_i(t_i) \equiv \frac{t_i}{t_{-i}}\frac{\phi}{\beta}, \tag{12}$$

which is the minimal density of medical care treatment before the clinic $-i$ goes in the red and relinquishes the competition, as long as clinic i supplies the treatment (12) to the patient at x.

In the Stackelberg case, the density of medical care treatment in equilibrium is given by

$$q_1^{S*}(|x_1 - x|) = \begin{cases} q_1^S(|x_1 - x|) & (0 \leq x \leq r_1) \\ \widehat{q}_1(|x_1 - x|) & (r_1 \leq x \leq \frac{x_1+x_2}{2}) \\ 0 & (\frac{x_1+x_2}{2} \leq x \leq r_2) \\ 0 & (r_2 \leq x \leq 1) \end{cases},$$

$$q_2^{S*}(|x_2 - x|) = \begin{cases} 0 & (0 \leq x \leq r_1) \\ 0 & (r_1 \leq x \leq \frac{x_1+x_2}{2}) \\ \widehat{q}_2(|x_2 - x|) & (\frac{x_1+x_2}{2} \leq x \leq r_2) \\ q_2^S(|x_2 - x|) & (r_2 \leq x \leq 1) \end{cases}, \tag{13}$$

where $r_1 = \frac{p\phi^2+2\beta\gamma x_1+4\beta\gamma x_2-\sqrt{(p\phi^2+2\beta\gamma x_1+4\beta\gamma x_2)^2-12\beta\gamma(p\phi^2 x_1+2\beta\gamma x_1 x_2+\beta\gamma x_2^2)}}{6\beta\gamma}$ satisfying $\hat{q}_1(t_1) = q_1^S(t_1)$, and $r_2 = \frac{-p\phi^2+2\beta\gamma x_2+4\beta\gamma x_1+\sqrt{(p\phi^2-2\beta\gamma x_2-4\beta\gamma x_1)^2-12\beta\gamma(-p\phi^2 x_2+2\beta\gamma x_1 x_2+\beta\gamma x_1^2)}}{6\beta\gamma}$ satisfying $\widehat{q}_2(t_2) = q_2^S(t_2)$. The number of visits in equilibrium in the Stackelberg case is given by

$$n^{S*}(x) = \begin{cases} \frac{\alpha Y}{\gamma\sqrt{|x_1-x|^2+\frac{p\phi^2}{\beta\gamma}|x_1-x|}} & (0 \leq x \leq r_1) \\ \frac{\alpha Y}{\gamma|x_1-x|+\frac{p\phi^2}{\beta}} & (r_1 \leq x \leq \frac{x_1+x_2}{2}) \\ \frac{\alpha Y}{\gamma|x_2-x|+\frac{p\phi^2}{\beta}} & (\frac{x_1+x_2}{2} \leq x \leq r_2) \\ \frac{\alpha Y}{\gamma\sqrt{|x_2-x|^2+\frac{p\phi^2}{\beta\gamma}|x_2-x|}} & (r_2 \leq x \leq 1) \end{cases}. \tag{14}$$

The total profit function for each clinic in the Stackelberg case is given by

$$\Pi_1^S(x_1, x_2)$$

$$
\begin{aligned}
&= \int_0^{r_1} \Big[\phi n \left(q_1^S(|x_1 - x|), |x_1 - x| \right) q_1^S(|x_1 - x|) \\
&\qquad\qquad - \beta n \left(q_1^S(|x_1 - x|), |x_1 - x| \right) \left(q_1^S(|x_1 - x|) \right)^2 \Big] dx \\
&\quad + \int_{r_1}^{(x_1+x_2)/2} \Big[\phi n \left(\widehat{q_1}(|x_1 - x|), |x_1 - x| \right) \widehat{q_1}(|x_1 - x|) \\
&\qquad\qquad - \beta n \left(\widehat{q_1}(|x_1 - x|), |x_1 - x| \right) \left(\widehat{q_1}(|x_1 - x|) \right)^2 \Big] dx,
\end{aligned}
$$

$$
\begin{aligned}
&\Pi_2^S(x_1, x_2) \\
&= \int_{(x_1+x_2)/2}^{r_2} \Big[\phi n \left(\widehat{q_2}(|x_2 - x|), |x_2 - x| \right) \widehat{q_2}(|x_2 - x|) \\
&\qquad\qquad - \beta n \left(\widehat{q_2}(|x_2 - x|), |x_2 - x| \right) \left(\widehat{q_2}(|x_2 - x|) \right)^2 \Big] dx \\
&\quad + \int_{r_2}^{1} \Big[\phi n \left(q_2^S(|x_2 - x|), |x_2 - x| \right) q_2^S(|x_2 - x|) \\
&\qquad\qquad - \beta n \left(q_2^S(|x_2 - x|), |x_2 - x| \right) \left(q_2^S(|x_2 - x|) \right)^2 \Big] dx. \qquad (15)
\end{aligned}
$$

In the Nash case, the density of medical care treatment in equilibrium is given by

$$
q_1^{N*}(|x_1 - x|) = \begin{cases} q_1^N(|x_1 - x|) & (0 \leq x \leq s_1) \\ \widehat{q_1}(|x_1 - x|) & (s_1 \leq x \leq \frac{x_1+x_2}{2}) \\ 0 & (\frac{x_1+x_2}{2} \leq x \leq s_2) \\ 0 & (s_2 \leq x \leq 1) \end{cases},
$$

$$
q_2^{N*}(|x_2 - x|) = \begin{cases} 0 & (0 \leq x \leq s_1) \\ 0 & (s_1 \leq x \leq \frac{x_1+x_2}{2}) \\ \widehat{q_2}(|x_2 - x|) & (\frac{x_1+x_2}{2} \leq x \leq s_2) \\ q_2^N(|x_2 - x|) & (s_2 \leq x \leq 1) \end{cases}, \qquad (16)
$$

where $s_1 = (2x_1 + x_2)/3$ satisfying $\widehat{q_1}(t_1) = q_1^N(t_1)$, and $s_2 = (x_1 + 2x_2)/3$ satisfying $\widehat{q_2}(t_2) =$

$q_2^N(t_2)$. The number of visits in equilibrium in the Nash case is given by

$$n^{N*}(x) = \begin{cases} \frac{\alpha Y}{\gamma|x_1-x|+\frac{p\phi^2}{2\beta}} & (0 \leq x \leq s_1) \\ \frac{\alpha Y}{\gamma|x_1-x|+\frac{p\phi^2}{\beta}} & (s_1 \leq x \leq \frac{x_1+x_2}{2}) \\ \frac{\alpha Y}{\gamma|x_2-x|+\frac{p\phi^2}{\beta}} & (\frac{x_1+x_2}{2} \leq x \leq s_2) \\ \frac{\alpha Y}{\gamma|x_2-x|+\frac{p\phi^2}{2\beta}} & (s_2 \leq x \leq 1) \end{cases}. \tag{17}$$

The total profit function for each clinic in the Nash case is given by

$$\begin{aligned} &\Pi_1^N(x_1,x_2) \\ &= \int_0^{s_1} \Big[\phi n\left(q_1^N\left(|x_1-x|\right), |x_1-x|\right) q_1^N\left(|x_1-x|\right) \\ &\qquad\qquad -\beta n\left(q_1^N\left(|x_1-x|\right), |x_1-x|\right)\left(q_1^N\left(|x_1-x|\right)\right)^2 \Big] dx \\ &\quad + \int_{s_1}^{(x_1+x_2)/2} \Big[\phi n\left(\widehat{q_1}\left(|x_1-x|\right), |x_1-x|\right) \widehat{q_1}\left(|x_1-x|\right) \\ &\qquad\qquad -\beta n\left(\widehat{q_1}\left(|x_1-x|\right), |x_1-x|\right)\left(\widehat{q_1}\left(|x_1-x|\right)\right)^2 \Big] dx, \\ &\Pi_2^N(x_1,x_2) \\ &= \int_{(x_1+x_2)/2}^{s_2} \Big[\phi n\left(\widehat{q_2}\left(|x_2-x|\right), |x_2-x|\right) \widehat{q_2}\left(|x_2-x|\right) \\ &\qquad\qquad -\beta n\left(\widehat{q_2}\left(|x_2-x|\right), |x_2-x|\right)\left(\widehat{q_2}\left(|x_2-x|\right)\right)^2 \Big] dx \\ &\quad + \int_{s_2}^{1} \Big[\phi n\left(q_2^N\left(|x_2-x|\right), |x_2-x|\right) q_2^N\left(|x_2-x|\right) \\ &\qquad\qquad -\beta n\left(q_2^N\left(|x_2-x|\right), |x_2-x|\right)\left(q_2^N\left(|x_2-x|\right)\right)^2 \Big] dx. \end{aligned} \tag{18}$$

In the first stage, each clinic chooses its location so as to satisfy the definition of Nash equilibrium,

$$\Pi_1(x_1^*, x_2^*) \geq \Pi_1(x_1, x_2^*), \quad \Pi_2(x_1^*, x_2^*) \geq \Pi_2(x_1^*, x_2), \tag{19}$$

in both the Stackelberg and Nash cases.

3 The model under DPC/PDPS

We consider the spatial competition of clinics under DPC/PDPS. Let the location of the clinic x_i be given. Under DPC/PDPS, the utility maximization problem of the patient at x is

$$
\begin{aligned}
\max_{n} \; u(nq_D, c) \;&=\; \alpha \ln(nq_D) + (1-\alpha)\ln(c), \quad 0 \le \alpha \le 1, \\
\text{subject to} \qquad & p\phi n + c \le Y - n\gamma t_i.
\end{aligned} \tag{20}
$$

The first order condition and the indirect utility function of the patient under DPC/PDPS are respectively

$$
\check{n}(q_D, t_i) = \frac{\alpha Y}{p\phi + \gamma t_i}, \tag{21}
$$

and

$$
V(q_D) = \alpha \ln\left[\frac{\alpha Y q_D}{p\phi + \gamma t_i}\right] + \text{Const.} \tag{22}
$$

However, the clinic i's local profit function under DPC/PDPS is written as

$$
\begin{aligned}
\max_{q_D(t_i)} \; \pi_i(q_D(t_i)) \;&=\; \phi n - \beta n q_D^2(t_i) \\
&=\; (\phi - \beta q_D^2(t_i))n \\
\text{subject to} \qquad & \pi_i(q_D(t_i)) \ge \underline{\pi}, \quad q_D(t_i) \ge \underline{q_D}.
\end{aligned} \tag{23}
$$

The term $\underline{q_D}$ represents the minimum density of medical care required to maintain service. For the sake of simplicity, we assume that $\underline{q_D} = 0$. Then, we obtain the first order condition of the clinic's local profit maximization problem,

$$
q_D(t_i) = \underline{q_D} = 0, \tag{24}
$$

and the break even point of the clinic,

$$
\bar{q}_D(t) = \sqrt{\frac{\phi}{\beta}} \ge \underline{q_D}. \tag{25}
$$

In the Stackelberg case under DPC/PDPS, the clinic determines $q_D(t_i)$, subject to the patient's response function (21), to maximize its own local profit function (23). Under DPC/PDPS, the density of medical care service $q_D^S(t_i)$ and the number of visits $n_D^S(t_i)$ in the Stackelberg case are, respectively,

$$q_D^S(t_i) = \underline{q_D} \tag{26}$$

and

$$n(q_D^S(t_i), t_i) = \check{n}(q_D^S(t_i), t_i). \tag{27}$$

In the Nash case under DPC/PDPS, the clinic determines $q_D(t_i)$, independent of the patient's response function (21) and yields (24). Then, the density of medical care service in the Nash case $q_D^N(t_i)$ and the number of visits in the Nash case $n(q_D^N(t_i), t_i)$ are determined as

$$q_D^N(t_i) = \underline{q_D}, \tag{28}$$

and,

$$n(q_D^N(t_i), t_i) = \check{n}(q_D^N(t_i), t_i). \tag{29}$$

It should be noted that there is no difference between Nash and Stackelberg under DPC/PDPS from (26), (27), (28) and (29).

3.1 Spatial competition of clinics under DPC

We consider the spatial competition of clinics under DPC/PDPS. In the second stage, when $V(q_{D,i}(t_i)) \geq V(q_{D,-i}(t_{-i}))$ is satisfied, the patient at x chooses clinic i. This condition is summarized as follows, along with the feasibility condition (25),

$$R_{D,i}(q_{D,2}, q_{D,1}) = \left\{ (q_{D,2}, q_{D,1}) \,\middle|\, q_{D,i}(t_i) \geq \frac{p\phi + \gamma t_i}{p\phi + \gamma t_{-i}} q_{D,-i}(t_{-i}), \quad 0 < q_{D,i}(t_i), q_{D,-i}(t_{-i}) < \sqrt{\frac{\phi}{\beta}} \right\}, \tag{30}$$

meaning that the clinic i obtains the patient at x if the combination $(q_{D,1}, q_{D,2})$ in (30) is chosen. We can also define the "entry-preventing" density of medical care treatment,

$$\widehat{q_{D,i}}(t_i) = \frac{p\phi + \gamma t_i}{p\phi + \gamma t_{-i}}\sqrt{\frac{\phi}{\beta}}, \tag{31}$$

as well as the case of FFSRS.

The density of medical care treatment in equilibrium is given by

$$\begin{aligned} q^*_{D,1}(|x_1 - x|) &= \begin{cases} \widehat{q_{D,1}}(|x_1 - x|) & (0 \leq x \leq \frac{x_1+x_2}{2}) \\ 0 & (\frac{x_1+x_2}{2} \leq x \leq 1) \end{cases}, \\ q^*_{D,2}(|x_2 - x|) &= \begin{cases} 0 & (0 \leq x \leq \frac{x_1+x_2}{2}) \\ \widehat{q_{D,2}}(|x_2 - x|) & (\frac{x_1+x_2}{2} \leq x \leq 1) \end{cases}. \end{aligned} \tag{32}$$

The number of visits in equilibrium in the case of DPC is given by

$$n^*_D(x) = \begin{cases} \frac{\alpha Y}{p\phi + \gamma t_1} & (0 \leq x \leq \frac{x_1+x_2}{2}) \\ \frac{\alpha Y}{p\phi + \gamma t_2} & (\frac{x_1+x_2}{2} \leq x \leq 1) \end{cases}. \tag{33}$$

The total profit function for each clinic is given by

$$\begin{aligned} &\Pi_{D,1}(x_1, x_2) \\ &= \int_0^{\frac{x_1+x_2}{2}} \left[\phi - \beta\left(q^*_{D,1}(|x - x_1|)\right)^2\right] n^*_D(x)dx \\ &= \int_0^{\frac{x_1+x_2}{2}} \left[1 - \left(\frac{p\phi + \gamma|x - x_1|}{p\phi + \gamma|x - x_2|}\right)^2\right] \frac{\phi\alpha Y}{p\phi + \gamma|x - x_1|}dx \\ &\Pi_{D,2}(x_1, x_2) \\ &= \int_{\frac{x_1+x_2}{2}}^1 \left[\phi - \beta\left(q^*_{D,2}(|x - x_2|)\right)^2\right] n^*_D(x)dx \\ &= \int_{\frac{x_1+x_2}{2}}^1 \left[1 - \left(\frac{p\phi + \gamma|x - x_2|}{p\phi + \gamma|x - x_1|}\right)^2\right] \frac{\phi\alpha Y}{p\phi + \gamma|x - x_2|}dx. \end{aligned} \tag{34}$$

In the first stage, each clinic chooses its location (x_1^*, x_2^*) to satisfy the definition of a Nash equilibrium.

4 Comparison Between FFSRS and DPC/PDPS

Spatial distribution of the density of medical care treatments

In Figure 1, we show the schematic diagrams that illustrate the spatial distribution of the density of medical care treatments determined in the second stage of the game. We observe that the higher density is quoted under every system at and around the middle point of the two clinics locational points.

Locational points in equilibrium under FFSRS

We show the locational points in equilibrium under FFSRS. The total profit function of the model is so complicated that we conduct simulations with respect to the key parameters, αY, ϕ, β, γ and p.

First, we set $\alpha Y = 4$, $\beta = 1$, $\gamma = 1$ and $p = 0.3$ and calculate the locational points in equilibrium at every parameter value for ϕ from 0 to 3.0. We plot the results in the upper left panel of Figure 4. We observe that the locational points in the Stackelberg case, $(x_1^{S,*}, x_2^{S,*})$, concentrate on the point $(1/2, 1/2)$ as ϕ increases. The locational points in the Nash case, $(x_1^{N,*}, x_2^{N,*})$, also concentrate on $(1/2, 1/2)$ as ϕ increases. We also observe that $(x_1^{S,*}, x_2^{S,*})$ falls outside of $(x_1^{N,*}, x_2^{N,*})$ in the market.

Second, we set $\alpha Y = 4$, $\beta = 1$, $\gamma = 1$ and $\phi = 1.5$ and calculated the locational points at each parameter value for p from 0 to 1.0. We plot the result in the upper right panel of Figure 4. We observe that $(x_1^{S,*}, x_2^{S,*})$ and $(x_1^{N,*}, x_2^{N,*})$ concentrate on $(1/2, 1/2)$ as p increases. We also observe that $(x_1^{N,*}, x_2^{N,*})$ falls outside of $(x_1^{S,*}, x_2^{S,*})$ in the market.

Third, we set $\alpha Y = 4$, $\beta = 1$ and $\phi = 1.5$ and calculated the locational points in equilibrium at each parameter value γ from 0 to 3.0. We plot the result in the lower left panel of Figure 4. We observe that both $(x_1^{S,*}, x_2^{S,*})$ and $(x_1^{N,*}, x_2^{N,*})$ shift toward $(1/3, 1/3)$ as γ increases. We also observe that $(x_1^{N,*}, x_2^{N,*})$ falls outside of $(x_1^{S,*}, x_2^{S,*})$ in the market.

Locational points in equilibrium under DPC/PDPS

We show the result of the simulation under DPC/PDPS. First, we set $\alpha Y = 4$, $\beta = 1$,

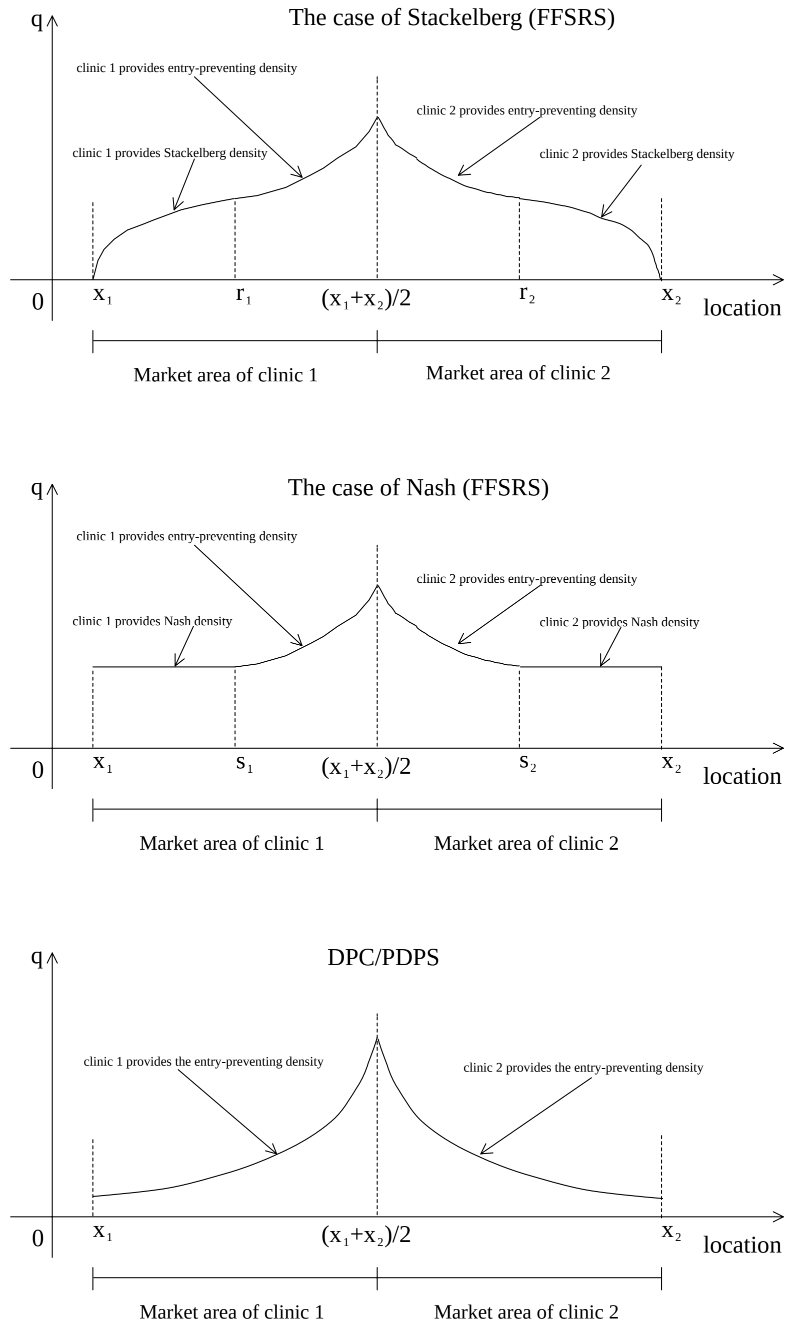

Figure 1: Spatial distributions of the density of the medical care treatments in equilibrium.

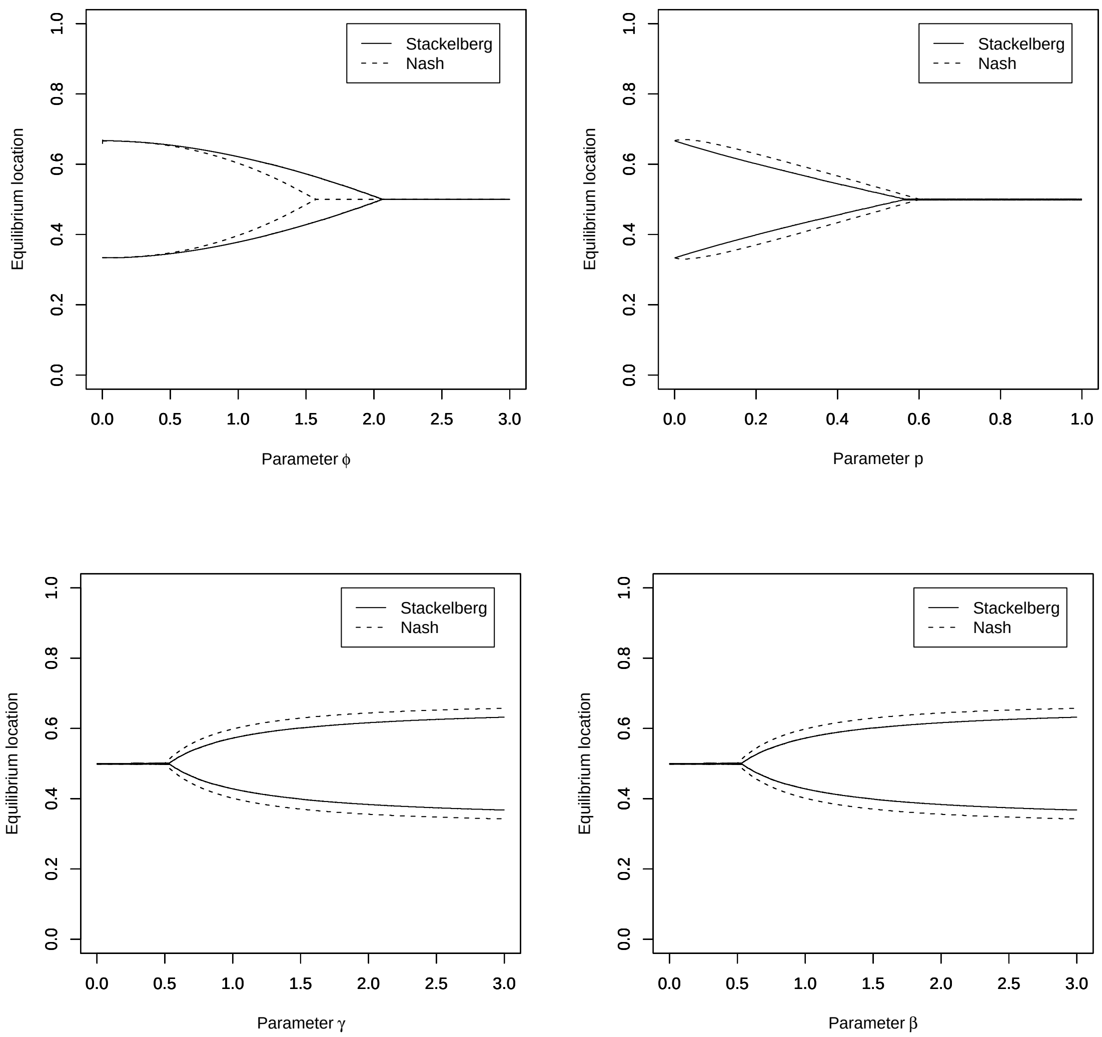

Figure 2: Plot of equilibrium location. (FFSRS)

$\gamma = 1$, $p = 0.1, 0.2, 0.3, 1.0$ and calculate the locational points in equilibrium $x^*_{D,1}$ and $x^*_{D,2}$ at every parameter value of ϕ from 0 to 5.0. We plot the result in the upper left panel of Figure 3. We observe that the clinics under DPC locate at symmetrically separated points for every ϕ from 0 to 5.0. We also observe that, as ϕ increases, $x^*_{D,1}$ and $x^*_{D,2}$ move toward the edges of the market and approach 1/4 and 3/4, respectively. When p increases from 0.0 to 1.0, $x^*_{D,1}$ and $x^*_{D,2}$ shift toward $x = 0$ and $x = 1$, respectively, for every parameter value of ϕ.

Second, we set $\alpha Y = 4$, $\beta = 1$, $\gamma = 1$, $\phi = 1.0, 5.0, 10.0, 50.0$ and calculate the locational points in equilibrium for every parameter value of p from 0.0 to 1.0. We plot the result in the upper right panel of Figure 3. We observe that the clinics under DPC locate at symmetrically separated points at every p from 0 to 1.0. We also observe that as p increases, the locational points $x^*_{D,1}$ and $x^*_{D,2}$ move toward the edges of the market and approach 1/4 and 3/4, respectively. When ϕ increases from 1.0 to 50.0, $x^*_{D,1}$ and $x^*_{D,2}$ shift toward $x = 0$ and $x = 1$, respectively, for every parameter value p.

Third, we set $\alpha Y = 4$, $\beta = 1$, $\phi = 1.5$ and calculated the locational points in equilibrium for every parameter value of γ from 0.0 to 5.0. We plot the result in the lower left panel of Figure 3. We observe that the clinics under DPC locate at symmetrically separated points at every γ from 0 to 5.0. As p increases, the locational points $x^*_{D,1}$ and $x^*_{D,2}$ move toward the center of the market and approach 1/4 and 3/4, respectively. We also observe that as p increases from 0.0 to 1.0, the locational points $x^*_{D,1}$ and $x^*_{D,2}$ shift toward $x = 0$ and $x = 1$, respectively, for every parameter value γ.

It should be noted that the speed with which $(x^*_{D,1}, x^*_{D,2})$ approaches $(1/4, 3/4)$ is very slow for each simulation under DPC/PDPS. We observe from the simulation that there are cases where the clinics concentrate in the market center under FFSRS but locate at dispersed points in the market under DPC/PDPS. This simulation result reveals that DPC/PDPS has a mechanism that minimizes the concentration of clinics compared with FFSRS. We also observe that the optimal location $(1/4, 3/4)$ that minimizes the patients moving distance in total can be achieved under DPC/PDPS, not under FFSRS.

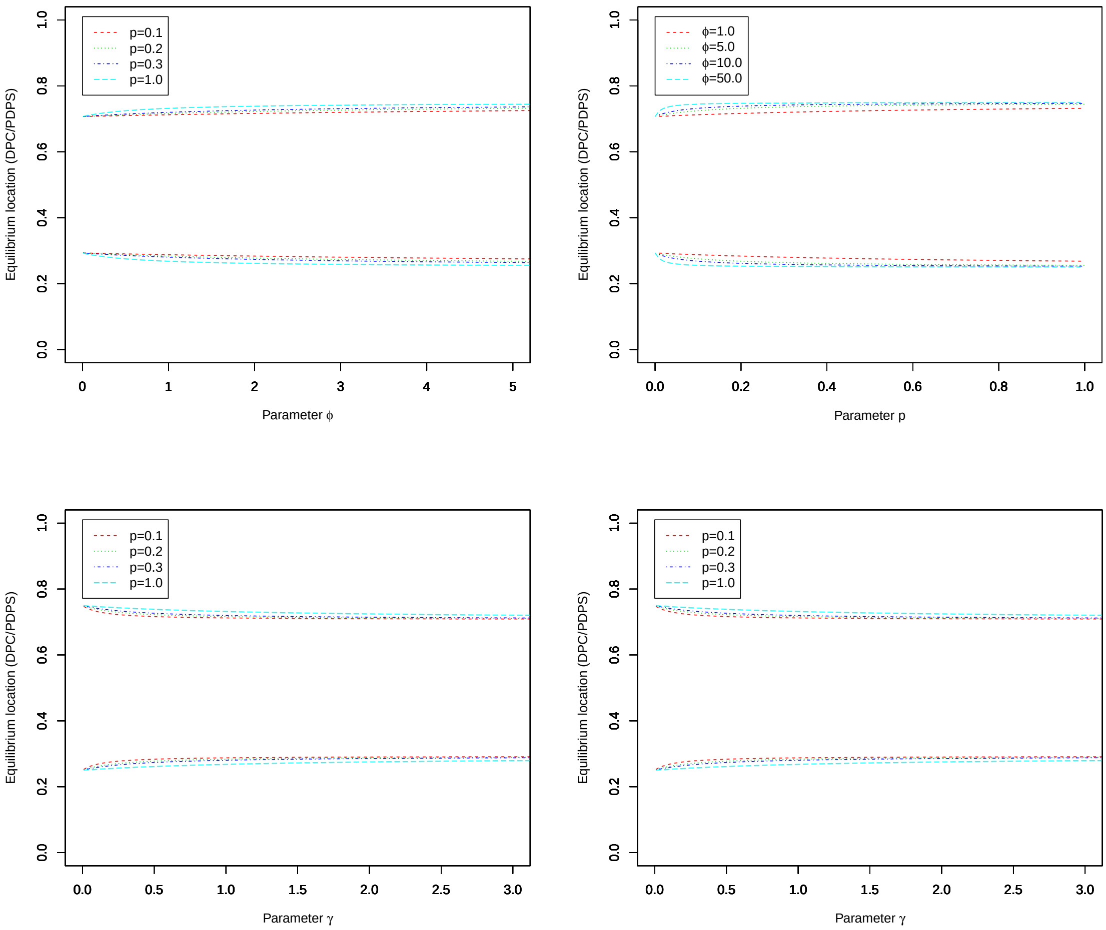

Figure 3: Plot of locational points in equilibrium. (DPC/PDPS)

Parameter to change		Patient's total utility		Clinic's total profit	
	(Fixed parameters)	Stackelberg	Nash	Stackelberg	Nash
ϕ	($p = 0.3$, $\beta = 1.0$, $\gamma = 1.0$)	$+-$	$+-$	$+$	$+$
β	($p = 0.3$, $\phi = 1.5$, $\gamma = 1.0$)	$-$	$-$	$-$	$-$
γ	($p = 0.3$, $\phi = 1.5$, $\beta = 1.0$)	$-$	$-$	$-$	$-$
p	($\phi = 1.5$, $\beta = 1.0$, $\gamma = 1.0$)	$-$	$-$	$-$	$-$

Table 1: The symbol "+" ("−") shows that the patient's welfare or the clinic's profit increases (decreases) when a parameter value is increased. The symbol "+−" shows that as a parameter value increases, the welfare or the profit increases in the beginning and decreases later. (FFSRS)

Welfare in equilibrium under FFSRS

We calculate the patient's and the clinic's welfare in equilibrium. Integrating every patient's utility in the entire market given (x_1^*, x_2^*), we obtain the total utility function of patients. We can also calculate the clinic's total profit given (x_1^*, x_2^*). In the simulation, we set $\alpha Y = 4$. In Table 1, our results for the numerical simulations show how the welfare of patients and the profit of clinics change as the value of the parameter shifts under FFSRS. The symbol "+" ("−") shows that the patient's welfare or clinic's profit increases (decreases) when a parameter value is increased. The symbol "+−" shows that, as a parameter value increases, the welfare or the profit increases in the beginning and decreases later.

The following two results are noteworthy. First, when we increase ϕ with $p = 0.3$, $\beta = 1.0$ and $\gamma = 1.0$ as illustrated in the left panel of Figure 4, the total utility of patients increases in the beginning and decreases if ϕ becomes larger than the critical value. We notice that increasing ϕ can enhance the patient's utility. Second, when we increase p as illustrated in Table 1, the patient's utility and the clinic's profit decrease in both the Stackelberg and Nash cases: an increase in p has only the effect of decreasing utility and profit. The following result is predictable. The clinic's profit is larger in the Stackelberg case than in the Nash. The patient's utility is larger in the Nash case than in the Stackelberg.

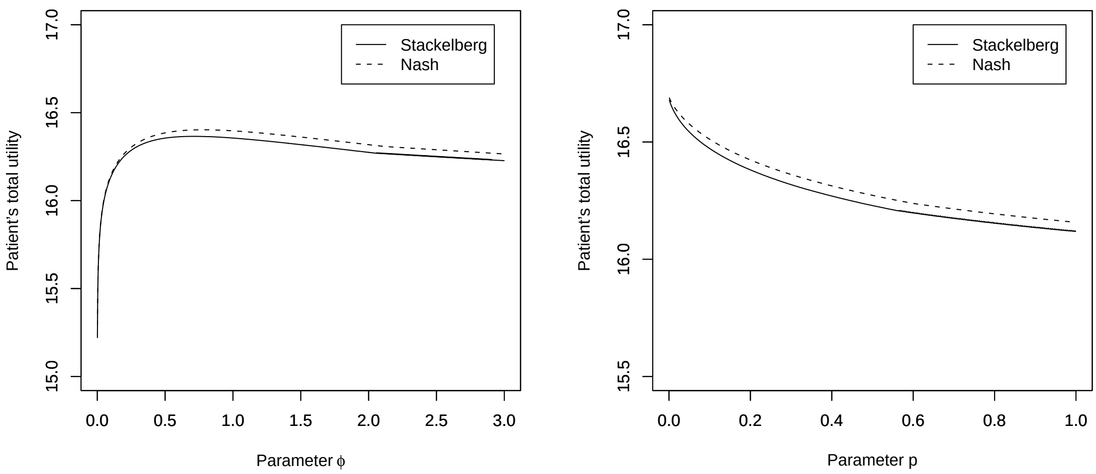

Figure 4: Plot of patient's total utility in equilibrium at every ϕ from 0.0 to 3.0. (FFSRS)

Welfare in equilibrium under DPC/PDPS

We calculate the patient's total utility and the clinic's total profit in equilibrium under DPC/PDPS. In Table 2, we present the summary of the numerical simulations for how the utility of patients and the profit of clinics change with respect to the key parameters ϕ, p, β and γ under DPC/PDPS. We set $\alpha Y = 4$.

First, when we increase ϕ with $p = 0.1, 0.2, 0.3, 1.0$, $\beta = 1.0$ and $\gamma = 1.0$, as illustrated in the left panel of Figure 5, not only the utility of patients but also the profit of the clinics increases in the beginning and decreases if ϕ becomes larger than the critical value. This result means that we can choose ϕ to maximize utility or profit. When we increase p, both total utility and total profit decrease at the given ϕ because the patient reduces his or her number of visits if p is increased.

Second, when we increase p from 0.0 to 1.0 with $\phi = 1.5$, $\beta = 1.0$, and $\gamma = 1.0$ as illustrated in Figure 6, both the patient's utility and the clinic's profit decrease.

Third, when we increase γ with $p = 0.1, 0.2, 0.3, 1.0$, $\phi = 1.5$ and $\beta = 1.0$ as illustrated

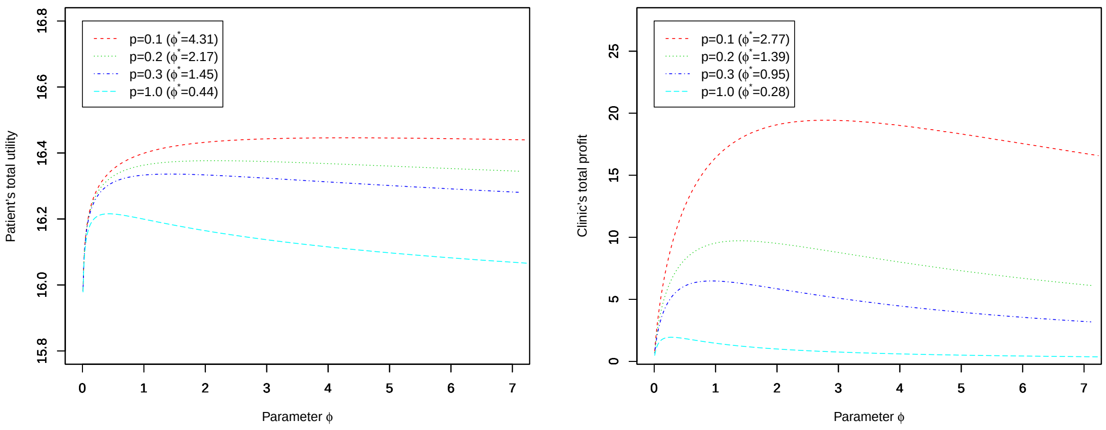

Figure 5: Plot of the patient's total utility and the clinic's total profit in equilibrium for every ϕ from 0.0 to 7.0. At ϕ^*s, total utility or total profit is maximized. (DPC/PDPS)

Parameter to change (Fixed parameters)		Patient's total utility	Clinic's total profit
ϕ	$(p = 0.1, 0.2, 0.3, 1.0,\ \beta = 1.0,\ \gamma = 1.0)$	$+-$	$+-$
β	$(p = 0.1, 0.2, 0.3, 1.0,\ \phi = 1.5,\ \gamma = 1.0)$	$-$	$-$
γ	$(p = 0.1, 0.2, 0.3, 1.0,\ \phi = 1.5,\ \beta = 1.0)$	$-$	$+-$
p	$(\phi = 1.0, 5.0, 10.0, 50.0,\ \beta = 1.0,\ \gamma = 1.0)$	$-$	Const.

Table 2: Welfare under DPC/PDPS.

in the left panel of Figure 7, we observe that the patient's total utility decreases. We also observe that the clinic's total profit increases in the beginning and decreases if γ becomes larger than the critical value.

Fourth, when we increase β with $p = 0.1, 0.2, 0.3, 1.0$, $\phi = 1.5$ and $\gamma = 1.0$ as illustrated in the left panel of Figure 8, we observe the patient's total utility decrease. This result is predictable using the model.

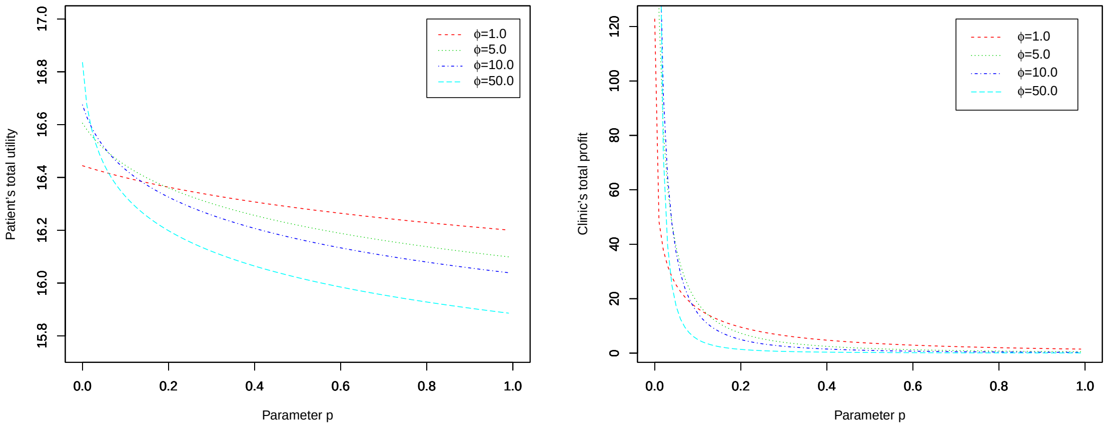

Figure 6: Plot of the patient's total utility and the clinic's total profit in equilibrium for every p from 0.0 to 1.0. (DPC/PDPS)

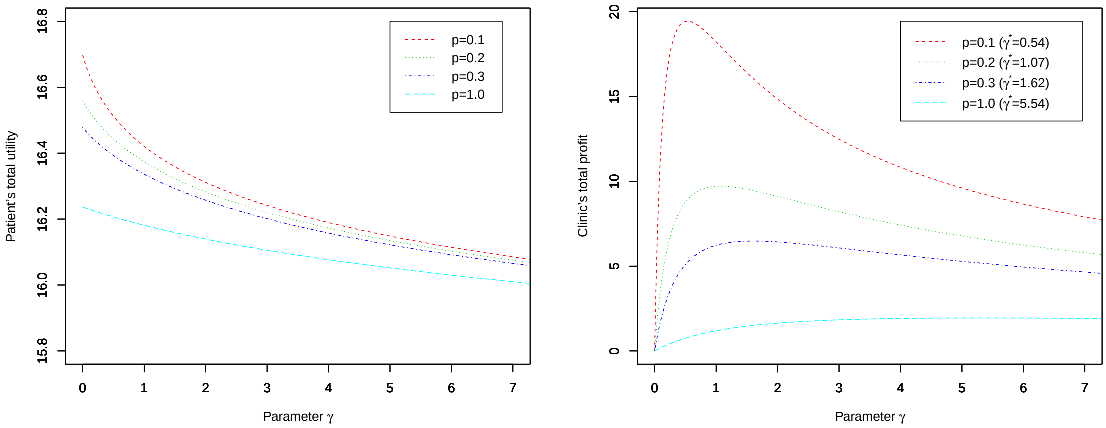

Figure 7: Plot of the patient's total utility and the clinic's total profit in equilibrium for every γ from 0.0 to 7.0. At γ^*s, the total profit of the clinic is maximized. (DPC/PDPS)

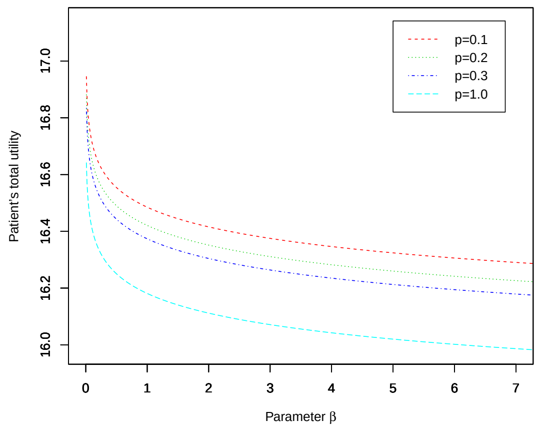

Figure 8: Plot of the patient's total utility in equilibrium for every β from 0.0 to 7.0. (DPC/PDPS)

5 The discriminated fee for medical service to induce the location of clinics in the underpopulated area

One possible way to induce the new entry of clinics into the underpopulated region is to set the fee for medical service in the underpopulated area higher than in the populated area. To consider this type of optimal fee for medical services, we modify the model. We define the population density function in the city to be

$$f(x) = \begin{cases} \frac{3}{2}, & 0 \leq x \leq \frac{1}{2} \\ \frac{1}{2}, & \frac{1}{2} \leq x \leq 1 \end{cases}. \tag{35}$$

We also define the unit fee for medical services as a function with respect to the locational point of the clinic x_i,

$$\phi(x_i) = \begin{cases} \phi_1, & 0 \leq x \leq \frac{1}{2} \\ \phi_2, & \frac{1}{2} \leq x \leq 1 \end{cases}. \tag{36}$$

The parameter ϕ_1 is fixed to 1.0, and we increase the parameter ϕ_2 from 0.0 to 10.0. Then, at every parameter value of ϕ_2, we calculate the locational points of clinics, the total utility of patients and the total profit of clinics in equilibrium under two systems, FFSRS in the Stackelberg case and DPC/PDPS. Throughout the following simulation, the key parameters are set to $\alpha Y = 4$, $p = 0.0, 0.1, 0.2, 0.3, 1.0$, $\beta = 1.0$ and $\gamma = 1.0$.

Locational points in equilibrium

In Figure 9, we show the locational points of the two clinics in equilibrium under FFSRS. When $p = 0.0$, the two clinics concentrate on the boundary line of two areas as ϕ_2 increases. When $p \geq 0.1$, the result appears to be complex. When $\phi_2 < 1.8$, the two clinics choose different locational points in the populated area $[0.0, 0.5)$. When $\phi_2 > 1.8$, one clinic locates at 0.5 for every ϕ_2 and the other locates in the underpopulated area $(0.5, 1.0]$. As ϕ_2 increases, the locational point in the underpopulated area moves toward 1.0. This result indicates that the fee for medical services for clinics in the underpopulated area should be at least 1.8 times larger than that in the populated area to induce the new entry of clinics into the underpopulated area.

In Figure 10, we show the result under DPC/PDPS. When $p = 0.0$ and ϕ_2 is greater than 2.9, we observe that one clinic locates in the populated area and the other locates in the underpopulated area. When $p =$ 0.1, 0.2, 0.3, 0.5 and 1.0, the two clinics choose different locational points in the populated area. Especially when $p =$ 0.2, 0.3, and 0.5, these two locational points are determined independent of ϕ_2. This result indicates that DPC/PDPS is not appropriate for inducing the new entry of clinics into the underpopulated area.

Welfare in equilibrium

In Figures 11 and 12, we show the total utility of patients in equilibrium under FFSRS and DPC/PDPS respectively. From Figure 11, we observe that the total utility of patients is non-increasing with respect to ϕ_2. From Figure 12, we observe that the total utility of patients can be regarded as constant with respect to ϕ_2 when $p = 0.1, 0.2, 0.3, 0.5, 1.0$. This result indicates that increasing ϕ_2 does not impact on the total utility of patients except for the case $p = 0.0$ under DPC/PDPS.

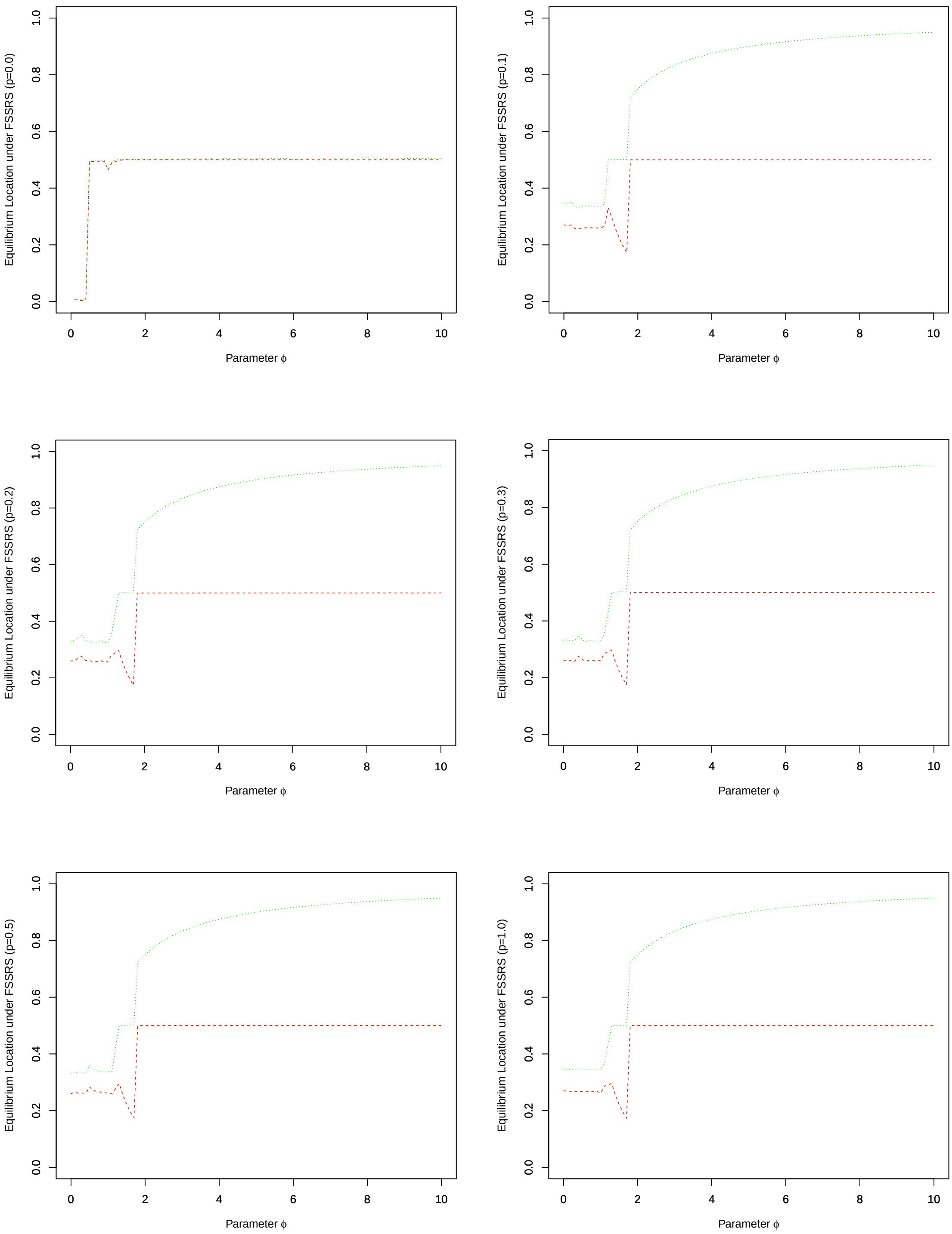

Figure 9: The locational points of the two clinics in equilibrium under FFSRS when the market is divided into populated and underpopulated areas and the fee for medical services is differentiated between the two areas.

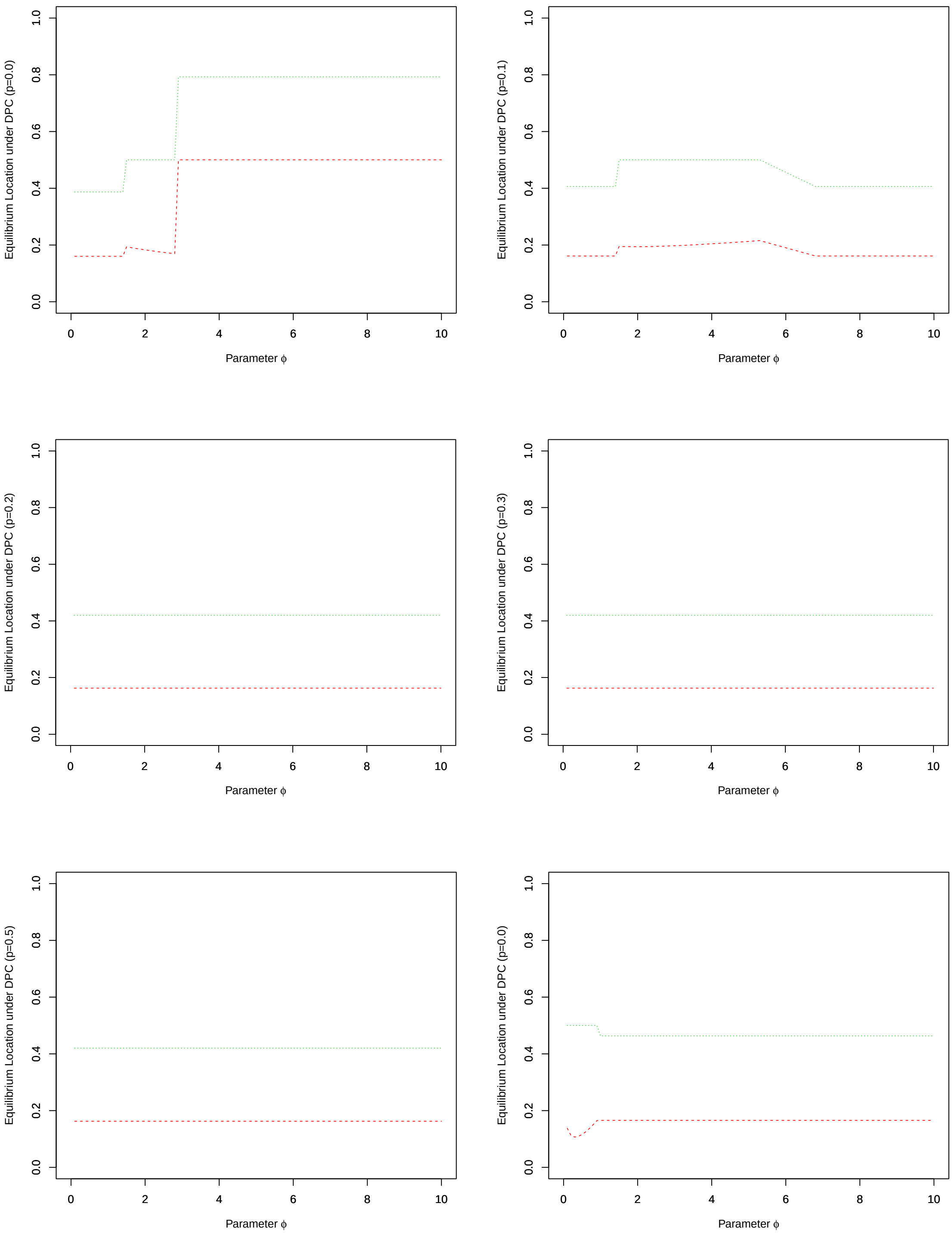

Figure 10: The locational points of the two clinics in equilibrium under DPC/PDPS when the market is divided into populated and underpopulated areas and the fee for medical services is differentiated between the two areas.

In Figures 13 and 14, we show the total profit of clinics in equilibrium under FFSRS and DPC/PDPS, respectively. From Figure 13, we observe that there exist optimal ϕ_2^*s that maximize the total profit of clinics when $p = 0.1, 0.2, 0.3, 0.5$, and 1.0. ($\phi_2^* \approx 2.7$ ($p = 0.1$), $\phi_2^* \approx 2.2$ ($p = 0.2$), $\phi_2^* \approx 2.0$ ($p = 0.3$), $\phi_2^* \approx 1.5$ ($p = 0.5$), $\phi_2^* \approx 1.8$ ($p = 1.0$)). These optimal values of ϕ_2^*s do not necessarily coincide with the critical value $\phi_2 = 1.8$, the point over which the new entry of clinics into the underpopulated area is induced under FFSRS. From Figure 14, we also observe that there exist optimal ϕ_2^*s that maximize the total profit of clinics when $p = 0.1, 0.5$, and 1.0 under DPC/PDPS. However, it appears that increasing ϕ_2 does not impact the profit of the total clinics under DPC/PDPS in many cases.

6 Discussion

In this paper, we consider the competitive locational equilibrium of clinics and welfare under FFSRS and DPC/PDPS using an extended Hoteling's spatial competition model. Under both systems, the clinics select their location in the first stage and then select the density of medical services in the second stage. Patients maximize their utility by controlling for the number of visits. Clinics maximize their profit by controlling for the density of medical care services. We consider the Stackelberg and Nash cases. Under DPC/PDPS, there is no difference between Stackelberg and Nash. Next, we conduct simulations to identify location and welfare in equilibrium with respect to key parameters, the unit fee for medical services, the co-payment rate, the cost parameter to provide medical care service and the transportation cost for the patients.

Under FFSRS, we find that clinics not only concentrate at the center of the market but also locate at symmetrically separated points from the center of the market for both the Stackelberg and the Nash cases. In contrast, under DPC/PDPS, we do not observe the concentrated locational point but only the separated one. This simulation result reveals that DPC/PDPS does not have enough influence to cause concentrated location. We also find that DPC/PDPS is better suited than FFSRS to induce the new entry of clinics into

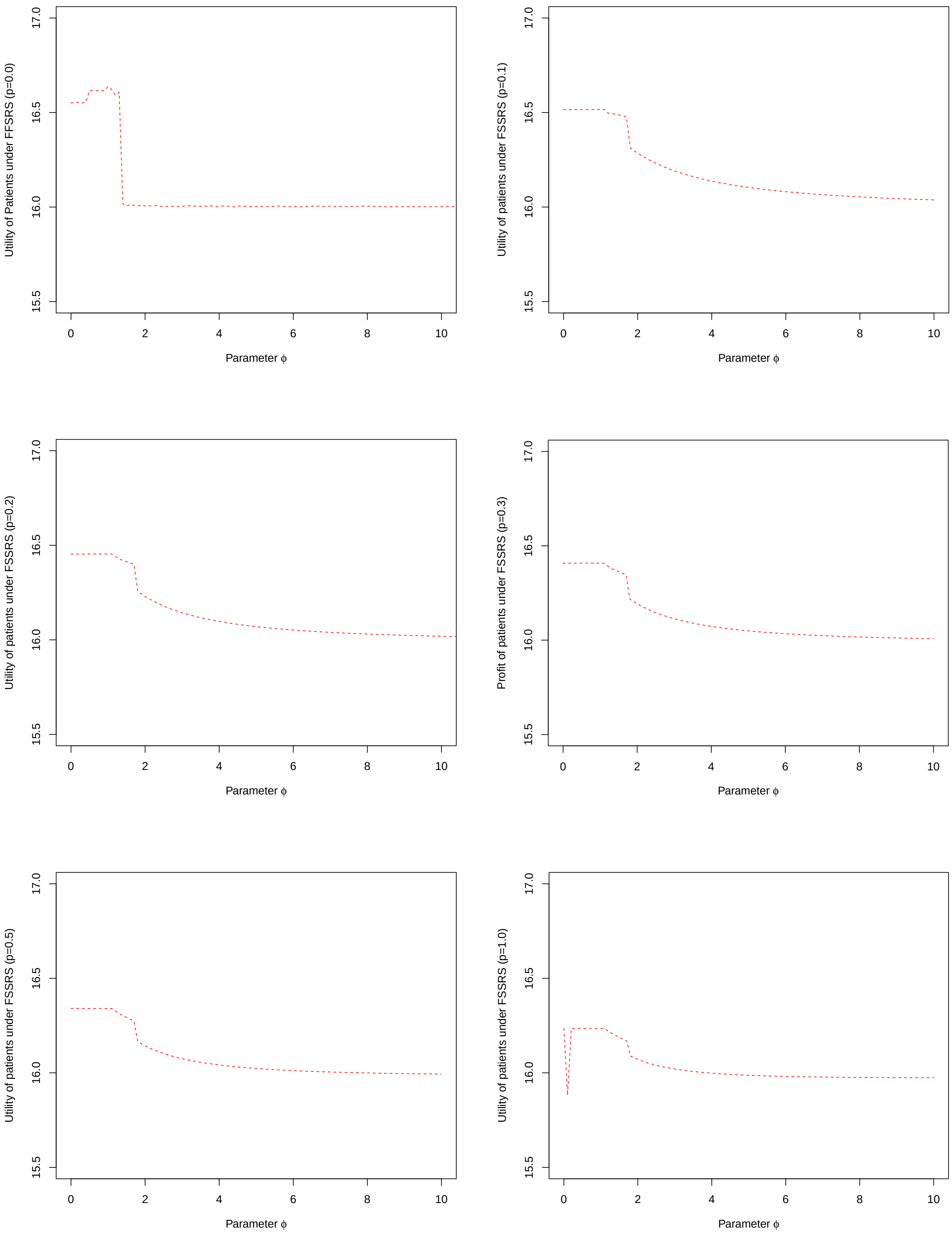

Figure 11: The total utility of patients in equilibrium under FFSRS when the market is divided into populated and underpopulated areas and the fee for medical services is differentiated between the two areas.

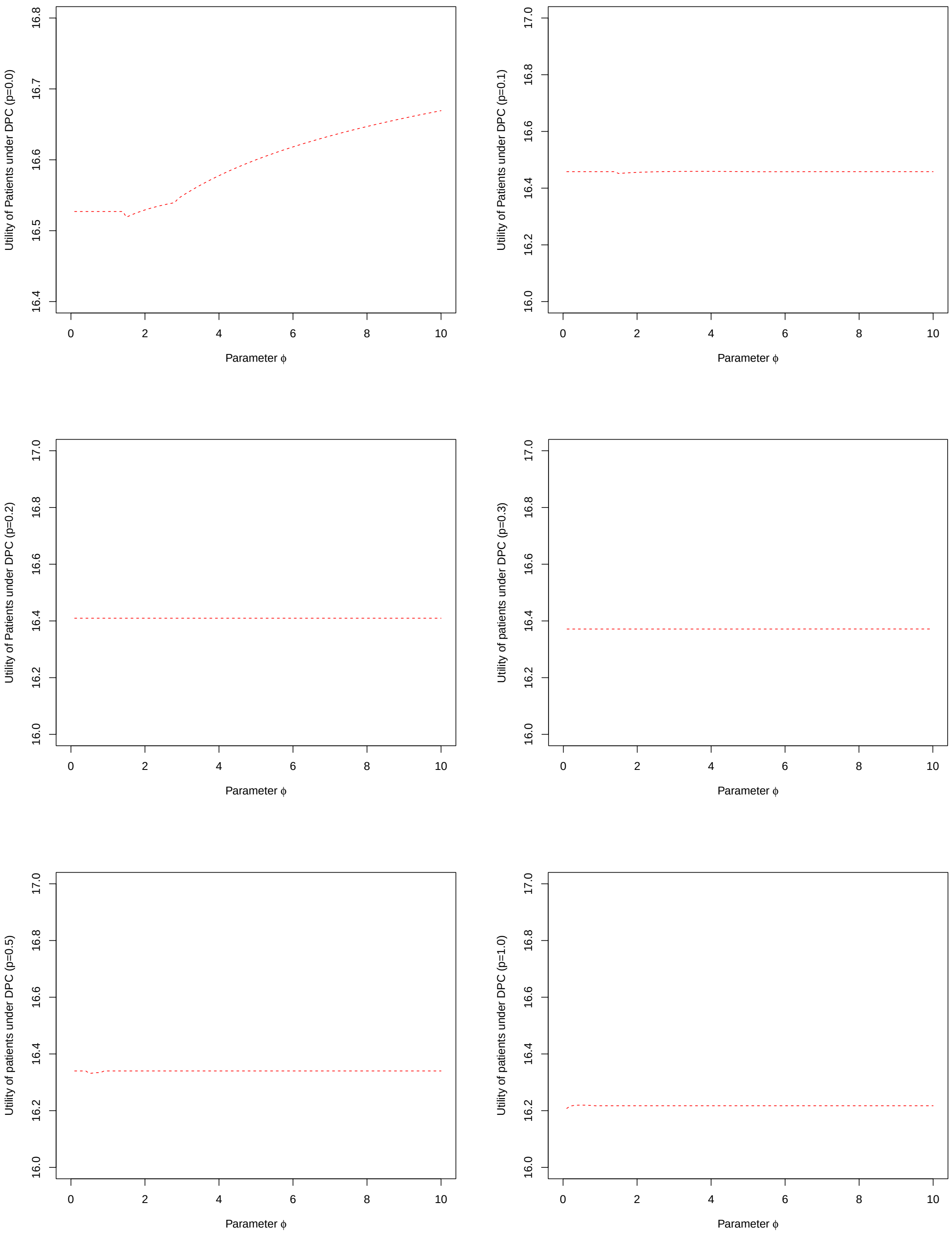

Figure 12: The total utility of patients in equilibrium under DPC/PDPS when the market is divided into populated and underpopulated areas and the fee for medical services is differentiated between the two areas.

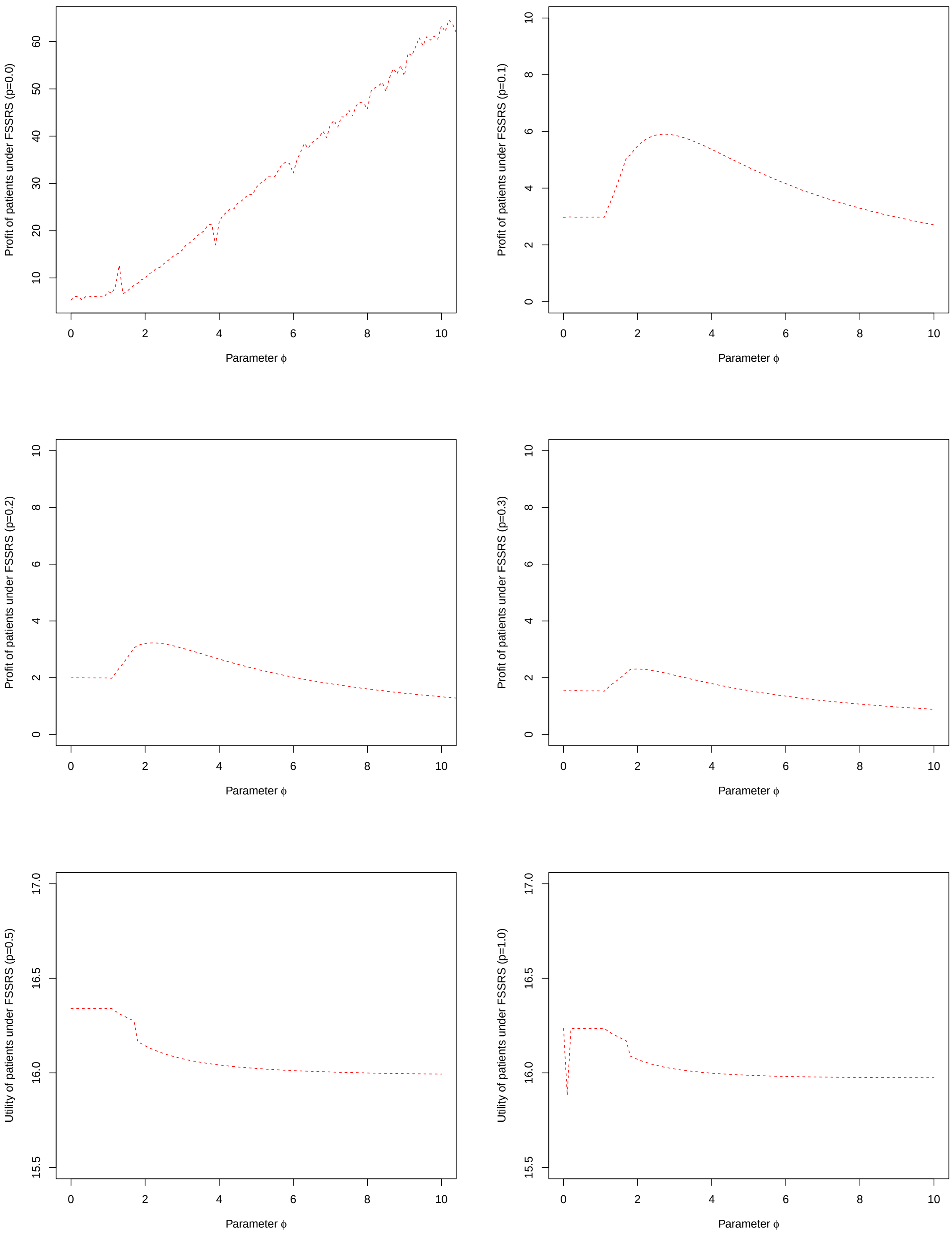

Figure 13: The total profit of the two clinics in equilibrium under FFSRS when the market is divided into populated and underpopulated areas and the fee for medical services is differentiated between the two areas.

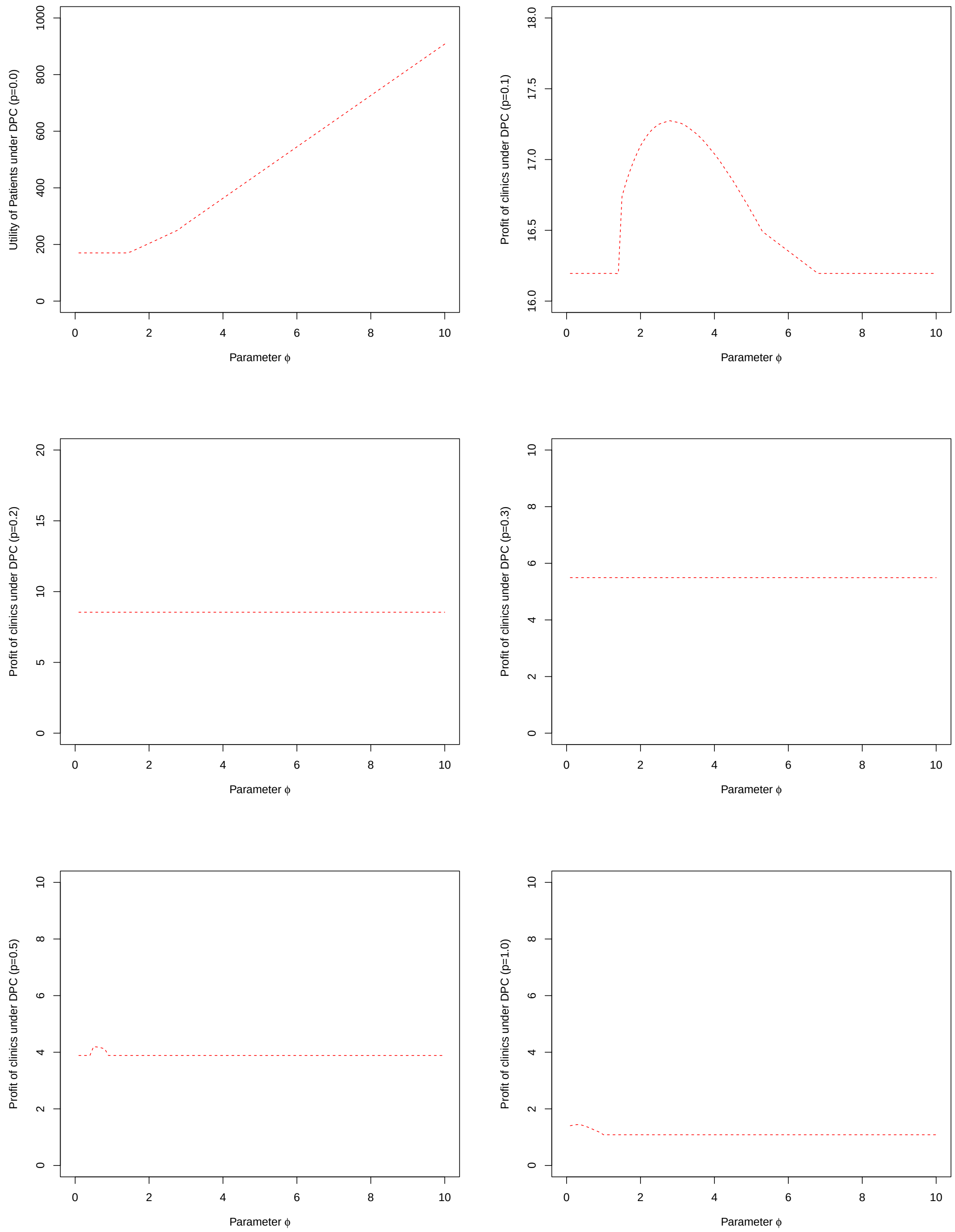

Figure 14: The total profit of the two clinics in equilibrium under DPC/PDPS when the market is divided into populated and underpopulated areas and the fee for medical services is differentiated between the two areas.

the periphery of the market if the unit fee for medical service is uniform in the market. We observe that the unit fee for medical service can increase the total utility of patients both under FFSRS and DPC/PDPS. It is noteworthy that increasing the unit fee for medical service can sometimes enhance patient utility. The co-payment rate, the cost parameter of clinics and the transportation cost cannot increase the total utility of patients under both FFSRS and DPC/PDPS. This result is predictable.

When we increase the unit fee for medical service under FFSRS, the total profit of the clinics continues to increase. Under DPC/PDPS, when we increase the unit fee for medical service, the total profit of clinics increases in the beginning and decreases if it becomes larger than the critical value. This result indicates that FFSRS can generate higher profits for clinics than DPC/PDPS. This result is also predictable if we consider that the nature of FFSRS tends to cause medical arms race.

It has been discussed that the government should introduce a fee for medical services that is discriminated among the populated and underpopulated areas to induce the location of clinics in underpopulated areas. However, we did not know what level of unit fee should be established by the government in underpopulated areas to induce new entry. Through the model in Section 5 under FFSRS, we know that the unit fee for medical services in the underpopulated area should be at least 1.8 times larger than that in the populated area, although the setting in the key parameters appears to be inexhaustive. Under DPC/PDPS, we have not identified the locational point in the underpopulated area except for the case $p = 0.0$. It appears that FFSRS is better suited than DPC/PDPS to induce the location of clinics in underpopulated area.

For further study, we will perform empirical studies as in Yoshida and Kohno (2007) to validate the conclusions from our paper.

Acknowledgements

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