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Reimbursement and hospital competition in China

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ABSTRACT

Quality and the costs of health care are of concern among patients. Differing from previous research into hospital competition, this article captures the impact of price subsidy of public hospitals on the quality of private hospitals, considering both horizontal and vertical product differentiation by employing a two-stage dynamic game under Cournot and Stackelberg competition. Firstly, the results of this study indicate that medical reimbursement of public hospitals has stimulating effects on the quality of private hospitals and the improvement of quality is related to the degree of hospital competition. Second, the quality of health care and patients' surplus and social welfare are the highest under Stackelberg competition if the public hospital is the leader while the private hospital is the follower. Finally, the demand for health care rises with the price subsidy of public hospitals. These conclusions have significant policy implications for health care system reform, especially for China.

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1. Introduction

With China's unprecedented economic growth and success in lifting millions out of poverty, the level of national health improved significantly. Meanwhile, diseases related to diet, such as obesity, cardiovascular disease, diabetes and others caused by smoking and drinking have become increasingly prominent. It has led to a dramatic increase in China's demand for health care and greater health expenditure. Recently, China's health reform programmes have successfully widened the availability of health care services. On one hand, the basic health insurance coverage has extended to the general population (Yip et al., 2012). On the other hand, private capital is allowed to enter the market to compete with the public sector. Establishing and improving the health care protection system aims to ensure more people are covered with reasonable medical resources. In other words, more and more people should be able to see doctors under regulated costs. The investment of medical insurance improves people's health but seriously increases government financial burden.

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In China, there are two types of hospitals, public hospitals and non-public hospitals. Public hospitals dominate the health care industry in terms of market share and the *China Health Statistics Yearbook 2015* shows that public hospitals occupy nearly 90% of the market share measured by total treated patients. Private hospitals only hold 10.9% of the market share but recently that has started increasing. Many factors result in that structure, but a major reason for it is that patients can be reimbursed for hospitalisation expenses when they see doctors in public hospitals. But the expenditures of seeing a doctor at a private hospital are not included in the basic health insurance programme, which means patients at private hospitals would not receive any reimbursement from the government for their medical treatment.

The reimbursement is actually a kind of price subsidy to public hospitals. Under the price subsidy of public hospitals, it is difficult for private hospitals to initiate price competition and therefore they may try to differentiate themselves by improving the quality of their products and services. With the increase of income, people need better medical quality and different medical care services. Many upscale private hospitals, such as the United Family Hospital that mainly services the well-off, have emerged to satisfy the general medical care market.

Whether competition between public and private hospitals can play a positive role in the health care market remains a controversial topic in both developed and developing countries. Quality is a major concern in health care. Many scholars think that competition can promote health care quality and reduce health care costs. Employing empirical data, Pan et al. (2015) showed that hospital competition is significantly correlated with shorter outpatient waiting time and lower patient costs. Eggleston and Yip (2004) developed a model of public-private hospital competition under regulated prices, and used data from China to calibrate a simulation model of the impact of China's recent payment and organisational reforms on cost and quality.

Our research aims to capture the effects of medical insurance reimbursement on the quality and quantity competition in the hospital industry by adopting different game models. Our results indicate reimbursement of public hospital stimulates the total medical care demand and improves the quality of private hospital. Moreover, the speed of quality improvement is the fastest and total utility of patients is the largest in the Stackelberg case when the public hospital is the leader and the private hospital is the follower.

The rest of this article is organised as follows. Literature review is outlined in section 2 to offer an overall review of the prior research. Then this article sets up Cournot and Stackelberg competition models in section 3. And we will give the propositions after model analysis in section 4. In the last section concluding remarks and some discussions are given.

2. Literature review

Nearly all countries enforce medical insurance because it improves the average health condition of the population. Some researchers showed that medical insurance is conducive to health. Using survey data for urban residents, Pan et al. (2013) found that medical insurance can improve the health of insured people. Finkelstein et al. (2012) implied that Oregon's OHP (Oregon Health Plan) standard (one kind of medical insurance) plays a significantly positive role in mental health, but has no effect on mortality. There are also authors who advocate that medical insurance significantly promotes health service utilisation, and improves people's health status (Currie & Gruber, 1996a, 1996b; Hanratty, 1996;

Xie, 2009). Besides, medical insurance eased the personal medical burden and stimulated medical demand (MaCall et al., 1991; Finkelstein et al., 2012) and the rising of demand led to higher health costs (Hu, Luan, & Li, 2015). Unfortunately, this research mainly focuses on the effect of medical insurance coverage, but there is little literature that focused on the effect of medical reimbursement rate on medial quality and demand. Zhao, Zeng, and Yin (2015) got the optimal health insurance reimbursement rate by constructing individual utility and social welfare maximisation and validated that China's current Urban Resident Basic Medical Insurance and New Rural Basic Medical Insurance have not reached the optimal reimbursement rate using a city-level data set collected from a 'natural experiment'. They also studied the effects of health insurance reimbursement rate on utilisation of in-patient services.

Another favourable factor for health improvement is competition of hospitals because competition forces hospitals to enhance their quality. Ongoing reforms in several countries to stimulate competition and patient choice in hospital markets have highlighted the importance of establishing more understanding about the relationship between competition and quality. There is vast research on hospital competition. Gaynor (2006) identified key issues concerning the nature of competition in health care markets and its impacts on quality and social welfare from the theoretical and empirical literatures. Theoretical models about hospital competition are mostly based on the hotelling model (Brekke, Siciliani, & Staume, 2008). The existing theoretical literature, though relatively scant, is clear that competition increases quality and improves consumer welfare, although the impacts on social welfare are ambiguous (Ma & Burgess, 1993; Calem & Rizzo, 1995; Gravelle & Masiero, 2000; Brekke, Nuscheler, & Straume, 2006, 2007). Empirical work in this issue is growing rapidly, but the empirical evidence implied an ambiguous relationship between competition and hospital quality. A few studies, including Kessler and McClellan (2000) and Tay (2003), found a positive relationship. Chen and Cheng (2010) examined the effects of market competition on patient-perceived quality of service under a single-payer system in Taiwan. They found that quality of service from the patient's perspective is sensitive to the degree of competition using patient-reported data. Gowrisankaran and Town (2003) showed a negative relationship while Mukamel, Zwanziger, and Tomaszewski (2001) found no effects. However, many authors believed that market competition is the most efficient approach to address health care challenges.

In this work, we extend and generalise the received theoretical literature by simultaneously including: (1) heterogeneous patients, and for-profit providers; (2) convex costs that are non-separable in quantity and quality; (3) both horizontal and vertical product differentiation in different quality and price subsidy; and (4) comparative analysis under Cournot and Stackelberg competition. Our research aims to examine the effects of medical insurance on quality and the relationship between the degree of hospital competition and quality considering both horizontal and vertical product differentiation.

3. The model

Residents

The model of two hospitals is formally established next. Assume all residents buy the basic medical insurance. Residents are endowed with a utility function separable in wealth and benefits derived from reimbursement that government provides and hospital care. A resident demands one unit of hospital care that means we do not consider repeated consumption because information is symmetric and one-time consumption has no different from repeated consumption. Reimbursement that the government provides is τ_i. When a resident takes one episode of hospital care from the private hospital, he or she can get no reimbursement or τ_1=0 but higher quality q_1. In this study, quality means medical treatment technology and service level of the hospital. If the patient choose the public hospital, he or she can get reimbursed for τ_2, $0 < \tau_2 < 1$ fraction of the expenses,[1] and quality q_2. With private capital entering markets to compete with public sector and increase of income, many non-public hospitals with high quality emerge to appeal to the demands of people. So here, we further assume $q_1 > q_2$. Without losing of generality, we focus on quality of the private hospital and standardise $q_2$to 0 to simplify the model.[2] On the other hand, public hospital is strictly regulated by the government, so it has low motivation to improve the quality of its service and we standardise its quality to constant. We can be liberated to focus our attention on the effect of reimbursement ratio τ_2 on the quality of private hospital.

Because both wealth and medical treatment or service quality of hospitals increase residents' utilities, we employ the Cobb-Douglas utility for residents. Then the utility for a resident is:

$$\begin{aligned} u_1 &= \alpha(1 + q_1), \\ u_2 &= \alpha. \end{aligned} \tag{1}$$

and representative consumer (resident) surplus (cs) functions is

$$\begin{aligned} cs_1 &= \alpha(1 + q_1) - p_1, \\ cs_2 &= \alpha - p_2(1 - \tau_2). \end{aligned} \tag{2}$$

α uniformly distribute in [1,2] represents the wealth of the resident.[3] p_i, $(i = 1, 2)$ is the prices. The demand function is determined by (2). If a resident selects the private hospital, the following relationship holds: $cs_1 > cs_2$. This indicates that:

$$\alpha \geq \frac{p_1 - p_2(1 - \tau_2)}{q_1}. \tag{3}$$

Assume the total population is 1with wealth evenly distribute in [1, 2]. Accordingly, we obtain the demand for medical care of the private hospital

$$x_1 = 2 - \frac{p_1 - p_2(1 - \tau_2)}{q_2}. \tag{4}$$

A patient selecting public hospital if $0 < cs_2 < cs_1$, or equivalently

$$p_2(1 - \tau_2) < \alpha < \frac{p_1 - p_2(1 - \tau_2)}{q_1}. \tag{5}$$

Accordingly, we obtain the demand for health treatment of the public hospital as:

$$x_2 = \frac{p_1 - p_2(1-\tau_2)}{q_1} - p_2(1-\tau_2). \tag{6}$$

And the corresponding inverse demands are:

$$\begin{aligned} p_1 &= (2-x_1)(1+q_1) - x_2, \\ p_2 &= \frac{2-x_1-x_2}{1-\tau_2}. \end{aligned} \tag{7}$$

And consumer surpluses are outlined as the following:

$$\begin{aligned} CS_1 &= \int_{\frac{p_1-p_2(1-\tau_2)}{q_1}}^{2} [\alpha(1+q_1) - p_1]d\alpha, \\ CS_2 &= \int_{p_2(1-\tau_2)}^{\frac{p_1-p_2(1-\tau_2)}{q_1}} [\alpha - p_2(1-\tau_2)]d\alpha. \end{aligned} \tag{8}$$

Hospitals

Here we model the two hospitals in this industry which offer products and service with different medical quality but only the public hospitals acquire medical insurance from the government.

The objective functions of the two hospitals are as follows.

$$\begin{aligned} \max_{x_1,q_1} \pi_1 &= p_1x_1 - q_1 - x_1^2 + x_1^2q_1, \\ \max_{x_2} \pi_2 &= p_2x_2 - x_2^2. \end{aligned} \tag{9}$$

Notice that $C(x_i, q_i) = q_i + x_i^2 - x_i^2q_i$ is the cost function and it is a quadratic function. The cost function is convex in quantity and linear in quality. The first term represents the costs result in quality and the second term means the costs of quantity. The last term or $x_i^2q_i$ is used to capture the 'learning effect', which means hospital costs decrease as cured patients and quality increase because a health treatment and quality increase will improve the experience of the hospital and will subsequently reduce the cost (Jaber & Saadany, 2011; Wahab & Jaber, 2010). 'Learning effect' lowers the cost, so the sign of $x_i^2q_i$ minus.

The timing of the game is as follows: At the first stage, the two hospitals commit the quality level of their products and service. At the second stage, according to the quality levels, patients determine whether to go to hospital and choose the hospital (public or private), while the hospitals make their capacity decision to meet the patients' need. Hospitals decide the quantity of the products. All solutions are obtained by backward induction.

3.1. Cournot-Nash model

Cournot competition is used as our benchmark model. Cournot competition is nearly to prefect competition structure. The Cournot behaviour model is based on the hospitals' simultaneous moves. All the members of the channel determine their own strategies simultaneously and non-cooperatively. In this situation, the first optimal conditions of function (9) are:

$$\begin{aligned}\frac{\partial \pi_1}{\partial x_1} &= \frac{\partial p_1(x_1, x_2, q_1)}{\partial x_1} x_1 + p_1(x_1, x_2, q_1) - (2 - 2q_1)x_1 = 0, \\ \frac{\partial \pi_1}{\partial q_1} &= \frac{\partial p_1(x_1, x_2, q_1)}{\partial q_1} x_1 - 1 + x_1^2 = 0, \\ \frac{\partial \pi_2}{\partial x_2} &= \frac{\partial p_2(x_1, x_2, q_1)}{\partial x_2} x_2 + p_2(x_1, x_2, q_1) - 2x_2 = 0.\end{aligned} \tag{10}$$

Solving equation (10) we obtain the equilibrium solutions of quality:

$$q_1^* = \frac{33 - 16\tau_2}{64(2 - \tau_2)^2}, \tag{11}$$

the equilibrium solutions of quantity:

$$(x_1^*, x_2^*) = (\frac{15 - 8\tau_2}{32 - 16\tau_2}, \frac{49 - 24\tau_2}{32(2 - \tau_2)^2}), \tag{12}$$

and the equilibrium prices are as follows:

$$(p_1^*, p_2^*) = (\frac{(15 - 8\tau_2)^2}{1024(2 - \tau_2)^3}, \frac{(3 - 2\tau_2)(49 - 24\tau_2)}{32(2 - \tau_2)^2(1 - \tau_2)}). \tag{13}$$

3.2. Stackelberg case 1

In this case, the public hospital is the leader and the private hospital is the follower. Solving function (9) by backward induction, which means we get the first optimal conditions of the follower hospital and they are outlined as:

$$\begin{aligned}\frac{\partial \pi_1}{\partial x_1} &= \frac{\partial p_1(x_1, x_2, q_1)}{\partial x_1} x_1 + p_1(x_1, x_2, q_1) - (2 - 2q_1)x_1 = 0, \\ \frac{\partial \pi_1}{\partial q_1} &= \frac{\partial p_1(x_1, x_2, q_1)}{\partial q_1} x_1 - 1 + x_1^2 = 0.\end{aligned} \tag{14}$$

Then we obtain the response function $x_1 = f(x_2)$. Substitute $x_1 = f(x_2)$ into the profits function of the public hospital and solve it, we have the following first optimal condition of the leader hospital:

$$\frac{\partial \pi_2}{\partial x_2} = \frac{\partial p_2(f(x_2), x_2, q_1)}{\partial x_2} x_2 + p_2(f(x_2), x_2, q_1) - 2x_2 = 0. \tag{15}$$

By solving equations (14) and (15) we have the equilibrium quality:

$$q_1^{**} = \frac{31 - 16\tau_2}{(15 - 8\tau_2)^2}, \tag{16}$$

the equilibrium solutions of quantity are as follows:

$$(x_1^{**}, x_2^{**}) = (\frac{7-4\tau_2}{15-8\tau_2}, \frac{92-48\tau_2}{(15-8\tau_2)^2}), \tag{17}$$

and the equilibrium solutions of price are:

$$(p_1^{**}, p_2^{**}) = (\frac{4(7-4\tau_2)^2(23-12\tau_2)}{(15-8\tau_2)^3}, \frac{253-316\tau_2+96\tau_2^2}{(15-8\tau_2)^2(1-\tau_2)}). \tag{18}$$

3.3. *Stackelberg case 2*

In this Stackelberg game case, the private hospital is the leader and the public hospital is the follower. The equilibrium solutions of the follower or the public hospital is decided by the following first optimal condition:

$$\frac{\partial \pi_2}{\partial x_2} = \frac{\partial p_2(x_1, x_2, q_1)}{\partial x_2} x_2 + p_2(x_1, x_2, q_1) - 2x_2 = 0, \tag{19}$$

and response function of the follower $x_2 = f^{'}(x_1)$. Substitute $x_2 = f^{'}(x_1)$ to the profit function of the leader and solve it, we obtain the following first optimal condition:

$$\begin{aligned} \frac{\partial \pi_1}{\partial x_1} &= \frac{\partial p_1(x_1, f^{'}(x_1), q_1)}{\partial x_1} x_1 + p_1(x_1, f^{'}(x_1), q_1) - (2-2q_1)x_1 = 0, \\ \frac{\partial \pi_1}{\partial q_1} &= \frac{\partial p_1(x_1, f^{'}(x_1), q_1)}{\partial q_1} x_1 - 1 + x_1^2 = 0. \end{aligned} \tag{20}$$

Then we get the equilibrium quality by solving functions (19) and (20):

$$q_1^{***} = \frac{1}{4(2-\tau_2)}, \tag{21}$$

the equilibrium quantity:

$$(x_1^{***}, x_2^{***}) = (\frac{1}{2}, \frac{3}{8-4\tau_2}), \tag{22}$$

and the equilibrium solutions of price:

$$(p_1^{***}, p_2^{***}) = (\frac{3(7-4\tau_2)}{8(2-\tau_2)}, \frac{3(3-2\tau_2)}{4(1-\tau_2)(2-\tau_2)}). \tag{23}$$

4. Comparative analysis

Here, we will carry on comparative analysis among the above three games and some interesting conclusions are acquired.

4.1. Quality analysis

Quality is a concern in health care. Patients are sensitive to quality and very concerned about a hospital's medical technology. Though public hospitals in China have inherent advantages in medical technology, the improvement of quality has fallen behind the growth in demand. With a great demand on health care, the relationship between patients and doctors are increasingly important. Presently, many high quality private hospitals emerged within the market to meet patients' diversified demands. For the quality, we have the following Proposition:

Proposition 1 $\frac{\partial q_1}{\partial \tau_2} > 0, \frac{\partial (q_1^{**} - q_1^{*})}{\partial \tau_2} > 0$ and $q_1^{***} < q_1^{*} < q_1^{**}$.

Proof. See the appendix. ∎

Remarks: The reimbursement of public hospital motivates the private hospital to improve its quality. Stimulating effects of reimbursement under Stackelberg case 1 is bigger than that under Cournot. The quality of the private hospital is the highest when the public hospital is the leader and the private hospital is the follower but the least under Stackelberg case 2. Proposition 1 indicates that the private hospital can offset its competition disadvantage by increasing its quality. More importantly, the fiercer the competition of the public hospital, the higher the quality of the private hospital. The market structure that public hospitals dominate can be more conducive to improving medical technology and that is the reality in today's China.

4.2. Demand analysis

With the development of the economy, people pay more attention to their health and more of them choose to see a doctor when they fall ill. Medical demand has risen in China in recent years.

Proposition 2 $\frac{\partial x_1}{\partial \tau_2} \leq 0, x_1^{**} < x_1^{*} < x_1^{***} = \frac{1}{2}, \frac{\partial x_2}{\partial \tau_2} > 0$, and $\frac{\partial (x_1 + x_2)}{\partial \tau_2} > 0$.

Proof. See the appendix. ∎

Remarks: Reimbursement makes the public hospital more attractive to the patients than the private hospital. As a result, more and more residents choose the public hospital when they are sick. The total demand for health care increases with the reimbursement ratio. Interestingly, with the price subsidy to the public hospital, the market share of the private hospital will never exceed $\frac{1}{2}$ or half of the market, no matter what its quality is. On one hand, the price subsidy of the public hospital lightens the burden of medical care of residents. On the other hand, incomes have gone up. A growing number of people can afford to pay hospital bills. However, the price subsidy of the public hospital limits peoples' desire to use private hospitals for medical care. $\frac{\partial q_1}{\partial \tau_2} > 0$ and $\frac{\partial x_1}{\partial \tau_2} \leq 0$ implicate that the private hospital should allow a trade-off between quantity and quality, or the private hospital should increase its quality to offset the market share disadvantage.

4.3. Price analysis

By comparing equilibrium prices among the three cases above, we obtain the following Proposition.

Proposition 3 $\frac{\partial p_1}{\partial \tau_2} < 0$ while $\frac{\partial p_2}{\partial \tau_2} > 0$.

Proof. See the appendix. ∎

Remarks: The results are acquired in all three games. The reimbursement of the public hospital raises its price but reduces the price of the private hospital. Although patients who go to the public hospital are reimbursed, they are faced with higher prices for medical care and services. In other words, price reimbursement has both positive and negative effects on patients and the gross effects are weaker than expected.

Therefore, another competitive strategy for the private hospital is to lower its price of medical treatments and services under price subsidy. Furthermore, $\frac{\partial p_2}{\partial \tau_2} > 0$ illustrates that the government should use price reimbursement carefully because price reimbursement enable the public hospital with the power to increase its price and all the reimbursement may offset by the price increase effects in extreme condition.

4.4. Patients' surplus

Patients' surplus is a concept that is similar to consumers' surplus. Combining function (7) and (8), we have the total patients' surplus given as the following

$$CS = CS_1 + CS_2 = \int_{\frac{p_1-p_2(1-\tau_2)}{q_1}}^{2} [\alpha(1+q_1) - p_1]d\alpha + \int_{p_2(1-\tau_2)}^{\frac{p_1-p_2(1-\tau_2)}{q_1}} [\alpha - p_2(1-\tau_2)]d\alpha. \quad (24)$$

And function (24) and the equilibrium prices of the three cases imply the following Proposition.

Proposition 4 $CS^{*} < CS^{***} < CS^{**}$.

Proof. See the appendix. ▪

Remarks: Proposition 4 shows that patients' surplus is the largest in the public- leader–Stacklberg case and it is the least in Cournot. Figures 1 and 2 illustrate the viewpoint by numerical analysis.

Consequently, letting the private capital enter the market to compete with the public sector is an effective health care reform policy, which is of great benefit to patients in China. Moreover, the benefit to patients is the greatest in such market structure in which the public hospital is dominant.

4.5. Social welfare

Another important factor we care about is social welfare, so next we will compare the social welfare under the above three games.

Denote the social welfare as SW, and then we have

$$SW = CS + \sum_{i=1}^{2} \pi_i. \quad (25)$$

And function (25) indicates the following Proposition.

Proposition 5 If $0 < \tau_2 < \overline{\tau}_2, \overline{\tau}_2 \in (0, 0.85)$, then $SW^{*} < SW^{***} < SW^{**}$.

Proof. See the appendix. ▪

Remarks: Social welfare is the largest under Stackelberg case 1 and the least under Cournot competition. From social welfare perspectives, Stackelberg case 1 is the best. In other words, public hospitals leading the private ones is the best for the whole society. Figures 3 and 4 illustrate the viewpoint by numerical analysis. Although Proposition 5 only holds under the constraint that $\overline{\tau}_2 \in (0, 0.85)$ and this interval is determined by mathematical technology, actually the reimbursement ratio of the public hospital is less than 80%, so this constraint can be ignored.

The results show that the improvement of social welfare is related to the competition structure or public leader–private follower Stackelberg competition is best of all. So, the policy implications of Proposition 3 and 4 indicate that the government should give private hospitals the chance to compete with public hospitals, but on the other hand, the government should enforce some regulations on private hospitals because they are less consumer-oriented organisations compared with public hospitals.

5. Conclusion

Considering the price subsidy of public hospitals and quality difference, this article analyses both the quality and the degree of hospital competition. From the existing literature we take both quality and price difference into consideration. By using a two-stage dynamic game under Cournot and Stackelberg competition, we argue that medical reimbursement of the public hospital has motivating effects on the quality of the private hospital, and the effects are the largest in the Stackelberg case where the public hospital is the leader while the private hospital is the follower. The improvement of quality is related to the degree of hospital competition, which is different from the conclusion obtained by Chen and Cheng (2011). Chen and Cheng found that competition was positively associated with the perceived quality of care empirically, but we argued that there is an optimal degree of competition that makes quality of health care improved faster theoretically. Correspondingly, we obtain the demand for health care rises with price subsidy of the public hospital. The results have been tested by many researchers (MaCall et al., 1991; Finkelstein et al., 2012).

With the improvement in quality of private hospitals and a rapid increase in income, more and more people will prefer private hospitals with higher quality. By comparing patients' surplus and social welfare we demonstrate that patients' surplus and social welfare are the largest under the public leader–private follower Stackelberg competition.

Cournot competition is our benchmark model and we compare the results in Stackelberg cases with the benchmark condition. Actually, the public hospital leader Stackelberg competition is almost the reality for the Chinese hospital industry because public hospitals dominate the competition. This study is based on Chinese medical markets, and it indicates that the present market structure of hospital competition with public hospitals playing the leader role is rational and price subsidy of public hospital can stimulate private hospital to make further efforts to increase medical treatment technology and its service quality. In other words, our conclusions have great policy implications for the government of China or even other similar countries. Capacity constraints (Chen, Nie, & Wang, 2015) and corporate social responsibility (Chen, Wen, & Lou, 2016) are two major factors that impact hospitals competition because hospitals operate with capacity constraints (limited hospital beds or limited doctors) and corporate social responsibility (hospitals are not complete profit maximisation firms). Further study will take those factors into account.

Notes

1. $\tau_2 = 0$ means no reimbursement while $\tau_2 = 1$ indicates free medical treatment both are out of our study.
2. q_2 is the basic quality of hospital service and we have $q_1 > q_2$. There is no difference to standardise q_2 to 0, 1 or any other constant because the only important thing is $q_1 > q_2$. If q_2 is not standardised to 0, then only need is to employ a new parameter $\Delta q = q_1 - q_2$, but that is nothing more than making the analysis complex, so we assume $q_2 = 0$.
3. $\alpha \in [1, 2]$ not $[0, 1]$ because $\tau \in (0, 1)$. If $\alpha \in [0, 1]$, then the wealth level is too low comparing with the reimbursement or the reimbursement of the public hospital is too high and that will let to unacceptable results.

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Appendices

Proof of Proposition 1

From equations (11), (16), and (21), we have $\frac{\partial q_1^*}{\partial \tau_2} = \frac{17-8\tau_2}{32(2-t_2)^3} > 0$, $\frac{\partial q_1^{**}}{\partial \tau_2} = \frac{128(2-\tau_2)}{(15-8\tau_2)^3} > 0$ and $\frac{\partial q_1^{***}}{\partial \tau_2} = \frac{1}{4(2-\tau_2)^2} > 0$. Then, we have $q_1^{**} - q_1^* = \frac{511-512\tau_2+128\tau_2^2}{64(15-8\tau_2)^2(2-\tau_2)^2} > 0$ and $q_1^{***} - q_1^* = -\frac{1}{64(2-\tau_2)^2} < 0$, so we can obtain $\frac{\partial q_1}{\partial \tau_2} > 0$, $q_1^{***} < q_1^* < q_1^{**}$ and $\frac{\partial(q_1^{**}-q_1^*)}{\partial \tau_2} = \frac{8161-12272\tau_2+6144\tau_2^2-1024\tau_2^3}{32(2-\tau_2^2)^3(15-8\tau_2)^3} > 0$.

Conclusions are therefore achieved and the proof is complete. ■

Proof of Proposition 2

From equations (12), (17) and (22), we have $\frac{\partial x_1^*}{\partial \tau_2} = -\frac{1}{16(2-\tau_2)^2} < 0$, $\frac{\partial x_2^*}{\partial \tau_2} = \frac{25-12\tau_2}{16(2-\tau_2)^3} > 0$ and $\frac{\partial(x_1^*+x_2^*)}{\partial \tau_2} = \frac{23-11\tau_2}{16(2-\tau_2)^3} > 0$.

$\frac{\partial x_1^{**}}{\partial \tau_2} = -\frac{4}{(15-8\tau_2)^2} < 0$, $\frac{\partial x_2^{**}}{\partial \tau_2} = \frac{16(47-24\tau_2)}{(15-8\tau_2)^3} > 0$ and $\frac{\partial(x_1^{**}+x_2^{**})}{\partial \tau_2} = \frac{4(173-188\tau_2)}{(15-8\tau_2)^3} > 0$. For the same reason we have $\frac{\partial x_1^{***}}{\partial \tau_2} = 0$, $\frac{\partial x_2^{***}}{\partial \tau_2} = \frac{12}{(8-4\tau_2)^2} > 0$ and $\frac{\partial(x_1^{***}+x_2^{***})}{\partial \tau_2} = \frac{12}{(8-4\tau_2)^2} > 0$. So, the results $\frac{\partial x_1}{\partial \tau_2} \le 0$, $\frac{\partial x_2}{\partial \tau_2} > 0$ and $\frac{\partial(x_2+x_2)}{\partial \tau_2} > 0$ are all obtained under the three cases of competition. Then, we have $x_1^{***} - x_1^* = \frac{1}{30-16\tau_2} > 0$, $x_1^{**} - x_1^* = \frac{1}{16(30-31\tau_2+8\tau_2^2)} < 0$.

Conclusions are therefore achieved and the proof is complete. ■

Proof of Proposition 3

From equations (13), (18) and (23), we have $\frac{\partial p_1^*}{\partial \tau_2} = -\frac{(15-8\tau_2)(83-40\tau_2)}{1024(2+\tau_2)^4} < 0$, $\frac{\partial p_2^*}{\partial \tau_2} = \frac{248-419\tau_2+24\tau_2^2-48\tau_2^3}{32(2-\tau_2)^3(1-\tau_2)^2} > 0$ and $\frac{\partial p_1^{**}}{\partial \tau_2} = -\frac{16(273-296\tau_2+80\tau_2^2)}{(15-8\tau_2)^4} < 0$, $\frac{\partial p_2^{**}}{\partial \tau_2} = \frac{3103-5720\tau_2+3616\tau_2^2-768\tau_2^3}{(1-\tau_2)^2(15-8\tau_2)^3} > 0$. For the same reason we have $\frac{\partial p_1^{***}}{\partial \tau_2} = -\frac{3}{8(2-\tau_2)^2} < 0$ and $\frac{\partial p_2^{***}}{\partial \tau_2} = \frac{3(5-6\tau_2+2\tau_2^2)}{4(2-\tau_2)^2(1-\tau_2)^2} > 0$.

The results $\frac{\partial p_1}{\partial \tau_2} < 0$ and $\frac{\partial p_2}{\partial \tau_2} > 0$are all assured for three competitions.
Conclusions are therefore achieved and the proof is complete. ■

Proof of Proposition 4

From function (24) and the equilibrium solutions of the three cases, we have $CS^{***} - CS^* = \frac{3068785-6628536\tau_2+5588352\tau_2^2-2282496\tau_2^3+446464\tau_2^4-32768\tau_2^5}{524288(2-\tau_2)^5} > 0$ and

$CS^{**} - CS^{***} = \frac{883-98429\tau_2+181604\tau_2^2-124672\tau_2^3+37376\tau_2^4-4096\tau_2^5}{32(158-\tau)^4(2-\tau_2)^2} > 0$.

To illustrate this better, we offer the numerical simulation as follows (Figures 1 and 2).
Conclusions are therefore achieved and the proof is complete. ■

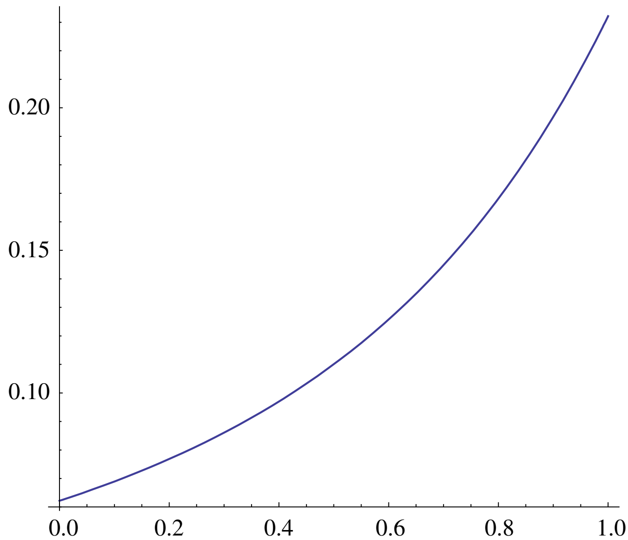

Figure 1. Numerical simulation of τ_2. Source: Simulated by the authors with Mathematica 9.0.

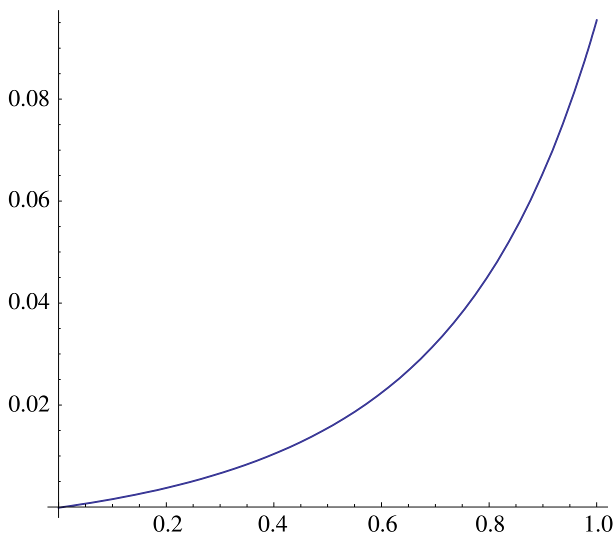

Figure 2. Numerical simulation of CS^{**} - CS^{***}. Source: Simulated by the authors with Mathematica 9.0.

Proof of Proposition 5

If $0 < \tau < \overline{\tau}_2$ and $\tau \in (0, 0.85)$ then we have

$$SW^{**} - SW^{***} = \frac{-22847+236126\tau_2-508933\tau_2^2+472212\tau_2^3-217856\tau_2^4+48640\tau_2^5-4096\tau_2^6}{32(15-8\tau_2)^4(2-\tau_2)^2(1-\tau_2)} > 0 \text{ and}$$

$$SW^{***} - SW^{*} = \frac{2902897 - 9482281\tau_2 + 12142648\tau_2^2}{524288(2-\tau_2)^5(1-\tau_2)} - \frac{7874944\tau_2^3 - 2733056\tau_2^4 + 479232\tau_2^5 - 32768\tau_2^6}{524288(2-\tau_2)^5(1-\tau_2)} > 0.$$

The result obtained by numerical simulation for the expressions are quite complex (see Figures 3 and 4).
Conclusions are therefore achieved and the proof is complete. ■

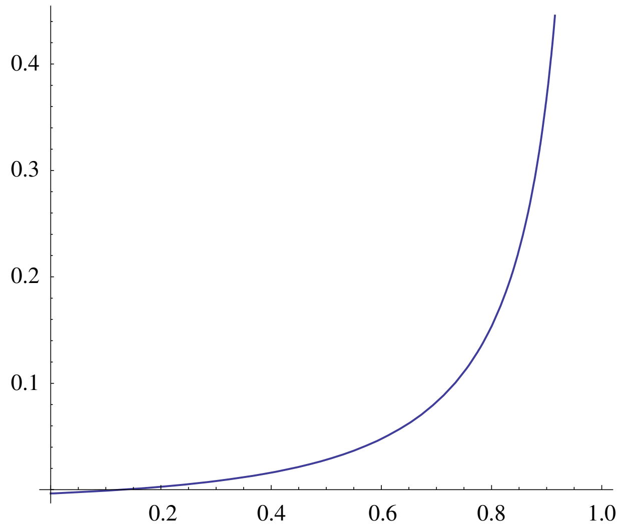

Figure 3. Numerical simulation of SW^{**} - SW^{***}. Source: Simulated by the authors with Mathematica 9.0.

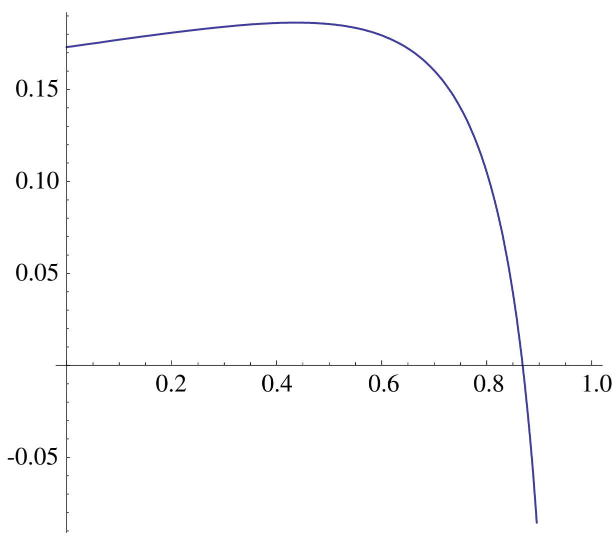

Figure 4. Numerical simulation of SW^{***} - SW^{*}. Source: Simulated by the authors with Mathematica 9.0.