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Hospital competition when patients have different willingness to pay for quality[†]

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Abstract

Two identical hospitals compete for patients choosing qualities and prices. We study the effect of the introduction of preferential provider agreement. If no hospital is preferred by the regulator, patients may pay a portion of the price no matter the provider selected. Otherwise patients may receive a reimbursement only if choosing the hospital preferred by the regulator.

We show that quality and patient surplus are always higher when hospitals are equally treated although total payments and coverage might be respectively higher and lower when one provider is preferred. A minimum quality standard has unambiguously positive effects: it increases patient surplus, welfare and market coverage, and it decreases total payment to hospitals.

Keywords: *hospitals, quality, minimum quality standards, preferential provider agreements*

JEL classification: I11, I18, L13, L52

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1. Introduction

Various theoretical contributions have studied strategic hospital quality competition. Some of them[1] extend the standard Hotelling (1929) location model allowing hospitals to choose qualities (usually under price regulation). Other contributions[2], instead, extend Salop (1979) circular-city location model in order to study the relationship between market structure and quality provision. A common feature of both branches of this literature is the assumption that patients have homogenous preferences with respect to quality. In other words, these works belong all to the family of models of horizontal product differentiation. Assuming in addition symmetric locations and full market coverage, these models produce symmetric equilibria in which all hospitals provide the same level of quality.

The aim of this paper is to study hospital quality competition relaxing the rather unrealistic assumption that patients have identical preferences for quality. Specifically, we make use of the vertical product differentiation framework proposed by Mussa and Rosen (1978) and explored in detail by Motta (1993). Intuitively, if consumers have heterogeneous preferences for quality and firms compete in qualities in the long-run and prices (or quantities) in the short-run, in equilibrium firms might provide different qualities to relax competition through (vertical) product differentiation. The same idea will work in our model. If for instance patients have different willingness to pay for quality[3], we would expect hospitals to vertically differentiate their services. In line with previous contributions[4] we assume that hospitals face fixed quality-dependent costs. The interpretation of such an assumption is that hospital quality can be increased for example through investments in technology[5]. Richer patients, for instance, might be willing to pay more to be treated with a more advanced (and maybe less painful or invasive) technique.

Lately cost containment of the hospital sector has become a priority for many national health system reforms worldwide. Among possible solutions to the problem, the introduction of preferential provider agreements has been proposed and adopted. A third party payer (an insurer or the health authority in a public national health system) may select one provider as preferred, for example allowing patients to receive a reimbursement only if treated by the preferred hospital. Under such a reimbursement system we would have competition between (with an insurer as a third party payer) in-plan and out-of-plan providers or (with a public health authority as the third party payer) between public and private providers. In this sense, our paper is closely related to Barros and Martinez-Giralt (2002), B-M (2002) from now on. The authors study a Hotelling (1929) duopoly in which hospitals are located at the endpoints of the linear city and, again, patients are assumed to have homogenous preferences with respect to quality. Two identical hospitals compete strategically in qualities and prices, under different reimbursement systems with preferential provider agreements.

The objective of our analysis is to consider how the introduction of preferential provider agreements can affect patients' welfare (also in terms of market coverage), quality provision and total payments to the hospital system when patients have heterogeneous preferences with respect to quality.

Specifically, we shall consider two reimbursement systems[6]: Pure Preferred, *PP*, and Fixed Reimbursement Rate, *FRR*. Following B-M (2002), we assume that all patients are covered by a health care insurance[7] and that the regulator[8] might prefer one hospital[9].

[1] See Calem and Rizzo (1995), Brekke et al. (2006) and (2007).

[2] See for example Gravelle and Siciliani (2008) and Brekke et al. (2008).

[3] As a matter of fact, marginal willingness to pay for quality can also be interpreted as patients' income. See Tirole (1988).

[4] The same assumption is adopted in Calem and Rizzo (1995), Brekke et al. (2006), (2007), B-M (2002).

[5] Clearly, in general quality is generated through a mix of fixed and variable (such as more skilled labour or raw materials) costs; in addition, hospital quality can be an even more complex concept, being usually thought as a multivariate vector of characteristics of the services that together form the quality of care (see Chalkley e Malcomson (2000)). To simplify the treatment will follow the related literature assuming the existence of only fixed quality-dependent costs.

[6] In B-M (2002) one additional copayment system is studied, i.e. Fixed Copayment system, in which the reimbursement received by patients treated by the out-of-plan hospital depends on the price chosen by the preferred provider. As pointed out by the authors, such a system better describes an arrangement with reference prices as in the pharmaceutical market rather than competition for secondary care.

[7] We can also imagine a public health care system regulated by a central planner who selects a preferred hospital. We shall use the terms insurer/planner and hospital/provider interchangeably throughout the text.

[8] Throughout the analysis we shall refer to a regulator. Alternatively we can think of an insurer or generic third party payer.

Under the *FRR* system all patients receive a reimbursement no matter the hospital they choose. Under *PP*, instead, patients treated by the out-of-plan hospital pay the full price; those who are treated in the preferred hospital pay only part of the price.

Given these two reimbursement systems, B-M (2002) showed that the model under *FRR* produces a symmetric equilibrium. Under *PP* instead the preferred hospital would charge a higher price and earn higher profits compared to the out-of-plan rival. In addition, the authors showed that under *PP* the preferred hospital would provide higher quality and charge a higher price than under *FRR*. In contrast, the out-of-plan hospital would provide higher quality and charge a higher price under *FRR*. The intuition is straightforward. Under *PP* the preferred hospital enjoys a competitive advantage (i.e. treating patients who would receive a reimbursement) and faces higher marginal revenues with respect to quality. Under *FRR* instead the two hospitals are treated equally by the regulator and the out-of-plan provider can enjoy too the possibility to serve patients who receive a reimbursement. A side effect (in particular for the health authorities considering cost controls) of this reimbursement system might be that total payments to hospitals will be higher under *FRR*.

Given patients' heterogeneity with respect to willingness to pay for quality, it follows that our model embodies instead two realistic sources of asymmetry in competition. First, similarly to B-M (2002), under *PP* system, even if hospitals may be identical, the hospital preferred by the insurer enjoys a competitive advantage since part of the admission price charged is sustained by the insurer[10]. The second source of asymmetry, absent in B-M (2002), is related to the assumption that patients have different willingness to pay. In fact, the high quality provider would enjoy the advantage to charge richer patients. Consequently, our model produces two equilibria (symmetric under *FRR* and asymmetric under *PP*) under each reimbursement system and reverses most of the results described in B-M (2002). In particular under *PP* if the preferred hospital is the high quality provider, it can now enjoy both types of competitive advantages and consequently charge higher prices and earn higher profits. Qualities are again lower compared to *FRR*. Interestingly and in contrast to B-M (2002), prices charged by the preferred hospital will be so high that the total payments to the hospitals will be higher under *PP*. This result would indicate that the adoption of preferential agreements motivated by cost containing reasons can not be defended when patients have different willingness to pay for quality.

In contrast to related contributions mentioned above, our model considers equilibria with partial coverage. Some patients might have a willingness to pay so low not to find beneficial to access hospital care. We show that comparisons in term of market coverage between the two reimbursement systems depend on the specific equilibrium considered. In particular market coverage will be higher under *PP* (under *FRR*) if the preferred hospital provides in equilibrium the low (high) quality service. It follows that the main message of our paper is that consideration of the type of competition and the nature of patients' preferences should play a crucial role when evaluating the effects of the introduction of preferential provider arrangements for secondary care.

After describing and comparing the different equilibria of the model, the paper studies the effects of the introduction of a Minimum Quality Standard, MQS. If quality provision were suboptimal, a regulator might impose a MQS, for instance in the form of a minimum level of investment in technology. The paper shows that the introduction of a MQS may produce positive effects on all variables of the model (except the profits of the high quality provider, when the preferred hospital offers the low quality service) and helps containing the level of the total payments to the hospital system. Intuitively, a MQS (restricting the quality space) increases the level of competition in the short-run and, since qualities are strategic complements (as we are going to show below), quality provision, patient surplus, and market coverage increase, while prices decrease. The positive social effect of the adoption of a MQS more than offsets the possible negative effect on profits, increasing total welfare. This result is again in contrast to B-M (2002), where unregulated qualities were in general socially excessive. In our model instead an increase in qualities (for instance due to the adoption of a MQS) would produce an unambiguous positive effect on patients (who would enjoy higher qualities for lower prices, due to the increase in competition generated by the reduction in

[9] The analysis of the regulator/insurer choice of the preferred hospital and the adoption of an efficient bargaining system is out of the scope of this paper.

[10] This type of advantage is absent in related contribution on vertical product differentiation.

vertical product differentiation) and market coverage, more than offsetting potential negative effects on hospital profits.

The reminder of the paper is organized as follows. In section two we introduce the model. In section three we describe the unregulated equilibria under *FRR*. In section four we describe the equilibria under *PP* and produce our main results. In section five we study the effects of the introduction of a MQS on the main variables of the model. Section six concludes.

2. The model

The model has the following assumptions.

- Two identical hospitals offer the same treatment; their services are differentiated only with respect to quality. Qualities are observable but not contractible. Let us define $s_i \in \Re_+$, $q_i \in \Re_+$, $p_i \in \Re_+$ as, respectively, the quality provided, the number of patients treated and the price charged by hospital *i*, $i = 1, 2$.
- There is a unit mass of patients and they all have hospital care coverage; each patient requires at most one unit of hospital service; in addition, patients have different willingness to pay for quality, represented by the parameter $t \in [0,1]$, uniformly distributed on its support with density equal to one; the net surplus of a generic patient *k* treated by hospital i is given by $v_k^i = b + t_k s_i$, where $b \in \Re_+$ represents the benefit from recovering from a disease and it might be thought as the level of severity of the illness. We are therefore considering the case in which all patients are affected by the same health problem[11] but, since preferences with respect to quality are heterogeneous (e.g. income may differ among patients), they receive different levels of surplus depending on the level of quality provided.
- Patients' indirect utility depends on the reimbursement system adopted and, under *PP*, on the hospital chosen. Specifically, define $c \in (0,1]$ the parameter that represents the quote of the price paid by a generic patient *k*, with willingness to pay equal to t_k, served by hospital *i*. Under *FRR* the regulator allows a copayment no matter the hospital chosen and patient *k*'s indirect utility is given by: $U_k^i = v_k^i - cp_i$. Alternatively, under *PP* the regulator allows a copayment only if patients access a preferred hospital. Consequently, the indirect utility of the patients accessing the out-of-plan hospital would be $U_k^j = v_k^j - p_j$ (in other words patients have to pay the full price charged).
- The quality-dependent cost function is given by $F_i = (s_i)^2 / 2$; in line with previous literature[12], let us assume that the cost of care for each patient is equal to zero.

The problem of the two hospitals is profit maximization[13] through the choice of their investment in quality and the selection of the price for their services. Hospital *i*'s, $i = 1, 2$, profit function is given by:

$$\Pi_i(p_i, s_i) = p_i q_i - F_i \qquad (1)$$

Without loss of generality, in what follows we shall assume that if the regulator selects a hospital as preferred, then hospital 1 will be the chosen one.

We want to study the Subgame Perfect Nash Equilibria of the following three stage game[14]:

- In stage one hospitals choose simultaneously and non-cooperatively qualities and incur the related costs.

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[11] This is a key difference with respect to previous contributions adopting a horizontal differentiation framework. In those contributions patients are assumed to share the same willingness to pay for quality and suffer different diseases.

[12] Adding variable costs would complicate the analysis without adding any valuable insight. In particular, if costs were variable and quality-dependent the model would produce qualitatively similar results in line with related literature on vertical product differentiation. See for example the unregulated equilibrium in Motta (1993) and the analysis of the introduction of a MQS in Crampes and Hollander (1996).

[13] Profits maximization is a standard assumption in most of the theoretical contributions on hospital competition. It can be shown that the strategic quality choice of hospitals in a mixed duopoly equilibrium would be qualitatively unchanged.

[14] In line with previous contributions, we assume that quality decisions require a higher level of commitment compared to price selection for the provision of secondary care.

- In stage two, hospitals select prices, given qualities and reimbursement system.
- In stage three, patients choose the hospital in which to receive care and pay the price of the service according to the reimbursement system adopted.

We solve the game by the method of backwards induction.

3. No hospital preferred (*FRR*)

In this section we describe the case in which patients will receive a copayment no matter the hospital chosen. In this scenario both provider are essentially equally financially treated by the health authority. To this benchmark case we shall compare in section 4 the alternative reimbursement system *PP*.

Given the symmetry under *FRR* and the fact that the two hospitals are ex-ante identical, the model produces two symmetric equilibria, depending on the quality ranking. The model is essentially a more general case of the standard pure vertical differentiation model[15] as described in Motta (1993). Let us suppose, without loss of generality, that $s_2 > s_1 > 0$.

Hospitals market shares are given by the conditions that define the willingness to pay of the marginal patients, i.e. the patient indifferent to go to either hospital and the patient indifferent to be treated in the low quality hospital or not to receive any hospital care at all. The willingness to pay for quality of the former patient, say a generic patient *k*, is given by the solution of the following condition:

$$U_k^i\left(t_k, s_i, s_j, p_i, p_j, b\right) = U_k^j\left(t_k, s_i, s_j, p_i, p_j, b\right) \quad i = 1, 2,\ j \neq i \tag{2}$$

The willingness to pay for quality of the latter patient, say a generic patient *z*, is given by the solution of the following condition:

$$U_z^i\left(t_z, s_i, p_i, b\right) = 0 \quad i = 1, 2 \tag{3}$$

If the parameter *b* is sufficiently low, i.e. patients suffer a low severity pathology, those with a low willingness to pay for quality might prefer not to receive any treatment. In what follows, given our interest in studying the effects of the adoption of different reimbursement systems and minimum quality standards on market coverage, we shall focus our interest on the case in which patients are affected by a low severity health problem (i.e. low *b*). Applications of the model can be, for example, decisions regarding plastic surgery or screening (when both cases are not induced by a serious health condition). Since for *b* sufficiently low, qualitative results do not depend on the particular level of severity, in what follows we shall focus only on the case $b = 0$ for expositional clarity.

Define t_2 the willingness to pay that satisfies (2) and t_1 the willingness to pay that satisfies (3). If $s_2 > s_1 > 0$, then we have that:

$$t_1 \equiv \frac{cp_1}{s_1} \qquad t_2 \equiv \frac{c\left(p_1 - p_2\right)}{s_1 - s_2} \tag{4}$$

and consequently

$$q_1 = t_2 - t_1 \qquad q_2 = 1 - t_2 \tag{5}$$

In stage two of the game hospitals maximize profits with respect to own prices. Substituting market shares given by (5) into (1), profit functions are given by:

$$\Pi_1 = \frac{p_1 c\left(p_1 - p_2\right)}{s_2 - s_1} - \frac{cp_1^2}{s_1} - \frac{s_1^2}{2} \qquad \Pi_2 = p_2 + \frac{p_2 c\left(p_1 - p_2\right)}{s_2 - s_1} - \frac{s_2^2}{2} \tag{6}$$

[15] The standard model assumes that $c = 1$.

Equilibrium prices are given by the simultaneous satisfaction of the first order conditions[16]:

$$p_1 = \frac{s_1(s_2 - s_1)}{4c(s_1 - s_2) - 3cs_1} \qquad p_2 = \frac{2(s_2 - s_1)((s_2 - s_1) + s_1)}{c(4(s_1 - s_2) - 3s_1)} \tag{7}$$

Note that $p_2 > p_1$ for any $c \in (0,1]$. In B-M (2002) under the same reimbursement system the two hospitals would select identical prices instead. In our model, since hospital 2 treats patients with a higher willingness to pay, it can charge higher prices compared to the rival. This is an important feature of models of vertical product differentiation that will pay an important role throughout our analysis.

We can now move to the first stage of the game where hospitals maximize profits choosing qualities and expecting prices given by (7). Profits are at this stage only functions of qualities.

Specifically:

$$q_1 = \frac{s_2}{4s_2 - s_1} \qquad q_2 = \frac{2s_2}{4s_2 - s_1} = 2q_1 \tag{8}$$

$$p_1 = \frac{s_1(s_1 - s_2)}{c(s_1 - 4s_2)} \qquad p_2 = \frac{2s_2(s_1 - s_2)}{c(s_1 - 4s_2)} \tag{9}$$

$$\Pi_1 = \frac{s_1\left(2s_2(s_2 - s_1) - cs_1(s_1 - 4s_2)^2\right)}{2c(s_1 - 4s_2)^2} \qquad \Pi_2 = \frac{s_2^2\left(8s_2(1 + cs_1) - 16cs_2^2 - s_1(8 + cs_1)\right)}{2c(s_1 - 4s_2)^2} \tag{10}$$

We report some important properties of the revenues functions of the two hospitals, where $R_i = p_i q_i \; i = 1,2$.

$$\begin{array}{llll} \frac{\partial R_1}{\partial s_1} > 0 \text{ if } s_2 > \frac{7}{4}s_1 & \frac{\partial R_1}{\partial s_2} > 0 & \frac{\partial^2 R_1}{\partial s_1^2} < 0 & \frac{\partial^2 R_1}{\partial s_1 \partial s_2} > 0 \\ \frac{\partial R_2}{\partial s_2} > 0 & \frac{\partial R_2}{\partial s_1} < 0 & \frac{\partial^2 R_2}{\partial s_2^2} < 0 & \frac{\partial^2 R_2}{\partial s_2 \partial s_1} > 0 \end{array} \tag{11}$$

Properties reported in (11) ensure that profit functions are concave[17] and that qualities are strategic complements ($ds_i / ds_j > 0$)[18] for both hospitals. In equilibrium, we require $s_2 \geq (7/4)s_1$ to ensure non negativity of the marginal revenues of hospital 1.

The simultaneous satisfaction[19] of the first order conditions for profit maximization in stage one ($\partial\Pi_1/\partial s_1 = \partial\Pi_2/\partial s_2 = 0$) gives:

$$s_1 = \frac{0.0482}{c} \qquad s_2 = \frac{0.2533}{c} \tag{12}$$

Table 1 provides the values of prices, demands and profits in equilibrium. Note that the high quality provider charges higher prices, treat more patients and earns higher profits compared to the rival.

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[16] Second order conditions are easily verified.

[17] Remind the convexity of the cost function with respect to quality.

[18] The slope of the quality best response function for hospital *i* is given by differentiating the focs of profits maximization with respect to qualities, i.e. $\frac{ds_i}{ds_j} = \frac{\partial^2 R_i}{\partial s_i \partial s_j} \Big/ \left(1 - \frac{\partial^2 R_i}{\partial^2 s_i}\right) > 0$.

[19] Socs are always satisfied and it can be easily shown that no hospital has incentive to leapfrog.

$p_1 = 0.0102 / c^2$	$q_1 = 0.2625$	$\Pi_1 = 0.0015 / c^2$
$p_2 = 0.1077 / c^2$	$q_2 = 0.5250$	$\Pi_2 = 0.0244 / c^2$

Table 1: equilibrium when no hospital is preferred and $s_2 > s_1$.

Let us now describe a set of variables useful for our analysis.
Average quality is given by

$$\bar{s} = \sum_i s_i q_i \Big/ \sum_i q_i \, , \; i = 1, 2 \tag{13}$$

and in equilibrium $\bar{s} = 0.1849 / c$.
Patient Surplus, *PS*, is given by:

$$\begin{aligned} PS &= \int_{t_1}^{t_2} (ts_1 - cp_1)\, dt + \int_{t_2}^{1} (ts_2 - cp_2)\, dt = \\ &= \frac{s_2^2 (4s_2 + 5s_1)}{2(s_1 - 4s_2)^2} \end{aligned} \tag{14}$$

In equilibrium $PS = 0.04321 / c$.
Note also that:

$$\frac{\partial PS}{\partial s_1} = -\frac{s_2^2 (5s_1 + 28s_2)}{2(s_1 - 4s_2)^3} > 0 \qquad \frac{\partial PS}{\partial s_2} = \frac{s_2 (5s_1 - 4s_2)(5s_1 + 28s_2)}{(s_1 - 4s_2)^3} > 0 \tag{15}$$

are both positive since $s_2 \geq (7/4) s_1$. It follows that a policy that would increases quality provision (for instance a MQS, as we are going to show later) would be unambiguously beneficial to patients.

Let us define the Total Welfare function as the sum of *PS*, hospitals' profits minus the amount of reimbursement incurred by the regulator:

$$TW = PS + \Pi_1 + \Pi_2 - (1-c)\, p_1 q_1 - (1-c)\, p_2 q_2 \tag{16}$$

In equilibrium $TW = (0.1024c - 0.0332) / c^2$. *TW* is maximized for $c \approx 0.6485$.

An insurer/regulator might be also concerned with cost control. Following B-M (2002), let us define Total Payment as the sum of all payments to hospitals:

$$TP = p_1 q_1 + p_2 q_2 \tag{17}$$

In equilibrium $TP = 0.0875 / c^2$.

The willingness to pay for quality of the marginal patients, given by (4), define the total market coverage $(q_1 + q_2 = 1 - t_1 \approx 0.7875)$ and the respective market share of each hospital (according to (5) and table 1).

Proposition 1 summarizes our results so far.

Proposition 1

Suppose that patients who access either hospital pay a portion $c \in (0,1]$ of the price charged, no matter the hospital chosen. If the hospitals compete in qualities and prices, then the high quality provider in equilibrium will charge higher prices, serve a higher number of patients and earn higher profits. In addition, prices, profits and total payments to the hospitals are all decreasing in c.

In B-M (2002) under *FRR* both providers would select identical prices and earn identical profits. In our framework with vertical product differentiation the high quality provider enjoys instead the advantage to treat patients with a higher willingness to pay for the service. It follows that in equilibrium the high quality hospital can charge a higher price and earn higher profits.

The fact that patients pay a portion *c* of the price clearly disappears if *c* tends to one, in which case our model would coincide with a standard duopoly with vertical differentiation and short-run price competition[20].

4. Reimbursement system with a preferred hospital (*PP*)

Let us now consider the possibility that only patients who access, say without loss of generality, hospital 1 receive a copayment, whereas patients accessing hospital 2 have to pay the full price. Serving patients who pay only a portion *c* of the price charged, hospital 1 (even if ex-ante identical to hospital 2) enjoys a competitive advantage. It follows that the model produces in this case two asymmetric equilibria, depending on which hospital is the high quality provider in equilibrium. In what follows we distinguish the case in which the preferred hospital is the low quality provider and the opposite one. The two equilibria will be then compared to the benchmark case described in the previous section.

4.1. Equilibrium with $s_2 > s_1 \geq 0$

In this subsection we study the case in which in equilibrium the preferred hospital 1 is the low quality provider. Such an equilibrium may resemble health care competition in those countries in which a copayment is provided only for treatment in a (low quality) public facility and patients can opt out of the public system and access a more expensive (and technologically advanced) private option.

In stage two of the game hospitals maximize profits with respect to own prices. Similarly to what we did in the previous section, we need to identify the willingness to pay of the marginal patients, respectively denoted by t_3 and t_4. If $s_2 > s_1$, marginal patients' willingness to pay for quality are given respectively by:

$$t_4 \equiv \frac{cp_1 - p_2}{s_1 - s_2} \qquad t_3 \equiv \frac{cp_1}{s_1} = t_1 \tag{18}$$

Given patients' utility function, it follows that hospitals market shares are given by

$$q_1 = t_4 - t_3 \qquad q_2 = 1 - t_4 \tag{19}$$

Substituting market shares given by (19) into (1), profit functions are given by:

$$\Pi_1 = \frac{p_1(cp_1 - p_2)}{s_2 - s_1} - \frac{cp_1^2}{s_1} - \frac{s_1^2}{2} \qquad \Pi_2 = p_2 + \frac{p_2(p_1 c - p_2)}{s_2 - s_1} - \frac{s_2^2}{2} \tag{20}$$

Equilibrium prices are given by the simultaneous satisfaction of the first order conditions[21]:

$$p_1 = \frac{s_1(s_2 - s_1)}{4c(s_1 - s_2) - 3cs_1} \qquad p_2 = \frac{2(s_2 - s_1)((s_2 - s_1) + s_1)}{(4(s_1 - s_2) - 3s_1)} \tag{21}$$

Note that now $p_2 > p_1$ for c sufficiently high (i.e. $c > s_1 / 2s_2$). In B-M (2002) instead under *PP* the only hospital that could enjoy a competitive advantage in the short-run was the preferred one and the price it charged was never lower than the price selected by the out-of-plan rival. The intuition of the

[20] See Motta (1993).

[21] Second order conditions are easily verified.

fact that the out-of-plan provider may charge the higher price in our model has to be found again in the assumption that patients have different willingness to pay for quality. The high quality provider (in this case hospital 2) can charge patients with a higher willingness to pay and might select a price higher than hospital 1.

We can now move to the first stage of the game where hospitals maximize profits choosing qualities and expecting prices given by (21). Profits are at this stage are only functions of qualities. It can be shown that the revenue functions show the same properties reported in (11).

Note that hospital 2's monopoly profits (i.e. profit that hospital 2 would earn if hospital 1 chooses $s_1 = 0$) are given by $\Pi_2^m = 1/32^2$. Note also that under *FRR* hospital 2's monopoly profits would be $\Pi_2^m = 1/32c^2$.

We are now in condition to compare the equilibrium qualities[22] when $s_2 > s_1 \geq 0$ depending on the reimbursement system adopted. In fact, given the expression of the high quality hospital's monopoly profits and the fact that the expressions of $ds_i / ds_j > 0 \;\; i = 1,2 \; i \neq j$ are identical under the two systems, the quality best response function of hospital 2 when the regulator does not have a preferred hospital lies above the best response function of the same hospital when the regulator prefers hospital 1 for any s_1. Moreover, since qualities are strategic complements, it follows that both qualities are higher when no hospital is preferred. The intuition of the result is straightforward. If no provider is preferred, then both hospitals enjoy the advantage to treat patients who pay only a portion of the price and can generate higher marginal revenues with respect to own quality. Given the strategic complementarity of qualities, it follows that both hospitals have a higher incentive to provide high qualities under *FRR* than under *PP*[23]. As we mentioned above, in B-M (2002) the preferred hospital would provide higher quality under *PP* instead.

Average quality is again given by (13) and since $\partial \overline{s} / \partial s_i > 0, i = 1,2$, given our discussion above, average quality is higher under *FRR*. Patient Surplus, *PS*, is given again by (14) and, since qualities will be higher, it follows that patient surplus will be higher under when no hospital is preferred. It is also easy to notice that in equilibrium p_i, Π_i and p_i / s_i are higher when no hospital is preferred.

Total Payment function is given again by (17). Total Welfare instead is given by

$$TW = PS + \Pi_1 + \Pi_2 - (1 - c)\, p_1 q_1 \tag{22}$$

Numerical simulations[24] show that demands are decreasing in *c* and are higher when hospital 1 is preferred (and provides the low quality). *TP* is decreasing in *c* and is higher under *FRR* (in line with B-M (2002). Total welfare, *TW*, is increasing (decreasing) in *c* under *FRR* (*PP*) and higher under *PP* for values of *c* sufficiently low. Intuitively under *FRR* an increase in *c* translates in a decrease in total payments that more than offsets the decrease in qualities, profits and patient surplus. Under *PP* instead an increase in *c* translates into an increase in the competitive advantage for hospital 1 that in turns increases its quality and (due to the strategic complementarity described above) induces an increase in the rival's quality too. On aggregate patients are better off and the increase in patient surplus more than offsets the increase in total payments to the hospitals.

Proposition 2 summarizes the comparisons of the equilibria when $s_2 > s_1$ under the two different reimbursement systems.

[22] We report in the appendix the results of numerical simulations describing the unregulated equilibria under the two different reimbursement systems.

[23] It can be shown that no hospital has the incentive to deviate from the equilibrium *leapfrogging* the rival, i.e. the low quality provider has no incentive to increase its quality to the point to provide the high quality in the market and *vice versa*.

[24] All calculations have been performed with the software Mathematica. See tables 3 and 4.

Proposition 2

Suppose that only patients who access hospital 1 pay a portion $c \in (0,1]$ *of the price charged. If the hospitals compete in qualities and prices and in equilibrium* $s_2 > s_1$*, then both hospitals' qualities (including average quality), prices and profits, and TP are lower compared to FRR. TW is higher when hospital 1 is preferred only for values of c sufficiently low.*

Most of the results described in Proposition 2 are clearly in contrast with what has been shown in a Hotelling framework by B-M (2002) where the preferred hospital would charge higher prices and provide higher quality under *PP*.

In our framework, instead, due to patients' heterogeneous preferences and the strategic complementarity with respect to quality, the preferred hospital charges lower prices and provides lower quality compared to the case in which both providers are treated equally by the regulator. The intuition is that the advantage that the out-of-plan hospital can enjoy in this equilibrium (i.e. the possibility to treat patients with high willingness to pay) more than offsets the advantage to treat patients with the copayment (as enjoyed by hospital 1).

In the next subsection we are going to consider the case in which $s_1 > s_2$, i.e. hospital 1 will provide high quality and be the preferred provider. We clearly expect the outcome of Proposition 2 to be partially reversed.

4.2. Equilibrium with $s_1 > s_2 \geq 0$

In this subsection we study the case in which in equilibrium hospital 1 offers the high quality service. Such an equilibrium may resemble health care competition where a copayment is provided only for treatment in a higher quality facility. An example might be competition between a public research university hospital and a private clinic (which might provide a lower level of technology and expertise).

Let us study first the short-run equilibrium, where hospitals choose prices for given qualities. Define t_5 the willingness to pay of the patient indifferent to access hospital 2 or not to receive any treatment, and t_6 the willingness to pay of the patient indifferent to access either hospital.

If $s_1 > s_2 \geq 0$, marginal patients' willingness to pay for quality is given respectively by:

$$t_6 \equiv \frac{cp_1 - p_2}{s_1 - s_2} = t_4 \qquad t_5 \equiv \frac{p_2}{s_2} \tag{23}$$

Hospitals market shares are now given by:

$$q_1 = 1 - t_6 \qquad q_2 = t_6 - t_5 \tag{24}$$

Substituting market shares given by (24) into (1), the respective profit functions are given by:

$$\Pi_1 = p_1 + \frac{p_1 (cp_1 - p_2)}{s_2 - s_1} - \frac{s_1^2}{2} \qquad \Pi_2 = \frac{p_2 (p_2 s_1 - cp_1 s_2)}{s_2 (s_2 - s_1)} - \frac{s_2^2}{2} \tag{25}$$

The simultaneous satisfaction of the first order conditions[25] gives:

$$p_1 = \frac{2s_1 (s_1 - s_2)}{3cs_1 + c(s_1 - s_2)} \qquad p_2 = \frac{(s_1 - s_2)(s_2)}{(3s_1 + (s_1 - s_2))} \tag{26}$$

[25] Second order conditions are once more easily verified.

Note that now $p_1 > p_2$. This result is in line with B-M (2002). However, now hospital 1 charges the high price for two reasons. First it is the high quality provider and it can exploit the advantage to treat patients willing to pay more for quality. Second, being the preferred hospital, it treats patients who pay only a portion of the price.

In the first stage of the game, hospitals maximize profits choosing qualities and expecting prices given by (26). Revenue functions show the same properties we have described in the previous section. In equilibrium the condition $s_1 \geq (7/4)s_2$ must be satisfied to ensure non-negative marginal revenues for hospital 2.

The profits that hospital 1 would earn if hospital 2 does not enter the market (i.e. $s_2 = 0$) are given by $\Pi_1^m = 1/2$.

The result of the comparisons between equilibrium qualities under the two reimbursement regimes considered is similar[26] to the outcome described before. Since qualities are strategic complements, it follows that if no hospital is preferred, then both qualities are again higher. Figure 1 provides a graphical description of the two (equally plausible according to a Pareto criterion) pure strategy Subgame Perfect Equilibria of the game that we have described so far. Let s_i^* $i = 1,2$ represent the level of quality chosen by the rival for which hospital $j = 1,2,\ j \neq i$ is indifferent whether to be the high or the low quality provider. Such a *switchpoint* s_i^* solves equation:

$$\max_{s_j} \Pi_h = \max_{s_j} \Pi_l \qquad (27)$$

where subscripts *h* and *l* represent the profits of firm *j* if it is respectively the high or the low quality provider. $s_1(s_2)$ is the quality best response function of firm *1* with respect to the quality selected by firm 2. $s_2(s_1)\big|_{PP}$ and $s_2(s_1)\big|_{FRR}$ represent respectively the quality best response function of firm *2* with respect to the quality selected by firm 1 under *PP* and *FRR*.

Clearly, given the fact that the two hospitals are identical and that under *FRR* the regulator treats them equally, the equilibria under *FRR* are perfectly symmetric. The *PP* regime, instead, produces a clear competitive advantage only for hospital 1 that can treat richer patients in the short-run. Notice that for $c = 1$ our model reproduces the case shown in Motta (1993).

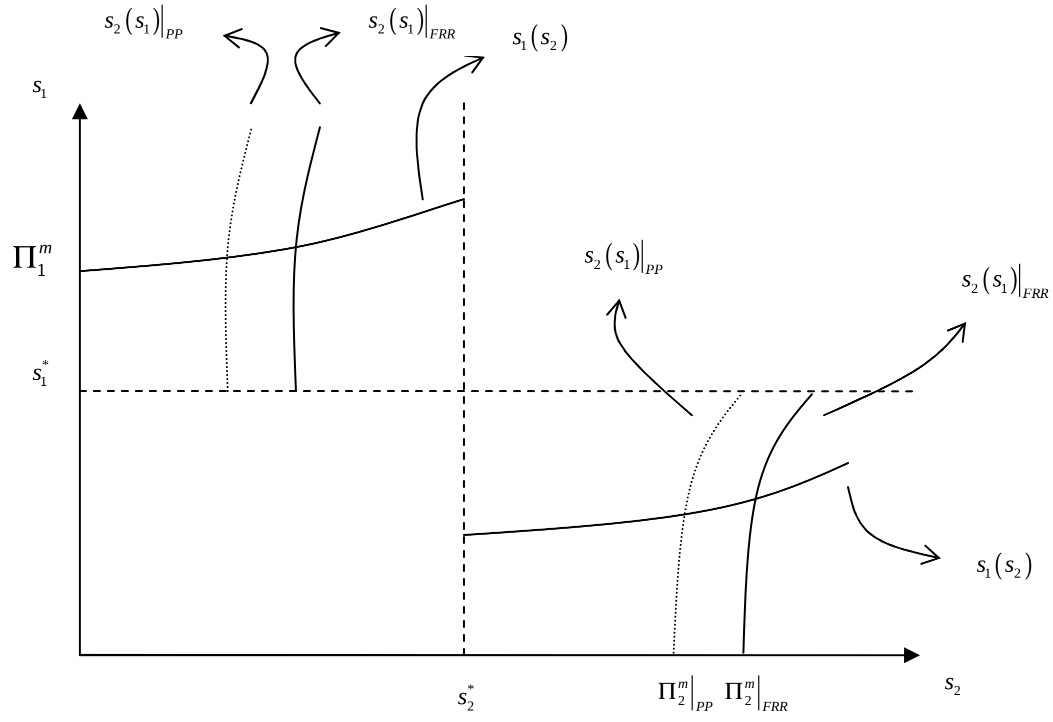

Figure 1: quality best response functions and unregulated equilibria

[26] The same intuition proposed above can be applied here. In addition, the result is obvious under FRR, given the perfect symmetry of the model for any *c*.

The definition of *PS* is now given by:

$$PS=\int_{t_4}^{t_3}\left(ts_2-p_2\right)dt+\int_{t_3}^{1}\left(ts_1-cp_1\right)dt=$$
$$=\frac{s_1^2\left(4s_1+5s_2\right)}{2\left(s_2-4s_1\right)^2} \tag{28}$$

Note that:

$$\frac{\partial PS}{\partial s_1}=\frac{s_1\left(4s_1-5s_2\right)\left(2s_1+s_2\right)}{2\left(4s_1-s_2\right)^3}>0 \qquad \frac{\partial PS}{\partial s_2}=\frac{s_1^2\left(28s_1+5s_2\right)}{2\left(4s_1-s_2\right)^3}>0 \tag{29}$$

Again, *PS* would be higher if no hospital is preferred, since qualities would be higher.

Notice that the out-of-plan hospital's prices and profits are lower[27] when hospital one is preferred provider. In contrast to the equilibrium described in the previous section and as we expected, p_1, Π_1 and p_1/s_1 are higher when hospital 1 under *PP*. Intuitively, hospital 1 is exploiting the advantage to be the preferred and the high quality provider.

The Total Welfare function, *TW*, is given again by the sum of *PS*, hospitals' profits minus the amount of reimbursement incurred by the regulator. Total Payment is again described by (17). The equilibrium values of the willingness to pay for quality of the marginal patients, given by (23), define the total market coverage $\left(q_1+q_2=1-t_5\right)$ and the respective market share of each hospital, according to (24).

It can be shown[28] that the unregulated equilibrium qualities produced ensure that an increase in *TW* follows an increase in either quality. Numerical simulations show that *TW* (initially increasing and then decreasing in *c*) and *TP* (*c* sufficiently low) are higher under *PP*. Both demands (non-decreasing in *c*) are higher under *FRR*.

Notice that when the preferred hospital is the high quality provider, less patients are treated but in aggregate they receive a higher benefit (due to the higher quality provided). Payments to the hospitals are also higher in this case (due to the high prices charged by the preferred hospital). Comparisons[29] between the two equilibria under *PP* in terms of social welfare are ambiguous and depend on *c*.

Proposition 3 compares the equilibria described in this section where hospital 1 is preferred to the equilibrium described in section 3 where both hospitals are equally treated by the regulator.

Proposition 3

Suppose two identical hospitals play a quality/pricing game. Suppose in addition that hospitals face fixed quality-dependent costs and that two alternative reimbursement systems, namely PP and FRR, may be implemented. Then individual qualities and patient surplus are always higher under FRR, i.e. when no hospital is preferred.

In addition,

a) if $s_2>s_1\geq 0$*, under FRR average quality and total payment are always higher than under PP. Market coverage is instead always higher under PP. Total welfare is higher (lower) under PP for low (high) levels of c.*

b) if $s_1>s_2\geq 0$*, total welfare is higher under PP. Market coverage is higher under FRR. The total payment to the hospital system and average quality are higher under PP for c sufficiently low.*

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[27] Notice, again, that *leapfrogging* is not a profitable deviation from the equilibrium for either hospital.

[28] See tables 5-6 in the appendix.

[29] A general equilibrium model might be necessary to identify optimal selection of provider by the regulator. We leave this analysis for future research.

Interestingly, in contrast to B-M (2002), our model shows that not necessarily *FRR* is the system that generates the highest payments to hospitals. In our model the quality ranking, i.e. whether the preferred hospital provides the high or the low quality in equilibrium, plays a crucial role. In fact, if hospital 1 is the high quality provider and the hospital chosen by the regulator, it enjoys a competitive advantage so high that may increase significantly the payments required. Eventually, total payments might be higher under *PP*.

It is important to stress that, again in contrast to B-M (2002), in our model due to the quality strategic complementarity hospital 1 will choose a lower quality and charge lower prices under *PP*.

Finally, our model provides some information about the equilibrium market coverage. In our setup market coverage is defined by the willingness to pay of the marginal patient indifferent to access the low quality hospital treatment or not be treated at all. In the equilibrium under *PP* in which $s_2 > s_1 \geq 0$ (case (a) in the proposition) the willingness to pay of the marginal patient is defined by a portion *c* of the hedonic price p_1 / s_1 (see (18)). As we mentioned above, if preferred, hospital 1 charges a lower hedonic price. The intuition is that under *PP both* hospitals have a smaller incentive to provide high qualities and that translates into a lower degree of differentiation. The fact that under *PP* qualities are lower produces the direct effect to increase p_1 / s_1; however the lower degree of differentiation at the same time has a negative effect on hospital 1's price that more than offsets that direct effect mentioned above. The intuition of the result is more straightforward for the equilibrium in which $s_1 > s_2 \geq 0$. The willingness to pay of the patient indifferent to access hospital 2 or to receive no treatment at all such a patient is clearly lower under *FRR* since he would pay only a portion *c* of the price even if accessing the out-of-plan provider.

From a policy point of view the model presents a possible trade-off. If the regulator targets patient welfare maximization, then both providers should be treated equally (for higher levels of the co-payment parameter *c FRR* performs better also from a social point of view). However, a regulator might be concerned (for political and budget reasons[30]) also with the level of *TP* generated by the hospital system or with the degree of market coverage; if this is the case, then it might be necessary to consider specific situations, since the regulator might have to face a trade-off between total welfare and the level of total payment (or market coverage).

5. The introduction of a Minimum Quality Standard

We have shown that an increase in the qualities provided in the unregulated equilibria, no matter the reimbursement system and no matter the quality ranking, would be beneficial to patients. A health authority might be able to impose a minimum quality standard, i.e. a minimum level of quality that each hospital has to provided in order to serve the market. Related literature on MQS and vertical product differentiation has shown that the effects of a MQS depend on the type of short-run competition[31] (i.e. price or quantity competition) and on the number of rivals in the market[32]. The intuition is that depending on the degree of competition in the short-run or the number of firms in the market, rivals would react differently to an (imposed) increase in the lowest quality in the market.

Given the strategic complementarity we have described above, we can expect that the result of the introduction of a standard that increases the lowest quality in the unregulated equilibrium would produce an increase on the high quality too, unambiguously increasing patitients' surplus. Still it remains to understand what would be effects of a MQS on other variables in the model.

To study the effects of the introduction of a marginal MQS, i.e. a MQS slightly higher than the lowest quality provided in the unregulated equilibrium, we consider the total differential of the main variables of the model and perform comparative static analysis on the equilibrium when the low quality is marginally increased[33].

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[30] The analysis might even by more complex if we consider the presence of externalities produced by the quality of the hospital service. Again a general equilibrium model might be necessary to answer precisely the question of the ideal level of reimbursement and such an analysis is out of the scope of our paper.
[31] See Ronnen (1991) and Valletti (2000).
[32] See Scarpa (1998) and Pezzino (2010).
[33] It is out of the scope of our paper the study of endogenous MQS, i.e. standards chosen by a regulator to maximize social welfare. See Ecchia and Lambertini (1997).

Tables 2 and 3 and Proposition 4 report the effects of the introduction of a marginal MQS on the main variables of the model[34]. The symbol + (-) means that the introduction of standard has a positive effect on the variable considered.

$s_2 > s_1$	$\frac{ds_2}{ds_1}$	$\frac{d\Pi_1}{ds_1}$	$\frac{d\Pi_2}{ds_1}$	$\frac{d\overline{s}}{ds_1}$	$\frac{dCS}{ds_1}$	$\frac{dTW}{ds_1}$	$\frac{dt_1}{ds_1}$	$\frac{dt_2}{ds_1}$	$\frac{dTP}{ds_1}$
PP	+	+	-	+	+	+	-	-	-
FRR	+	+	-	+	+	+	-	-	-

Table 2: effects of the introduction of a marginal MQS when $s_2 > s_1$.

$s_1 > s_2$	$\frac{ds_1}{ds_2}$	$\frac{d\Pi_1}{ds_2}$	$\frac{d\Pi_2}{ds_2}$	$\frac{d\overline{s}}{ds_2}$	$\frac{dCS}{ds_2}$	$\frac{dTW}{ds_2}$	$\frac{dt_1}{ds_2}$	$\frac{dt_2}{ds_2}$	$\frac{dTP}{ds_2}$
PP	+	-	+	+	+	+	-	-	-
FRR	+	-	+	+	+	+	-	-	-

Table 3: effects of the introduction of a marginal MQS when $s_1 > s_2$.

Proposition 4

Regardless the reimbursement system adopted, the introduction of a MQS increases both qualities, average quality, consumer surplus, welfare and market coverage. The total payment to the hospital system decreases and the profits of the high (low) quality provider decrease (increase).

The results are in line with related literature[35] on MQS. The intuition is that a standard reduces the quality space for hospitals and, therefore, increases the degree of competition in the short-run. With fiercer competition, qualities increase and prices decrease; all other results follow. In particular, notice that an increase in both qualities due to the MQS has a positive effect on social optimum. The result stands however in contrast to the outcome described in B-M (2002) where equilibrium qualities were socially excessive under both reimbursement systems.

Notice that we have focused our attention on the introduction of a standard slightly above the lowest quality provided in the unregulated equilibrium. In particular, we did not consider the possibility that the regulator could impose a standard sufficiently high to drive the low quality hospital out of the market[36]; we have not considered the possibility that for standards sufficiently high the high quality hospital could strategically increase its quality in order to deter the entrance of the low quality hospital[37].

In line with related contributions, we have assumed throughout the analysis that quality (e.g. technology) was observable but not contractible; at most a regulator can impose a minimum level of quality in the form of a MQS. Clear, an interesting question would be how the outcome of the model would be affected by the assumption that quality would be not observable, for example to the regulator or to the patients. The regulator might have to incur monitoring costs and consider an incentive scheme to induce the providers to perform efficiently; patients might require information provided for instance by general practitioners (who in turn would require an appropriate incentive scheme to provide information efficiently). We leave the study of these issues for future research.

[34] The use of numerical simulations was required to identify the sign of the effect of the MQS on *TW*, t_1, t_2 and *TP*.

[35] See Ronnen (1991).

[36] In fact, it can be shown that for a MQS sufficiently high the low quality hospital's profits start decreasing, eventually to the point to turn negative.

[37] It could be worth it to consider the possibility that hospitals compete in quantities in the short run. Since Cournot competition is milder than Bertrand competition, we should expect that the model might produce different results, especially regarding the effects of the introduction of a MQS (see Valletti (2000) and Pezzino (2010)).

6. Conclusions

The aim of the paper was to describe the role played by heterogeneous patient willingness to pay for quality in a simple model of hospital quality competition. Introducing such a realistic feature (and to our knowledge surprisingly not considered so far in previous contributions) implies that hospital competition might have some features described by models of pure vertical product differentiation. Quality is a key variable in the hands of hospital management to differentiate their service and to relax short-run competition in attracting patients. At the same time, patients might have different willingness to pay for quality for instance due to different income endowments. Richer patients might be willing to pay more for their recovery at a hospital that provides more advanced technology and more comfortable facilities.

We studied hospital competition, modeled according to the standard framework of pure vertical competition, in qualities and prices under different reimbursement systems.

We first considered equilibria under *FRR*. Depending on the quality ranking, the model produces two symmetric (since the two hospitals are assumed identical and are treated equally by the regulator) equilibria. In other words, under *FRR* only the asymmetry produced by the vertical differentiation survives. Under *PP* instead one hospital is preferred and only patients treated by the preferred hospital receive a reimbursement. Under such a system the preferred hospital has a clear competitive advantage over the rival. In this case the model will produce two asymmetric equilibria, depending on the quality ranking. We showed that under *FRR* in contrast to B-M (2002) the high quality provider will charge higher prices, serve a higher number of patients and earn higher profits. Intuitively, in our model the high quality provider is exploiting the possibility to treat patients with a high willingness to pay. Under *PP* we will have to distinguish between two cases. First, if the preferred hospital provides the low quality in equilibrium, then in contrast to B-M (2002) both hospitals' qualities (including average quality), prices and profits, and are lower compared to *FRR*. In addition the preferred hospital might charge a price lower than the out-of-plan rival. Intuitively, the advantage to be the high quality producer in our framework more than offsets the advantage to be the preferred hospital under *PP*. Not surprisingly, total payments to hospitals are instead lower under *PP*, in line with B-M (2002).

In addition, we have described the effects of the introduction of a marginal minimum quality standard in such a model. The main message of the paper is that the evaluation of the performance of different reimbursement systems hinges significantly on the nature of hospital competition and on the type of heterogeneity among patients' preferences.

Specifically, we have shown that both qualities provided in the two unregulated equilibria and patient surplus are higher under *FRR*. Other results and policy implications, some of which in contrast to what has been shown in B-M (2002), have been described. For example, not necessarily *PP* is the system that ensures lower payments to hospitals. We have shown that when the preferred hospital is the high quality provider, then the result shown in B-M (2002) will be reversed. In addition, the out-of-plan hospital might not charge always lower prices, for instance when providing the high quality service.

We have finally shown that the introduction of MQS has positive effects on all variables of the model (except the profits of the high quality provider, when the preferred hospital offers the low quality service) and helps containing the level of the total payment to the hospital system.

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APPENDIX

Numerical Simulations

C	s_1	s_2	Π_1	Π_2	p_1	p_2	t_1	t_2	***PS***	***TW***	$\overline{s}$	q_1	q_2	***TP***
0,5	0,1496	0,2840	0,1062	0,0042	0,4076	0,0774	0,1363	0,4242	0,0781	0,0770	0,2392	0,2879	0,5758	0,1619
0,1	0,1356	0,2781	0,0471	0,0075	0,1978	0,0812	0,1459	0,4306	0,0726	0,0765	0,2306	0,2847	0,5694	0,1025
0,15	0,1239	0,2735	0,0282	0,0102	0,1274	0,0844	0,1542	0,4362	0,0681	0,0760	0,2236	0,2819	0,5638	0,0835
0,2	0,1140	0,2699	0,0192	0,0123	0,0920	0,0872	0,1615	0,4410	0,0644	0,0754	0,2179	0,2795	0,5590	0,0744
0,25	0,1055	0,2670	0,0141	0,0141	0,0708	0,0896	0,1678	0,4452	0,0614	0,0748	0,2131	0,2774	0,5548	0,0694
0,3	0,0980	0,2646	0,0108	0,0156	0,0567	0,0918	0,1734	0,4490	0,0588	0,0742	0,2091	0,2755	0,5510	0,0662
0,35	0,0916	0,2627	0,0086	0,0168	0,0467	0,0937	0,1784	0,4523	0,0566	0,0737	0,2056	0,2739	0,5477	0,0641
0,4	0,0858	0,2611	0,0070	0,0179	0,0392	0,0955	0,1828	0,4552	0,0547	0,0732	0,2027	0,2724	0,5448	0,0627
0,45	0,0807	0,2598	0,0058	0,0189	0,0335	0,0971	0,1868	0,4579	0,0530	0,0727	0,2001	0,2711	0,5421	0,0617
0,5	0,0762	0,2587	0,0049	0,0197	0,0290	0,0985	0,1904	0,4603	0,0515	0,0723	0,1978	0,2699	0,5397	0,0610
0,55	0,0721	0,2577	0,0042	0,0204	0,0254	0,0998	0,1936	0,4624	0,0503	0,0719	0,1958	0,2688	0,5376	0,0605
0,6	0,0684	0,2569	0,0037	0,0211	0,0224	0,1010	0,1965	0,4643	0,0491	0,0715	0,1941	0,2678	0,5357	0,0601
0,65	0,0650	0,2562	0,0032	0,0217	0,0199	0,1021	0,1992	0,4661	0,0481	0,0711	0,1925	0,2669	0,5339	0,0598
0,7	0,0620	0,2556	0,0028	0,0222	0,0179	0,1031	0,2016	0,4677	0,0472	0,0708	0,1911	0,2661	0,5323	0,0596
0,75	0,0592	0,2551	0,0025	0,0227	0,0161	0,1040	0,2038	0,4692	0,0464	0,0705	0,1898	0,2654	0,5308	0,0595
0,8	0,0566	0,2546	0,0023	0,0231	0,0146	0,1048	0,2058	0,4706	0,0456	0,0702	0,1886	0,2647	0,5294	0,0594
0,85	0,0543	0,2542	0,0020	0,0235	0,0133	0,1056	0,2077	0,4718	0,0449	0,0699	0,1876	0,2641	0,5282	0,0593
0,9	0,0521	0,2539	0,0018	0,0238	0,0121	0,1063	0,2094	0,4730	0,0443	0,0696	0,1866	0,2635	0,5270	0,0592
0,95	0,0501	0,2536	0,0017	0,0241	0,0111	0,1070	0,2110	0,4740	0,0437	0,0694	0,1858	0,2630	0,5260	0,0592
1	0,0482	0,2533	0,0015	0,0244	0,0103	0,1077	0,2125	0,4750	0,0432	0,0692	0,1850	0,2625	0,5250	0,0592

Table 4: Equilibria under PP when $s_2 > s_1$

c	s_1	s_2	Π_1	Π_2	p_1	p_2	t_1	t_2	***PS***	***TW***	$\overline{s}$	q_1	q_2	***TP***
0,5	0,9640	5,0660	0,6110	9,7779	4,0977	43,0689	0,2125	0,4750	0,8641	-11,2484	3,6987	0,2625	0,5250	23,6856
0,1	0,4820	2,5330	0,1527	2,4445	1,0244	10,7672	0,2125	0,4750	0,4321	-2,3000	1,8493	0,2625	0,5250	5,9214
0,15	0,3213	1,6887	0,0679	1,0864	0,4553	4,7854	0,2125	0,4750	0,2880	-0,7946	1,2329	0,2625	0,5250	2,6317
0,2	0,2410	1,2665	0,0382	0,6111	0,2561	2,6918	0,2125	0,4750	0,2160	-0,3189	0,9247	0,2625	0,5250	1,4804
0,25	0,1928	1,0132	0,0244	0,3911	0,1639	1,7228	0,2125	0,4750	0,1728	-0,1222	0,7397	0,2625	0,5250	0,9474
0,3	0,1607	0,8443	0,0170	0,2716	0,1138	1,1964	0,2125	0,4750	0,1440	-0,0280	0,6164	0,2625	0,5250	0,6579
0,35	0,1377	0,7237	0,0125	0,1995	0,0836	0,8790	0,2125	0,4750	0,1234	0,0213	0,5284	0,2625	0,5250	0,4834
0,4	0,1205	0,6333	0,0095	0,1528	0,0640	0,6730	0,2125	0,4750	0,1080	0,0483	0,4623	0,2625	0,5250	0,3701
0,45	0,1071	0,5629	0,0075	0,1207	0,0506	0,5317	0,2125	0,4750	0,0960	0,0634	0,4110	0,2625	0,5250	0,2924
0,5	0,0964	0,5066	0,0061	0,0978	0,0410	0,4307	0,2125	0,4750	0,0864	0,0719	0,3699	0,2625	0,5250	0,2369
0,55	0,0876	0,4605	0,0050	0,0808	0,0339	0,3559	0,2125	0,4750	0,0786	0,0763	0,3362	0,2625	0,5250	0,1957
0,6	0,0803	0,4222	0,0042	0,0679	0,0285	0,2991	0,2125	0,4750	0,0720	0,0784	0,3082	0,2625	0,5250	0,1645
0,65	0,0742	0,3897	0,0036	0,0579	0,0242	0,2548	0,2125	0,4750	0,0665	0,0789	0,2845	0,2625	0,5250	0,1402
0,7	0,0689	0,3619	0,0031	0,0499	0,0209	0,2197	0,2125	0,4750	0,0617	0,0785	0,2642	0,2625	0,5250	0,1208
0,75	0,0643	0,3377	0,0027	0,0435	0,0182	0,1914	0,2125	0,4750	0,0576	0,0775	0,2466	0,2625	0,5250	0,1053
0,8	0,0603	0,3166	0,0024	0,0382	0,0160	0,1682	0,2125	0,4750	0,0540	0,0761	0,2312	0,2625	0,5250	0,0925
0,85	0,0567	0,2980	0,0021	0,0338	0,0142	0,1490	0,2125	0,4750	0,0508	0,0745	0,2176	0,2625	0,5250	0,0820
0,9	0,0536	0,2814	0,0019	0,0302	0,0126	0,1329	0,2125	0,4750	0,0480	0,0728	0,2055	0,2625	0,5250	0,0731
0,95	0,0507	0,2666	0,0017	0,0271	0,0114	0,1193	0,2125	0,4750	0,0455	0,0710	0,1947	0,2625	0,5250	0,0656

Table 5: Equilibria under FRR when $s_2 > s_1$

C	s_1	s_2	Π_1	Π_2	p_1	p_2	t_1	t_2	***PS***	***TW***	$\overline{s}$	q_1	q_2	***TP***
0,5	5.0002	0.0617	12.3446	0.0019	49.5378	0.0153	0.4985	0.2508	0.6386	-9.9991	3.3676	0.5015	0.2477	24.8493
0,1	2.5005	0.0609	3.0477	0.0018	12.2727	0.0149	0.4969	0.2515	0.3260	-2.0624	1.7006	0.5031	0.2454	6.1776
0,15	1.6673	0.0602	1.3376	0.0017	5.4058	0.0146	0.4954	0.2523	0.2218	-0.7188	1.1447	0.5046	0.2432	2.7311
0,2	1.2509	0.059	0.7433	0.0017	3.0153	0.0142	0.4940	0.2530	0.1696	-0.2914	0.8663	0.5060	0.2411	1.5291
0,25	1.0010	0.0586	0.4696	0.0016	1.9128	0.0140	0.4926	0.2537	0.1383	-0.1129	0.6994	0.5074	0.2389	0.9739
0,3	0.8347	0.0579	0.6687	0.0016	1.3176	0.0137	0.4912	0.2544	0.1174	-0.0266	0.5880	0.5088	0.2368	0.6736
0,35	0.7158	0.0571	0.4882	0.0015	0.9601	0.0134	0.4898	0.2551	0.1024	0.0190	0.5082	0.5102	0.2347	0.4930
0,4	0.6267	0.0564	0.3715	0.0015	0.7293	0.0131	0.4885	0.2558	0.0912	0.0446	0.4483	0.5115	0.2327	0.3761
0,45	0.5574	0.0556	0.2917	0.0014	0.5718	0.0128	0.4872	0.2564	0.0824	0.0592	0.4017	0.5128	0.2308	0.2962
0,5	0.502	0.0549	0.2348	0.0014	0.4597	0.0126	0.4859	0.2570	0.0754	0.0676	0.3642	0.5141	0.2289	0.2392
0,55	0.4567	0.0542	0.1928	0.0013	0.3771	0.0123	0.4847	0.2576	0.0696	0.0724	0.3336	0.5153	0.2271	0.1971
0,6	0.419	0.0535	0.1611	0.0013	0.3146	0.0121	0.4835	0.2582	0.0648	0.0748	0.3080	0.5165	0.2253	0.1652
0,65	0.3871	0.0528	0.1364	0.0012	0.2662	0.0118	0.4823	0.2588	0.0607	0.0758	0.2863	0.5177	0.2235	0.1405
0,7	0.3598	0.0521	0.1169	0.0012	0.2280	0.0116	0.4812	0.2594	0.0572	0.0759	0.2676	0.5188	0.2218	0.1209
0,75	0.3361	0.0514	0.1013	0.0012	0.1973	0.0113	0.4801	0.2599	0.0541	0.0754	0.2514	0.5199	0.2202	0.1051
0,8	0.3154	0.0508	0.0885	0.0011	0.1723	0.0111	0.4790	0.2605	0.0514	0.0745	0.2372	0.5210	0.2185	0.0922
0,85	0.2971	0.0501	0.0779	0.0011	0.1517	0.0109	0.4780	0.2610	0.0490	0.0733	0.2246	0.5220	0.2170	0.0815
0,9	0.2809	0.0495	0.0691	0.0011	0.1345	0.0107	0.4770	0.2615	0.0469	0.0720	0.2134	0.5230	0.2154	0.0726
0,95	0.2664	0.0489	0.0617	0.0010	0.1200	0.0105	0.4760	0.2620	0.0450	0.0706	0.2033	0.5240	0.2140	0.0651

Table 6: Equilibria under PP when $s_1 > s_2$