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Hospital Quality Competition: A Review of the Theoretical Literature

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Abstract

Policies to promote competition amongst hospitals have been introduced in many countries as a means of improving quality. The rationale is that when hospitals face fixed prices they can only attract additional patients by increasing quality and intensified competition increases the effect of quality on demand. We review theoretical models of hospital competition to examine this argument and explain how the effect of competition on quality is sensitive to the degree of hospital altruism, profit constraints, cost structures, the degree of specialisation, soft budgets, and sluggish demand adjustments.

Introduction

Policymakers in several OECD countries are increasingly keen to introduce or encourage competition among hospitals in the attempt to improve quality of care to patients. The intuitive idea is that if hospitals are paid a fixed (regulated) price for each patient treated, then hospitals will have to compete on quality to attract patients. The policy is often the subject of intense political and academic debate.[1]

1. This is certainly the case in England (see Bloom *et al*., 2011a and b; Pollock *et al*., 2011; Bevan and Skellern, 2011; OHE, 2012).

Our primary objective in this chapter is to summarise a selection of theoretical models which highlight the mechanisms through which competition may or may not increase quality. We show how the predicted effect of competition on quality is sensitive to assumptions about the form of competition policies and the specific features of the hospital sector such as altruistic motives, profit constraints, cost structures, degree of specialisation, soft budgets and sluggish demand adjustments. We also briefly discuss optimal price regulation and the effect of competition on quality when prices are not regulated.

Following the literature we model hospitals as a single decision maker. In reality, hospitals are complex organisations with several decision makers, including managers and doctors, where arguably doctors give more weight to patient benefit compared to managers who will be concerned also with costs and overall profitability. The hospital's objective function used below is a reduced form. The quality chosen by the hospital can be interpreted as the outcome of an agreement reached by the key decision makers within the hospital. We start by providing a general model of hospital quality competition which allows for both altruistic preferences and profit motives. We also allow for profit constraints to capture key institutional features of non-profit and public hospitals.

We argue that more competition affects both the responsiveness of demand to quality and the level of demand faced by providers. If hospitals seek to maximise profit (ie are non-altruistic) and if the marginal cost of output is constant with respect to output and quality, then more competition increases quality if the price-cost margin is positive. Constraints on profit distribution generally diminishes the potential positive effect of competition on quality since the provider is less responsive to financial incentives.

If the marginal cost of treatment is increasing in output or in quality, then the positive effect of competition on quality due to a higher demand responsiveness to quality can be reinforced (or dampened) if competition leads also to lower (or higher) demand for each firm. For example, if greater competition arises from the entry of an additional provider, this typically involves less demand for each hospital. In contrast, if greater competition arises from potential patients being offered a bigger choice amongst existing providers, this could increase overall demand, with increases at higher quality providers, reductions at lower quality providers, and higher demand overall as some potential patients decide to be treated.

We discuss different possible micro-founded specifications of the demand functions, including Hotelling and Salop spatial frameworks where patients differ in the distance to the providers. In their simplest formulations with fixed total demand, lower transportation costs (ie more competition) imply a more responsive demand but have no effect on the demand of each hospital in equilibrium. If the Hotelling model is augmented with a monopolistic segment, then lower transportation costs will imply both more responsive demand and higher overall demand. In a Salop model a larger number of providers (more competition) implies that demand responsiveness to quality is unchanged (since competition is local), but each hospital faces a lower demand.

The presence of altruistic preference alters and potentially reverses the positive effect of competition on quality. In the presence of non-constant marginal cost of treatment, altruistic providers may operate at a negative profit margin and so potential increases in demand due to an increase in competition may lead them to reduce quality.

If hospitals can specialise (for example choose their location on the Hotelling line), they may respond to increased competition by further product differentiation to partially relax competition on quality.

The presence of sluggish demand adjustments implies that demand and quality may vary over time. In the presence of increasing marginal cost of treatments, quality and demand may move in opposite directions over time while converging to the steady state. The opposite holds in the presence of altruistic preferences and constant marginal cost: quality and demand move in the same direction over time. We also compare quality levels under different dynamic solution concepts which correspond to environments with different degree of competition. We show that the presence of increasing marginal cost implies that quality is lower in the more competitive environment. The opposite holds in the presence of altruistic preferences.

We conclude the review by examining the effect of competition in markets where hospitals, rather than regulators, set prices. With endogenous prices, the requirements for competition to increase quality are more stringent than with fixed prices. If competition reduces prices and thereby reduces the price-cost margin this will reduce the marginal incentive to invest in quality.[1]

A MODEL OF HOSPITAL BEHAVIOUR

In this Section, we outline a simple hospital model of quality choice and use it to make predictions about the effect of a policy which makes demand more responsive to quality. This specification brings out the importance of assumptions about the cost structure. We also show that assumptions about the hospital objectives are crucial and examine the implications of different specification of altruistic preferences. In the next section, we consider markets with several providers where demand for one provider depends on the quality of other providers. We identify the conditions under which qualities are strategic complements or substitutes (ie whether a provider responds to an increase in rival's quality by increasing or reducing

1. Our review of the literature covers a number of recent articles not included in Gaynor (2006), Gaynor and Town (2011) and Katz (2013). Moreover, it provides a much more detailed discussion and presentation of the theoretical models compared to Brekke *et al*. (2014).

quality). We then discuss the Hotelling and Salop specifications, which are common in the literature.[1]

The profit of the hospital is

$$\pi(q) = T + pD(q,\theta) - C(D(q,\theta),q) \tag{1}$$

where q is the quality of the hospital, p is the fixed price, $T \geq 0$ is a lump-sum transfer, $D(.)$ is demand,[2] θ is a competition parameter (discussed in more detail below). $C(.)$ is the cost function and depends both on the number of patients treated and quality (with $C_D > 0$, $C_q > 0$, and $C_{qq} > 0$). Both quality and quantity are costly. We assume that the hospital treats all patients who demand care: demand equals supply.[3]

We leave the specification of the cost function general with $C_{DD} \gtreqless 0$, $C_{qD} \gtreqless 0$. This specification encompasses several intuitive special cases. In the presence of diseconomies of scale, the marginal cost of treatment is increasing ($C_{DD} > 0$). This assumption will hold at least for larger hospitals: the empirical evidence shows that diseconomies of scale appear above 250-300 beds in the hospital sector (see, e.g., Aletras, 1999; Folland *et al.*, 2004, for literature surveys). The closer a hospitals' production is to capacity, the more costly it becomes to treat one more

1. The model presented in this Section is adapted from Brekke *et al.* (2011, 2012) who allow for profit constraints, altruistic preferences and non-constant marginal cost of treatment and quality. For a model where hospitals compete on waiting times rather than quality see Brekke *et al.* (2008).
2. Several empirical studies suggest that demand responds to variations in quality (see for example Beckert *et al.*, 2012, and Gaynor *et al.*, 2011 for the English National Health Service; and Luft *et al.*, 1990; Hodgkin, 1996; Tay, 2003; Ho, 2006; Howard, 2005 for the US).
3. We assume that quality can be perfectly observed by the patients. For models where quality is observed with some noise see Gravelle and Sivey (2010) and Montefiori (2005). For a model where patients face switching costs see Gravelle and Masiero (2000). For a model with gatekeeping doctors see Brekke *et al.* (2007). For a model which allows for excess demand, see Chalkley and Malcomson (1998b).

patient. The utilisation of capacity in hospitals seems to vary across countries with different health care systems. In more regulated (public) health care systems (e.g., the UK, the Scandinavian countries, Spain, Italy), there is typically excess demand (waiting), suggesting that hospitals operate at a steeper part of the marginal cost curve. However, in less regulated systems (e.g., the US, Germany, France), there is often excess supply, suggesting relatively constant hospital marginal costs. Small hospitals may instead be characterised by economies of scale ($C_{DD} < 0$).

We also allow for both cost substitutability ($C_{Dq} > 0$) and cost complementarity ($C_{Dq} < 0$) between quality and output. The assumption of cost substitutability holds if the marginal cost of treating a patient increases with quality. This is a plausible assumption. It is for example consistent with constant returns to scale with respect to the number of patients treated when the cost per patient is increasing in the quality provided ($C(.) = c(q)D$, with $C_{Dq} = c'(q) > 0$). On the other hand, treating more patients might in itself improve quality due to "learning-by-doing" effects. If sufficiently strong, it is possible that quality and output are cost complements ($C_{Dq} < 0$). As shown below, the cost structure has implications for predicting the effect of competition on quality.

We assume that providers care directly about quality, not just because of its effect on profit. This may be because they are altruistic and care about the effect of quality on patients. Or they may have reputational concerns or are intrinsically motivated. We denote the direct provider benefit from quality as $b(q)$, with $b_q(q) > 0$ and $b_{qq}(q) \leq 0$. We explore the implications of different specifications, for example with b depending on output as well, in the next subsection. Providers may also incur effort or non-monetary costs of providing quality, which we denote $\varphi(q)$, with $\varphi_q(q) > 0$ and $\varphi_{qq}(q) > 0$.

The hospital's objective function is

$$V(q) = (1 - \delta)\pi(q) + b(q) - \varphi(q) \tag{2}$$

where $\delta \in [0,1)$ is a parameter arising from constraints on the amount or distribution of profit. Some hospitals are public, some are non-profit and others are for-profit. The parameter δ captures the legal status of the provider and the type and tightness of any profit constraints. With for-profit hospitals with no intrinsic quality concerns or non-monetary effort costs, we could assume $\delta = 0$. With non-profit or public hospitals we could have $\delta > 0$. Non-profit hospitals cannot distribute profits in cash but have to spend any positive net revenues on perquisites. If owners prefer compensation in cash over compensation in perquisites, a monetary net surplus (profit) has lower value for the owner of a non-profit firm than for the owner of a for-profit firm, i.e., $\delta > 0$.[1]

The optimal level of quality q^* satisfies the first order condition

$$(1-\delta)\pi_q(q^*,\theta) + b_q(q^*) - \varphi_q(q^*) = 0 \tag{3}$$

where $$\pi_q \equiv [p - C_D(q^*,\theta)] \cdot D_q(q^*,\theta) - C_q(q^*,\theta)$$

We assume that the problem is well behaved and the second order condition is satisfied: $V_{qq} < 0$.

At the optimal quality the marginal monetary and non-monetary benefit is equal to the marginal monetary and non-monetary cost. The marginal non-monetary benefit is given by the altruistic component to provide quality. The marginal monetary benefit consists of the revenues. The difference in the monetary marginal benefit and cost gives the marginal profit, which is reduced in the presence of profit constraints.

The incentive to increase quality is stronger when the profit margin (price minus the marginal cost of output) is larger. In many hospital payment systems, a DRG-type pricing scheme is adopted with the regulated price being set at the average cost. This in turn implies that the profit

1. This type of modelling is used by Brekke *et al.* (2012), Glaeser and Shleifer (2001) and Ghatak and Mueller (2011).

margin (defined as the price minus marginal cost) is larger for procedures with large fixed costs and low marginal costs. The profit margin is positive for hospitals operating at volumes where the marginal cost is constant or decreasing. A hospital with increasing marginal cost and a sufficiently high volume, may be operating at a negative profit margin. The profit margin is greater in those countries where the regulated price includes investment/capital costs. Some countries, like Norway, set the fixed price as a proportion (40-60%) of the average cost. In such case the profit margin may be negative.

The effect of competition θ on quality is

$$\frac{\partial q^*}{\partial \theta} = \frac{-V_{q\theta}}{V_{qq}} = \frac{(1-\delta)\pi_{q\theta}}{-(1-\delta)\pi_{qq} - b_{qq} + \varphi_{qq}} \tag{4}$$

where

$$\pi_{q\theta} = (p - C_D)D_{q\theta} - \left(C_{DD}D_q + C_{Dq}\right)D_\theta \tag{5}$$

Since the denominator in (4) is negative (by the second order condition), the sign of $\partial q^* / \partial \theta$ depends on the sign of $\pi_{q\theta}$. If competition increases the responsiveness of demand, then $D_{q\theta} > 0$. Assuming that the price-cost margin is positive, the first term is positive and so makes it more likely that more competition will increase the profitability of a marginal increase in quality. This is the basic argument in the literature for competition to increase quality.

Competition will also have an effect on the overall demand, which is capturedby D_θ.[1] If the marginal cost of treating an extra patient is not affected by quality ($C_{Dq} = 0$) and the marginal cost is constant ($C_{DD} = 0$), then this effect is irrelevant. Otherwise, competition will also affect the profitability of quality investment through the effect on overall demand.

1. We could have $D_{q\theta}(q^*, \theta) > 0$ with $D_\theta(q^*, \theta) = 0$, so that the demand function pivots through the point $(D(q^*, \theta), q^*)$, but this cannot hold for all q.

As an example, suppose that the marginal cost of treatment is increasing ($C_{DD} > 0$) or that cost of treatment per patient increases with quality ($C_{Dq} > 0$). Assume also that "competition" implies that an additional hospital enters a given market, then it would seem natural to assume that $D_\theta < 0$: for a given catchment area population, a hospital faces a lower demand when another firm enters the market. Then the second term in (5) is also positive, and the positive effect of competition on quality is reinforced. Suppose instead that $D_\theta > 0$: For example, more patient choice and lower access costs encourage an overall increase in demand. Then the second term in (5) is negative and the positive effect of competition on quality is weakened (or potentially overturned).

The first order condition (3) shows that if the marginal intrinsic concern with quality ($b_q - \varphi_q$) is positive and sufficiently large, the hospital could choose to produce positive quality even if the price cost margin is negative. In this case, an increase in competition which increases the effect of quality on demand ($D_{q\theta} > 0$) can reduce quality even if the marginal cost of output is constant with respect to output and quality, since then (see 4) $\pi_{q\theta} = (p - c_D)D_{q\theta} < 0$. With a negative price-cost margin, the effect of competition on quality (through the higher responsiveness of demand $D_{q\theta}$) is reversed. The hospital reduces quality to offset the increase in demand since more patients reduce profit.

Intrinsic Motivation and Altruism

The possibility that providers are altruistic or motivated has long been recognised in the health economics literature. Becoming a physician requires several years of demanding training on how to cure patients. Medical schools in most countries require graduating students to take a modernised version of the Hippocratic Oath. Although physicians may not act as "perfect" agents for the patients, they may act at least as "imperfect" ones (McGuire, 2000). Moreover, doctors may have reputational concerns and may not want to be perceived as bad doctors by the community (patients and their peers).

In the previous section we assumed that intrinsic concerns related only to the quality of care. However, if providers are concerned about the effect of quality on patients, rather than just taking pride in quality per se, they should also take account of the number of patients affected by their quality. Thus, in line with the seminal paper by Ellis and McGuire (1986), we could write the intrinsic benefit component as $\alpha B(D(q, \theta), q)$, $B_D > 0$, $B_q > 0$, where $B(D, q)$ is the benefit to patients as perceived by the provider and the parameter $\alpha \in [0,1)$ captures the altruistic concern that providers have towards patients. More generally, we could change the specification of the benefit component to allow for providers to also take pride directly in their quality by writing the benefit function as $B^1(D(q, \theta), q, \alpha) = \alpha B(D(q, \theta), q) + b(q)$. This additional incentive to provide quality could be due for example to self-esteem or concerns over recognition in front of their peers and colleagues. It would be on top of the altruistic motive which is driven by patients' benefits. Note however that it is not possible to have a patient benefit function which respects patient preferences and which has the form $B(D(q, \theta), q)$, since patients demand care up to point where the benefit to the marginal patient is zero and $B_D = 0$. Hence, using this form assumes implicitly that providers do not fully take account of patient preferences (see Appendix for a formal statement).

It also seems sensible to recognise that the effort cost of producing quality will depend on the number of patients treated. Thus we can now write effort cost as $\varphi(D(q, \theta), q)$ instead of $\varphi(q)$. With these assumptions the optimality condition for quality is similar to (3) but the marginal benefit from the altruistic provider is now $\alpha B_q + \alpha B_D D_q$ and marginal effort cost is $\varphi_q + \varphi_D D_q$.

The optimal quality is now defined by

$$(1-\delta)\left[(p - C_D)D_q - C_q\right] + \alpha B_q + \alpha B_D D_q = \varphi_q + \varphi_D D_q \qquad (6)$$

and the effect of competition on quality is

$$\frac{\partial q^*}{\partial \theta} = \frac{-1}{V_{qq}}\{[(1-\delta)(p-C_D)+\alpha B_D-\varphi_D]D_{q\theta} \\ +\left[\alpha B_{DD}D_q-\left(\varphi_{DD}D_q+\varphi_{Dq}\right)-(1-\delta)\left(C_{DD}D_q+C_{Dq}\right)\right]D_\theta\} \tag{7}$$

Whether a more responsive demand implies an increase in quality (ie whether the first term in the first square bracket is positive) depends on the degree of altruism. To see this, we can re-write the optimality condition (6) as

$$(1-\delta)(p-C_D)=\frac{\varphi_q+(1-\delta)C_q-\alpha B_q}{D_q}+\varphi_D-\alpha B_D \tag{8}$$

This expression is negative for sufficiently low marginal monetary and non-monetary cost for quality and high enough altruism (α). Again, the presence of altruism may induce providers to work at a negative profit margin and therefore alter the effect of competition on quality. A higher responsiveness of demand may imply lower quality.

Altruism also alters the effect of competition on quality via the direct demand effect (second square bracket term of the numerator of (7)). For example, if the marginal benefit from treatment is decreasing ($B_{DD} < 0$) and competition implies lower demand for each provider ($D_\theta < 0$), then more competition tends to further increase quality. This arises because at lower levels of demand, the benefit from quality for the marginal patients is higher.

Competition

Intuitively a hospital faces a more competitive market if the effect of its quality on its demand increases. The previous sections used a specification with a single hospital to bring out some key determinants of the effect a policy change which made demand more responsive to quality. Now we consider a market with several firms to see how this modifies the previous results.

Strategic Interaction

We first consider how each hospital reacts to changes in the quality of rival hospitals. To focus on the strategic interactions suppose that hospital *i* is concerned only by its profits which are

$$\pi(q_i) = T + pD_i(q_i, q_{-i}, \boldsymbol{\theta}) - C(D_i(q_i, q_{-i}, \boldsymbol{\theta}), q_i) \tag{9}$$

where q_i is the quality of hospital *i*, and q_{-i} is (a vector of) the quality of the rival $N - 1$ hospitals, where $N \geq 2$ is the total number of hospitals in the market.[1] Hospital *i* takes the quality of its rivals as given and chooses its quality to satisfy[2]

$$\pi_{qi} = [p - C_D(D_i(q_i, q_{-i}, \boldsymbol{\theta}), q_i)]D_{iq_i}(q_i, q_{-i}, \boldsymbol{\theta}) - C_{q_i}(D_i(q_i, q_{-i}, \boldsymbol{\theta}), q_i) = 0 \tag{10}$$

The dependence of the quality of hospital *i* on the qualities of its rivals is captured in the reaction function which solves (10)

$$q_i^R = q_i^R(q_{-i}, \boldsymbol{\theta}) \tag{11}$$

Totally differentiating (10) with respect to the quality q_j of rival *j* we obtain

$$\frac{\partial q_i^R}{\partial q_j} = \left(-\pi_{q_i q_i}\right)^{-1}\left[\left(p - C_{D_i}\right)D_{iq_i q_j} - \left(D_{iq_i}C_{D_i D_i} + C_{D_i q_i}\right)D_{iq_j}\right] \tag{12}$$

The slope of the reaction function depends on its demand and cost functions. We assume that $D_{iq_j} < 0$ (otherwise *j* would not be a rival of hospital *i*). The reaction function is flat and qualities are independent if the demand function is linear in qualities ($D_{iq_i}q_j = 0$) and the marginal cost of treatment is constant and independent of quality ($C_{D_i D_i} = C_{D_i q_i} = 0$).

1. The following is adapted from Gravelle *et al.* (2014).
2. The Second Order condition is:

$$\pi_{q_i q_i} = \left(p - C_{D_i}\right)D_{iq_i q_i} - 2C_{D_i q_i}D_{iq_i} - C_{D_i D_i}D_{iq_i}^2 - C_{q_i q_i} < 0$$

In these circumstances provider i never alters quality in response to a change in a rival's quality.

The reaction function is positively sloped if the marginal cost of treatment is increasing in the number of patients treated ($C_{D_iD_i} > 0$) or increasing in quality ($C_{D_iq_i} > 0$), the price-cost margin is positive and an increase in rivals' quality increases the responsiveness of demand to provider's quality ($D_{iq_iq_j} > 0$). In this case, the hospital responds to an increase in a rival's quality by also increasing quality: their qualities are strategic complements. An increase in rival's quality reduces demand of hospital i, so that the marginal cost of treatment is reduced (because $C_{D_iD_i} > 0$), thereby increasing the profit margin ($p - C_{D_i}$). Moreover, it directly reduces the marginal cost of quality (because ($C_{Diq_i} > 0$)).

Conversely, the reaction function is negatively sloped if the marginal cost of treatment is decreasing ($C_{Diq_i} < 0$), the marginal cost of treatment is decreasing in quality ($C_{Diq_i} < 0$), the price-cost margin is positive and an increase in rivals' quality reduces the responsiveness of demand to provider's quality ($D_{iq_iq_j} < 0$). In this case, qualities are strategic substitutes. The results are summarised in Table 1.1.

Table 1.1 – Hospital Reaction Function (Sufficient Conditions)

	$C_{D_iD_i}$	$C_{D_iq_i}$	$D_{iq_iq_j}$
Qualities strategic independant	0	0	0
Qualities strategic complements	> 0	> 0	> 0
Quallities strategic substituers	< 0	< 0	< 0

Next consider the effect of a change in competition on the hospital's quality, holding the qualities of rivals constant. We have

$$\frac{\partial q_i^R}{\partial \theta} = \left(-\pi_{q_iq_i}\right)^{-1}\left[\left(p - C_{D_i}\right)D_{iq_i}\theta - \left(D_{iq_i}C_{D_iD_i} + C_{Diq_i}\right)D_{i\theta}\right] \qquad (13)$$

which is in line with equation (5), and has the same intuition.

To investigate the full effect of more competition we need to examine its effect on the Nash equilibrium of the market. Assuming symmetry, the Nash equilibrium is derived by solving the N reaction functions $q_i^R = q_i^R(q_{-i}, \theta)$ simultaneously to yield

$$q_i^E = q_i^E(\theta), \qquad i = 1,..., N. \tag{14}$$

The properties of the reactions functions $q_i^R(q_{-i}, \theta)$ are crucial to predicting the Nash equilibrium effects of more competition. To illustrate, suppose there are two hospitals in the market. The effect on the Nash equilibrium quality of hospital 1 to an increase in competition is

$$\frac{\partial q_i^E}{\partial \theta} = \left[\frac{\partial q_i^R}{\partial \theta} + \frac{\partial q_i^R}{\partial q_j} \frac{\partial q_j^R}{\partial \theta} \right] \Delta^{-1} \tag{15}$$

where

$$\Delta = 1 - \frac{\partial q_i^R}{\partial q_j} \frac{\partial q_j^R}{\partial q_i} > 0, \tag{16}$$

and where the sign of Δ follows from the requirement that the equilibrium should be stable (Dixit, 1986).

We see from (15) that whilst it is not necessary for quality to be a strategic complement for either hospital for the pro-competitive policy to increase quality for both hospitals, in general the magnitude of the pro-competitive effect will depend on the slopes of the hospital reaction functions with respect to rival quality. With identical hospitals $\frac{\partial q_i^R}{\partial \theta} = \frac{\partial q_j^R}{\partial \theta}$,we have

$$\frac{\partial q_i^E}{\partial \theta} = \frac{\partial q_i^R}{\partial \theta} \left(1 - \frac{\partial q_i^R}{\partial q_j} \right)^{-1} \tag{17}$$

and the direct effect of policy $\partial q_i^R / \partial \theta$ is amplified by interdependencies in hospital demand functions. The amplification is increasing in the cross effect $\partial q_i^R / \partial q_j$. The key insight is that the effect of competition on quality is amplified when qualities are strategic complement and reduced when they are strategic substitutes.

Hotelling

One disadvantage of specifying the demand function of the provider as $D(q, \theta)$ is that this specification is reduced-form and no micro-foundations based on patient preferences are provided. Therefore, we have no clear guide on what we should expect in terms of competition affecting overall demand (D_θ) and its responsiveness to quality ($D_{q\theta}$). In the next two subsections we discuss two specifications of the demand functions, and emphasise the relative merits of different modelling strategies.

A popular micro-founded specification of the demand function is within a Hotelling set-up with two hospitals where the two hospitals are located at each endpoint of the line segment $S = [0,1]$. In its simplest specification, patients are uniformly located on S with a total mass of one, and each patient demands one unit of health care (eg an elective surgery) from their most preferred hospital. The utility of a patient located at $x \in S$ receiving care from hospital i is given by

$$u(x) = \begin{cases} V + \beta q_1 - tx & if \quad i = 1 \\ V + \beta q_2 - t(1 - x) & if \quad i = 2 \end{cases} \tag{18}$$

where V is gross patient surplus, q_i is the quality of hospital i, β is the marginal benefit of quality, and t is a transportation cost parameter measuring the marginal disutility travelling. Demand for provider 1 is

$$D_1 = \frac{1}{2} + \frac{\beta}{2t}(q_1 - q_2) \tag{19}$$

which can also be interpreted as a market share. The parameter t is critical in a Hotelling set up and is typically interpreted as the (inverse of the) degree of competition. Lower transportation costs imply more competition. Transportation costs do not have to be interpreted literally. Policies that facilitate patients' choice (eg comparative information on quality among providers, removing institutional barriers to choice) can also be captured by lower t.

Since total demand is assumed to be fixed, in the symmetric equilibrium q^* we have $D_t = D_\theta = 0$ and $D_{qt} = -\frac{\beta}{2t^2}$ (so that $D_{q\theta} > 0$) and $\pi_{qt} = (p - C_D)D_{qt}$. Therefore more competition (lower transportation costs) implies a more responsive demand and induces an increase in quality when the price-cost margin is positive and there is no altruism.

One limitation of this specification is that total hospital demand is fixed. Although it is plausible that total demand is inelastic to quality, it is likely to be not completely inelastic. One way to have demand elastic to quality, is to augment the Hotelling model with a "monopolistic" segment. Therefore, suppose that there are two patient types —denoted with L(*ow*) and H(*igh*)—differing with respect to the gross valuation of treatment. A patient demands either one treatment from the most preferred hospital, or no treatment at all. The utility of a patient of type $s \in \{L, H\}$, who is located at x and being treated at hospital 1, located at 0, is given by

$$u^s(x) = \begin{cases} V + \beta q_1 - tx & \text{if} \quad s = H \\ v + \beta q_1 - tx & \text{if} \quad s = L \end{cases} \tag{20}$$

where $V - v > 0$ measures the difference in the gross valuation of treatment between the two types. Define λ as the proportion of high-valuation (inelastic) patients and $(1 - \lambda)$ as the proportion of low-valuation (elastic) patients. The demand function is now given by:

$$D(q_i, q_j) = \lambda\left(\frac{1}{2} + \frac{\beta(q_i - q_j)}{t}\right) + (1 - \lambda)\frac{2(v + \beta q_i)}{t} \tag{21}$$

In the symmetric equilibrium we now have $D_t = -(1 - \lambda)\frac{2(v + \beta q^*)}{t^2}$

(ie $D_\theta > 0$) and more competition increases aggregate demand. In line with the previous result we have $D_{qt} = (\lambda\beta + 2(1 - \lambda))t^{-2}$ (ie $D_{q\theta} > 0$) and

$$\pi_{qt} = (p - C_D)D_{qt} - \left(C_{DD}D_q + C_{Dq}\right)D_t. \tag{22}$$

The key insight is that more competition (lower transportation costs) tends to increase demand responsiveness and therefore quality. More competition also increases demand. In turn this implies that if the marginal cost is increasing or if treatment costs are increasing in quality, then the positive effect of competition on quality is dampened.

In terms of the strategic interaction, the above specification implies $D_{q_iq_j} = 0$, which simplifies the reaction function to:

$$\frac{\partial q_i^R}{\partial q_j} = \left(\pi_{q_iq_i}\right)^{-1}\left(D_{iq_i}C_{D_iD_i} + C_{D_iq_i}\right)D_{iq_j}. \tag{23}$$

Note however, that the fact that $D_{q_iq_j} = 0$ is a result of the uniform distribution of patients on the Hotelling line. If the distribution is not assumed to be uniform, then in general we have $D_{q_iq_j} \neq 0$.

Salop

One limitation of the Hotelling approach is that does not allow consideration of the effects of more competition induced by an increase in the number of hospitals. One way to introduce a demand function which allows for n providers is to adopt a Salop model. The model is similar to Hotelling but assumes that n hospitals are equidistantly located on a circle with circumference equal to 1. By similar computations, and assuming a total inelastic demand, we obtain:

$$D_i(q_i, q_{i+1}, q_{i-1}) = \frac{1}{n} + \frac{\beta(q_i - q_{i+1})}{2t} + \frac{\beta(q_i - q_{i-1})}{2t} \tag{24}$$

Although there are n providers in the market, competition is local. Therefore, increasing the number of hospitals n does not change the responsiveness of demand, $D_{qn} = 0$ (and $D_{q\theta} = 0$). This is somewhat counter-intuitive since one may expect a higher number of providers to increase the responsiveness of demand.[1] Moreover, we have that a larger number of hospitals implies that the demand of each hospital is correspondingly reduced, $D_n < 0$ (and therefore $D_\theta < 0$). This is natural implication since we have assumed a fixed overall demand on the circle: one extra entrant in the market will reduce demand for the others. The overall effect on the profitability of a marginal increase in quality is given by

$$\pi_{qn} = -\left(C_{DD}D_q + C_{Dq}\right)D_n. \tag{25}$$

There is a sharp difference between the interpretation of competition in terms of lower transportation costs as opposed to competition in terms of a larger number of providers. With a total fixed demand, lower transportation costs (either in a Hotelling or a Salop model) increase the responsiveness of demand ($D_{q\theta} > 0$) but have no effect on the demand of each provider ($D_\theta = 0$). In contrast, a larger number of providers within a Salop model, has no effect on the responsiveness of demand ($D_{q\theta} = 0$) but reduces the demand of each provider ($D_\theta < 0$). In a Hotelling model with a monopolistic segment, lower transportation costs increase both the responsiveness of demand ($D_{q\theta} > 0$) and overall demand ($D_\theta > 0$).

The above analysis has examined the effect of a larger number of hospitals on quality within a Salop model with fixed total demand. In some countries and institutional settings (typically publicly-funded ones), it may seem plausible to assume that areas with larger number of providers are also characterised by a larger catchment population. This scenario can be investigated by adapting the Salop model. Instead of normalising

1. The independence between the number of hospitals and the demand responsiveness to quality is caused by the assumption of constant marginal disutility of travelling. If transportation costs are convex in distance, a higher number of hospitals (implying shorter distances between hospitals) will make demand more responsive to changes in quality provision.

the catchment population to 1 we define it as a separate variable P. The demand function is now:

$$D_i\left(q_i, q_{i+1}, q_{i-1}\right) = \frac{P}{n} + \frac{P\beta\left(q_i - q_{i+1}\right)}{2t} + \frac{P\beta\left(q_i - q_{i-1}\right)}{2t} \tag{26}$$

Suppose further that the population is proportional to the number of hospitals, ie $P = kn$ where k is a positive parameter. Then,

$$D_i\left(q_i, q_{i+1}, q_{i-1}\right) = k + \frac{kn\beta\left(q_i - q_{i+1}\right)}{2t} + \frac{kn\left(q_i - q_{i-1}\right)}{2t} \tag{27}$$

It is straightforward to verify that the effect of competition as proxied by a larger number of providers n has a similar effect on quality to competition as proxied by lower transportation costs. A larger number of hospitals implies a more responsive demand to quality, $D_{q\theta} > 0$, but has no effect on the demand faced by each hospital, $D_\theta = 0$.

These examples show that the effect of competition policies on quality may vary with the specification of market and with what is meant by competition.

Specialisation

The models presented so far assume that hospitals compete only on quality. Hospitals may try to relax or dampen quality competition by specialising (ie offering specialised type of treatments) and attracting particular types of patient. By specialising, providers can reduce the quality competition they face in their specialist treatment. We may think of specialisation as a longer term decision than quality investment. Decisions over quality and specialisation should then be modelled sequentially, rather than simultaneously, with the choice about specialisation taken before the choice of quality.

The Hotelling model presented on page 39 can be readily adapted to investigate hospitals' incentives to specialise following Brekke, Nuscheler and Straume (2006). Assume that the utility of a patient who is located at z and seeking treatment at provider i, located at x_i, is given by

$$U(z, x_1, q_1) = V + q_1 - t(z - x_1)^2, \tag{28}$$

$$U(z, x_2, q_2) = V + q_2 - t(x_2 - z)^2, \tag{29}$$

where V is the gross valuation of medical treatment; q_1 (q_2) is quality of provider 1 (2); t is a travelling cost parameter (inverse of competition); and x_1 (x_2) is the location of provider 1 (2) on the unit line. The distance between the two hospitals can be interpreted as their degree of specialisation. If hospitals are located close to each other, for example close to the middle of the unit line, then quality competition will be fierce. Quality competition will be relaxed if hospitals are located at the extremes of the unit line. Differently from (18), we assume that transportation costs are quadratic to guarantee the existence of equilibrium.

The patient who is indifferent between seeking treatment at hospital i and hospital j is located at $\overline{z}$ such that

$$v - t(\overline{z} - x_1)^2 + q_1 = v - t(x_2 - \overline{z})^2 + q_2, \tag{30}$$

So demand for hospital 1 is :

$$D(q_1, q_2, x_1, x_2, t) = \frac{x_1 + x_2}{2} + \frac{q_1 - q_2}{2t(x_2 - x_1)}.$$

and for hospital 2 is $1 - D$. We adopt a simplified objective function of provider 1 with zero altruism and constant marginal cost $(C^1 = cD(\cdot) + K(q_1))$:

$$\pi_1 = (p - c)D(q_1, q_2, x_1, x_2, t) - K(q_1) \tag{31}$$

where p is the regulated price, and $K(q_1)$ if the fixed cost of providing quality. In Stage 1 providers simultaneously choose locations x_1 and x_2 and in stage 2 they choose qualities q_1 and q_2. As customary, we solve by backward induction. In stage 2, quality 1 is chosen by provider 1 such that

$$\frac{p - c}{2t(x_2 - x_1)} = K'(q_1),$$

where $\frac{\partial q_1}{\partial x_1} = \frac{p-c}{2t(x_2 - x_1)^2 K''(q_1)} > 0$. If provider 1 gets closer to provider 2, quality competition intensifies and quality increases. Similarly, define $\Delta := (x_2 - x_1)$, then $\frac{\partial q_1}{\partial \Delta} < 0$ and a higher difference in location reduces quality: the further apart the two providers are located, the lower is the scope for quality competition (this is due to the assumption of quadratic costs). If $q_1 = q_2$ the profit function reduces to:

$$\pi_1 = (p-c)\frac{x_1 + x_2}{2} - K(q_1(x_1, x_2)). \tag{32}$$

In Stage 1 hospitals determine the optimal location. Differentiating with respect to x_1, we have:

$$\frac{\partial \pi_1}{\partial x_1} = \frac{p-c}{2} - K'(q_1(x_1, x_2))\frac{\partial q_1}{\partial x_1} = 0. \tag{33}$$

In order to ensure equilibrium existence in the two-stage game, we make an exogenous restriction on each hospital's location choice set by assuming that $x_1 \in \left[0, \frac{1}{2} - \overline{x}\right]$ and $x_2 \in \left[\frac{1}{2} + \overline{x}, 1\right]$, where $\overline{x}$ is a (small) positive number, implying that $\Delta \in [2\overline{x}, 1]$. The first-order conditions for an interior solution in the symmetric equilibrium of the location game are given by

$$\frac{\partial \pi_1}{\partial x_1} = \frac{p-c}{2}\left(1 - \frac{K'(q)}{K''(q)}\frac{1}{t\Delta^2}\right), \tag{34}$$

$$\frac{\partial \pi_2}{\partial x_2} = -\frac{p-c}{2}\left(1 - \frac{K'(q)}{K''(q)}\frac{1}{t\Delta^2}\right). \tag{35}$$

The key intuition is that the marginal benefit from a higher market share from less specialisation has to be traded off with more intense (and therefore costly) quality competition. There are three possible solutions:

1) *minimal differentiation* (corner solution), where the equilibrium distance between the hospitals is given by $\Delta^* = 2\overline{x}$. This arises when the

convexity of the cost function of quality is high. In this case the marginal benefit from increasing the market share from lower specialisation is always higher than the marginal cost from increased quality competition.

2) There is *maximal differentiation* (corner solution), where the providers are located at the extremes of the unit line (implying $\Delta^* = 1$). This arises when the convexity of the cost function of quality is low. In this case the marginal benefit from more specialisation in terms of reduced quality competition is always higher than the cost from reducing the market share.

3) There is *intermediate differentiation* (interior solution) with $2\overline{x} < \Delta^* < 1$. This solution is characterised by $\partial q^* / \partial t < 0$ and $\partial \Delta^* / \partial t < 0$. More competition proxied by lower transportation costs t imply a higher quality and more product differentiation/specialisation. Lower transportation costs encourage higher quality (and more intense quality competition), which the providers try to relax by locating further apart. Similarly, $\partial \Delta^* / \partial p > 0$ and $\partial q^* / \partial p > 0$. A higher regulated price increases quality but also product differentiation/specialisation. A higher price encourages higher quality (and therefore more intense quality competition), which the providers try to relax by locating further apart.

In summary, this section shows that quality incentives could be significantly altered if hospitals can compete along other dimensions such as the degree of specialised services.

Dynamic Analysis

The analysis above assumes that quality can be varied instantly and that when varied demand quickly adjusts to the new level. Demand for health care tends to respond sluggishly to changes in quality provision. Because quality is not always easily observable and because of habits or trust in specific health care providers, patients may have sluggish beliefs about quality, which in turn will make demand adjustment sluggish. If a provider increases quality, sluggish beliefs about quality imply that it will take some time before the potential demand increase is fully realised. The implications of demand sluggishness for quality provision are analysed in a differential-game dynamic setting by Brekke *et al*. (2012) and Siciliani *et al*. (2013). Both studies make use of a Hotelling framework.

The key assumptions of the model are as follows. Define the *potential demand* of Provider 1 at time τ as

$$\widehat{D}(\tau) = \frac{1}{2} + \frac{q_1(\tau) - q_2(\tau)}{2t}, \tag{36}$$

and $D(\tau)$ as the *actual demand* of Provider 1 at time τ. The law of motion of actual demand is given by

$$\dot{D}(\tau) := \frac{dD(\tau)}{d\tau} = \gamma\left(\widehat{D}(\tau) - D(\tau)\right). \tag{37}$$

The actual demand adjusts sluggishly to quality changes. At each point in time, only a fraction $\gamma \in (0,1)$ of patients become aware of changes in relative quality offered by the providers. The lower is γ, the more sluggish is demand. The parameter γ is therefore an inverse measure of the degree of demand sluggishness n the market. Sluggish demand adjustments can be due to habitual behaviour or imperfect information about quality among consumers, implying that it takes some time before changes in provider quality are observed and acted upon in the market.

As in the general set-up we assume that providers are partially altruistic and maximise a weighted sum of consumers' utility and profits. The instantaneous objective function of Provider 1 is

$$\begin{aligned} V_1(\tau) = T + pD(\tau) - \left[cD(\tau) + \frac{\beta}{2}D^2 + \frac{\theta}{2}q_1(\tau)^2\right] \\ + \alpha\int_0^{D(\tau)} (v + q_1(\tau) - tx)\,dx, \end{aligned} \tag{38}$$

Below we will discuss two cases of special interest: (i) no altruism, ie $\alpha = 0$ (with increasing marginal cost of treatment); (ii) constant marginal cost of treatment, ie $\beta = 0$ (with positive altruism).

In this type of dynamic models with strategic interactions (known as differential games) there are two main solution concepts for the Nash equilibrium: a) *open-loop solution*, where each provider knows the initial quality (and thus potential demand) of the other provider, but not quality in the following periods; b) *closed-loop solution*, where each provider knows the quality of the other provider, not only in the initial state, but also in all of the subsequent periods. The latter is therefore dynamically time consistent (but much more complicated to solve for). Since under the closed-form solution providers are allowed to revise their investment decisions more frequently, it can be interpreted as the outcome of the more competitive environment.

We first describe the open-loop solution since this gives an insight of the off-equilibrium dynamics (which are qualitatively similar under the closed-loop solution). We then compare the quality provision under open and closed-loop solution (ie the least and most competitive environment).

The optimal open-loop solution is characterised by

$$\begin{aligned}\dot{q}_1 &= \frac{\alpha\gamma}{\theta}\left(\frac{1}{2} + \frac{q_1 - q_2}{2t} - D\right) \\ &\quad - \frac{\gamma}{2t\theta}(p - c - \beta D + \alpha(v + q_1 - tD)) + (\rho + \gamma)\left(q_1 - \frac{\alpha}{\theta}D\right).\end{aligned} \tag{39}$$

together with the dynamic equation (37). Define $Q := q_1 - q_2$ as the difference in quality between the two providers. The dynamics of the equilibrium are described by

$$\dot{Q} = \frac{1}{\theta}\left[\left(\alpha(3\gamma + 2\rho) - \frac{\beta}{t}\gamma\right)\left(\frac{1}{2} - D\right) + \left(\theta(\gamma + \rho) + \frac{\alpha}{2t}\gamma\right)Q\right], \tag{40}$$

$$\dot{D} = \gamma\left(\frac{1}{2} + \frac{1}{2t}Q - D\right), \tag{41}$$

which can be represented in a phase diagram in D-Q-space.

Assume $\alpha = 0$ (Figure 1.1). Suppose we start off steady state at a level where the initial demand is low: $D(0) < D^s$. One possible interpretation is the case of a provider who at time 0 enters a previously monopolistic market. The solution is then characterised by a period of increasing demand and decreasing quality. Notice that the optimal solution for the "incumbent" is precisely the opposite and it is equivalent to the case where the demand is high ($D(0) < 1/2 \Leftrightarrow 1 - D(0) > 1/2$). For this provider, we should observe a period of decreasing demand and increasing quality. A key result is that if the marginal cost of treatment is increasing, demand and quality move in opposite directions over time on the equilibrium path to the steady state. When variable costs are strictly convex in output, $\beta > 0$, marginal profits depend on actual demand. More specifically, for a given level of quality, the instantaneous marginal profit gain of higher quality is monotonically decreasing in the actual demand facing the provider, since new consumers are increasingly costly to serve. Thus, if a provider faces actual demand $D < D^s$, the instantaneous marginal profit gain of quality investments is above the steady state level and he will therefore set quality $q > q^s$. As demand increases along the equilibrium dynamic path, the marginal profit gain of quality decreases; consequently, the provider will gradually reduce quality until the steady state level is reached.

Assume $\beta = 0$ (Figure 1.2). If the initial demand for Provider 1 is above one half $\left(D > \frac{1}{2}\right)$, then the quality difference Q is strictly positive and converges towards zero as D converges towards the steady-state level $\left(\frac{1}{2}\right)$. Intuitively, if the initial demand is above one half, the marginal benefit from quality (through the altruistic motive) is higher for Provider 1 as quality affects a larger number of consumers. Thus, for $D_0 > \frac{1}{2}$, Provider 1 has a stronger incentive than Provider 2 to provide quality in the initial period of the game, implying a positive initial quality difference: $Q(0) > 0$. However, on the equilibrium dynamic path, the quality difference is sufficiently small such that $\widehat{D}(Q) < D_0$, implying that Provider 1's potential demand is lower than its actual demand. As demand for Provider 1 reduces over time, this provider's incentive to invest in quality reduces correspondingly, while the opposite is true for the rival provider. This process continues until the steady state where quality and demand differences vanish. In this scenario demand and quality move in the same direction over time.

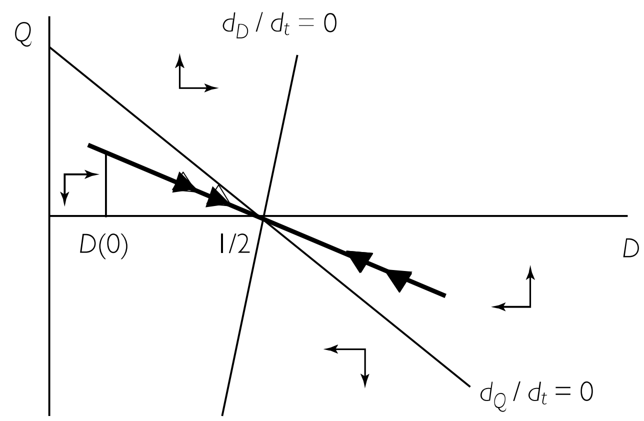

Figure 1.1 – Quality and Demand Move in the Same Direction over Time.

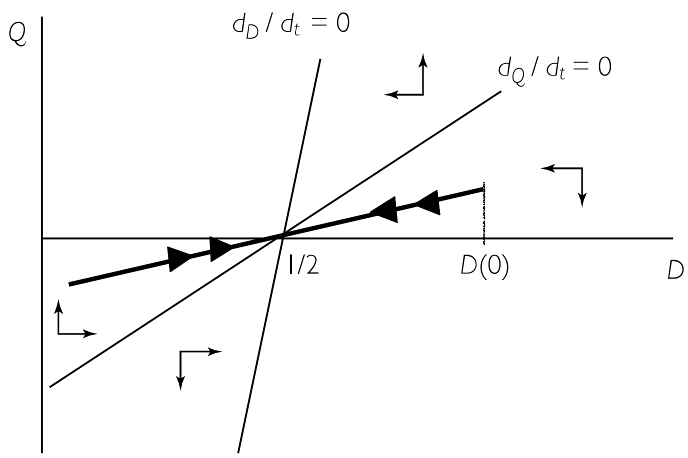

Figure 1.2 – Quality and Demand Move in Opposite Direction over Time.

In the symmetric game in the steady state under the open-loop solution we obtain

$$q^{OL} = \frac{(2(p-c)-\beta)\gamma + \alpha(\gamma(2v+t)+2t\rho)}{4\theta t(\gamma+\rho)-2\alpha\gamma} \tag{42}$$

where it can be shown that less sluggish demand (more competition) increases quality, $\partial q^{OL} / \partial\gamma < 0$.

We now move to the closed-loop solution, which is as mentioned above can be interpreted as the more competitive environment. We investigate whether quality is higher in the more "competitive" environment (as we may perhaps intuitively expect). It is useful to distinguish three special cases.

First, assume that altruism is zero and the marginal cost of treatment is constant ($\alpha = \beta = 0$). Then, quality under the two solution concepts are identical.

Second, assume that altruism is zero and the marginal cost of treatment is increasing ($\alpha = 0$; $\beta > 0$). Then quality is lower under the closed-loop solution. The reason is that quality choices are strategic complements in this case. In a dynamic game, this provides an incentive to compete less aggressively.[1]

Third, assume that altruism is positive and the marginal cost of treatment is constant ($\alpha > 0$; $\beta = 0$). Then quality is higher under the closed-loop solution. The intuition is that the presence of motivated providers affects the strategic nature of quality competition. Suppose that Provider 1 increases its quality. This reduces the number of patients of Provider 2 and therefore also reduces the marginal benefit of quality investments

1. A similar results is derived in Brekke *et al.* (2010), where demand adjust instantaneously but quality is akin to a stock $q(\tau)$ which increases over time τ only if the investment in quality $I(\tau)$ is higher than its depreciation rate: $\partial q(\tau) / \partial\tau = I(\tau) - \delta q(\tau)$. Quality provision is found to be lower in the more competitive environment, where providers are allowed to revise their quality decisions more frequently.

for altruistic reasons. Consequently, Provider 2 responds by reducing its quality. Qualities are now *strategic substitutes*. If the price is sufficiently high, this strategic substitutability makes dynamic competition tougher in the feedback closed-loop solution, where players can set their quality choices according to the evolution of demand and taking into account the strategic interaction at each instance of time. By increasing its quality today, Provider 1 can provoke a quality reduction from its competitor tomorrow (and vice versa). To summarise, since competition is more intense under the closed-loop solution and qualities are strategic substitutes (due to providers' altruism), providers' incentives to raise quality are amplified under this solution concept.

Soft Budgets

An important feature of many health care systems, is that providers, especially publicly owned hospitals, face soft budgets with funders partially covering deficits or partially confiscating profits (Kornai, 2009). This section explores the implications of soft budgets on quality competition. We provide a simplified version of Brekke, Siciliani and Straume (2015) which assumes that demand is uncertain and that patients can choose which hospital to be treated at based on quality. Surpluses occur in the low demand state, whereas deficits occur in the high demand state. This arises because providers cannot increase prices when demand is high (prices being regulated), and because hospitals cannot turn down patients who demand treatment.[1]

Within a Hotelling set up where hospitals have fixed location at the extremes of the unit line, the patient who is indifferent between the two hospitals is located at $\hat{x} = \frac{1}{2} + \frac{q_1 - q_2}{2t}$. The two hospitals face

1. Empirical papers on soft budgets in the hospital market include Duggan (2000), Shen and Eggleston (2009), and Eggleston and Shen (2011); see Eggleston (2008) for a different theory.

uncertainty about the total number of patients seeking treatment. The distribution of patients is known and given, but the density can take one of two values. In *state L*, which occurs with probability μ, demand is low with a density function equal to $f(x) = 1$ and a mass of patients in each location x normalised to one, while in *state H*, demand is high with a density function still equal to $f(x) = 1$ and a mass in each location x equal to $n > 1$ so that demand is higher in *state H*. Thus, the demands for treatment in hospital 1 is

$$d = \begin{cases} \hat{x} & \text{in State } L \\ n\hat{x} & \text{in State } H \end{cases} \tag{43}$$

The profit of Hospital i in *state* j is given by

$$\pi_i^j = pD^j - \frac{c}{2}\left(D^j\right)^2 - \frac{k}{2}q_i^2, \tag{44}$$

where p is as usual the fixed price, and c_i and k are cost parameters related to output and quality investment, respectively. Positive profits are confiscated by the regulator with a probability θ. β is the probability that a hospital running a deficit will be bailed out and can be interpreted as a measure of the degree of budget softness. The expected payoff of Hospital i is given by

$$\Pi_i = \mu(1-\theta)\pi_i^L + (1-\mu)(1-\beta)\pi_i^H, \tag{45}$$

where we assume that hospitals have a positive profit in *state L* and a negative profit in *state H* $(\pi_i^L > 0 \text{ and } \pi_i^H < 0)$. Equilibrium quality is given by

$$q^* = \frac{\mu(1-\theta)\left(p - \frac{c}{2}\right) + (1-\mu)(1-\beta)n\left(p - \frac{nc}{2}\right)}{2kt(1-\beta+\mu(\beta-\theta))}. \tag{46}$$

When making quality choices in the face of uncertainty, each hospital chooses optimally to invest in quality up to the point where the expected marginal revenue is equal to the marginal cost of quality. The marginal revenue of quality investments is the increase in demand (due to higher quality) times the profit gain of treating these extra patients. In equilibrium, this profit gain (i.e., the profit margin) is positive in *state L* and negative in *state H*, which means that *state H* contributes negatively to the expected marginal revenue of quality investments.

The effect of softer budgets on equilibrium quality is given by

$$\frac{\partial q^*}{\partial \beta} = \frac{\mu(1-\theta)(1-\mu)(n-1)((n+1)c-2p)}{4kt(1-\beta+\mu(\beta-\theta))^2} > 0. \tag{47}$$

A softer budget reduces the expected deficit in *state H*, which implies that the profit margin becomes less negative in this state. This means that the expected revenue of quality investments increases, which consequently strengthens each hospital's incentive for investing in quality.[1]

The effect of profit confiscation on quality is given by

$$\frac{\partial q^*}{\partial \theta} = \frac{\mu(1-\beta)(1-\mu)(n-1)((n+1)c-2p)}{4kt(1-\beta+\mu(\beta-\theta))^2} < 0. \tag{48}$$

A higher probability of profit confiscation reduces the profit margin in *state L* and therefore reduces the marginal revenue of quality investments, implying that the hospitals have weaker incentives for quality provision.

Increased competition (interpreted as a reduction in *t*) affect equilibrium quality provision in the following way:

$$\frac{\partial q^*}{\partial t} = -\frac{\mu(1-\theta)\left(p-\frac{c}{2}\right)+n(1-\mu)(1-\beta)\left(p-\frac{nc}{2}\right)}{2kt^2(1-\beta+\mu(\beta-\theta))} < 0, \tag{49}$$

1. Brekke *et al.* (2014) show that the effects of soft budgets on quality are ambiguous when providers can expend cost-containment effort (i.e., reduce the marginal cost of treatment) to increase their profit margin. The reason is that softer budgets reduce cost-containment effort, which in turn enhances the negative effect of profit confiscation on quality and counteracts the positive effect of bailouts on quality. Therefore, soft budgets can reduce quality if the effect on cost-containment effort is sufficiently pronounced.

The effect of increased competition on quality is composed of two opposite sub-effects, as represented by the two terms (with opposite signs) in the numerator of (49). A reduction in t increases demand responsiveness to quality, which stimulates quality incentives if the profit margin is positive but discourages quality incentives if the profit margin is negative. Although the profit margin is negative in equilibrium in *state H*, the expected profit margin is nevertheless positive, implying that the first term in the numerator of (49) is larger (in absolute value) than the second term. Thus, in line with the existing theoretical literature on competition between profit-maximising hospitals facing fixed prices, we find an unambiguously positive relationship between competition intensity and equilibrium quality. In summary, the presence of soft budgets does not qualitatively alter the predictions of competition on quality.

Optimal Price Regulation

The analysis so far has assumed that the price p received by the hospital for each patient treated is fixed at an exogenous level. In current payment systems this often reflects the average cost of provision. We can ask from a normative perspective what is the optimal price that would maximise welfare. We define welfare as the difference between patients benefits and costs, possibly weighted by the opportunity cost of public funds λ, i.e. $B(.) - (1 + \lambda)[C(.) + \varphi(.)]$. The optimal (first-best) quality is given by

$$\begin{aligned} &B_q(q^F) + B_D(D(q^F,\theta))D_q(q^F,\theta) \\ &= (1+\lambda)\left[C_D(D(q^F,\theta))D_q(q^F,\theta) + C_q(q^F) + \varphi(q^F)\right]. \end{aligned} \tag{50}$$

We can compare this condition with the optimality condition of the provider (3), reproduced here for reader's convenience:

$$\begin{aligned} &(1-\delta)\left[(p - C_D(D(q^*,\theta)))D_q(q^*,\theta) - C_q(q^*)\right] \\ &+ \alpha B_q(q^*) + \alpha B_D(D(q^*,\theta))D_q(q^*,\theta) = \varphi_q(q^*). \end{aligned} \tag{51}$$

The optimal price which implements first-best quality is:

$$\begin{aligned} p^f &= \left[\beta_q(q^F) + B_D(D(q^F,\theta))D_q(q^F,\theta)\right]\frac{(1-\alpha)}{(1-\delta)} \\ &\quad -\frac{(\lambda+\delta)}{(1-\delta)}\left[C_D(D(q^F,\theta))D_q(q^F,\theta) - C_q(q^F)\right] - \frac{\lambda}{(1-\delta)}\varphi_q(q^F). \end{aligned} \tag{52}$$

Qualitatively, this condition suggests that the optimal price is proportional to marginal patients' benefit. Higher altruism generally implies a lower price: since the provider is already motivated, it needs to be incentivised to a lower extent through a price mechanism. Profit constraints instead imply that providers will respond less to financial incentives and competition and therefore implies a higher price. Higher opportunity cost of public funds, which effectively implies a higher cost of quality, implies a lower price.

This section shows that if the regulator can implement first-best prices, then a policy that encourages competition has no bite. Even if hospital quality responds to competition, the regulator can always adjust the price to implement the first-best quality. Perhaps paradoxically, a regulator could respond to a policy which encourages competition by lowering the optimal price to avoid an excessively high provision of quality (ie $\partial p^F / \partial \theta < 0$). This type of reasoning also suggests that policymakers believe that current (average-cost based) prices are too low since they try to encourage increases in quality by fostering competition.

Endogenous Price

This final section provides a model of competition when providers compete on prices in additional to quality, ie prices are not fixed. The model could be applied for example to England in the period that precedes Payment by Results (introduced in 2003) where Health Authorities had to negotiate (some sort of unit) prices with different hospitals. It also captures some features of the US healthcare market; hospitals' payment for patients outside of Medicare and Medicaid (the public programmes that cover the elderly and the poor) are not subject to fixed-price rules. It also applies to those markets where patients have to pay a proportion of the price charged by hospitals. The model shows that the predictions of the effect of competition on quality are even more ambiguous when price is endogenous than when price is fixed.

To illustrate the effect of competition on quality under endogenous price, we adopt a Hotelling model with two hospitals equidistantly located on unit line equal to 1 (as (18)). This a simplified version of the model contained in Brekke, Siciliani and Straume (2010).[1] The utility of a patient located at x is $U_i = v + \beta q_i + u(Y - \gamma p_i) - tx$, where Y is gross income, γ is the proportion of the price paid by the patient and $u(.)$ is a function weakly concave in net income. Demand for hospital 1 is

$$D = \frac{1}{2} + \frac{\beta(q_1 - q_2)}{2t} - \frac{u(Y - \gamma p_2) - u(Y - \gamma p_1)}{2t}. \tag{53}$$

with $\frac{\partial D}{\partial q_i} = \frac{\beta}{2t} > 0$ and $\frac{\partial D}{\partial p_i} = -\frac{\gamma}{2t}u_y < 0$. Hospitals are profit maximisers. Hospital i's profits are $\pi_i = p_i D - C(D, q_i)$. Hospitals choose price and quality simultaneously.[2] The first-order conditions for price and quality are given by

$$\frac{\partial \pi_i}{\partial p_i} = D + [p_i - C_D(D, q_i)]\frac{\partial D}{\partial p_i} = 0, \tag{54}$$

$$\frac{\partial \pi_i}{\partial q_i} = [p_i - C_D(D, q_i)]\frac{\partial D}{\partial q_i} - C_q(D, q_i) = 0. \tag{55}$$

1. See Barros and Martinez (2012) and Gaynor and Town (2011) for reviews of the literature where prices are bargained between purchaser and provider. See also seminal paper by Spence (1975).

2. It may be more plausible to assume that price and quality are chosen sequentially, with quality being a longer-term decision than price. This does not qualitatively affect the key insight of this section, ie that the effect of competition on quality is ambigous.

In the symmetric equilibrium, the price satisfies:

$$p^* - C_D\left(\frac{1}{2}, q^*\right) = \frac{t}{2\gamma}\frac{1}{u_y(Y - \gamma p^*)}. \tag{56}$$

This provides the familiar monopolistic pricing rule, which suggests that the price mark up is inversely related to the degree of competition (lower transportation costs). Substituted in the optimal quality condition, under symmetry, the optimal quality satisfies:

$$\frac{\beta}{2\gamma u_y(Y - \gamma p^*)} = C_q\left(\frac{1}{2}, q^*\right). \tag{57}$$

A reduction in transportation costs (more competition) has the following effects:

$$\frac{\partial p^*}{\partial t} = \frac{(p^* - C_D)\gamma u_y C_{qq}}{\Delta t^2}, \quad \frac{\partial q^*}{\partial t} = \frac{(p^* - C_D)\beta u_{yy}}{\Delta t^2 n u_y}, \tag{58}$$

where $\Delta > 0$ is a function of the model's parameters. Lower transportation costs affect equilibrium prices and quality as follows: (i) If utility is linear in income, prices fall while quality is unaffected; (ii) If utility is strictly concave in income, prices fall while quality increases. The result that more competition reduces prices is standard. The effect on quality is less obvious. Increased competition implies that demand becomes more responsive to both price and quality. This gives each hospital an incentive to reduce the price and increase quality. However, a price reduction implies a lower price-cost margin, which reduces the incentive to provide quality. Due to these two counteracting effects, the total equilibrium effect of increased competition on quality is *a priori* ambiguous. The results show that the total effect depends crucially on the marginal utility of income. If the marginal utility is constant, the two effects cancel each other out and the equilibrium quality level is independent of t, as in Ma and Burgess (1993) and Gravelle (1999). However, if utility is strictly concave, the indirect effect on quality incentives through a lower price-cost margin is reduced, implying that lower non-monetary transportation costs will increase the equilibrium supply of quality. Thus, with a decreasing marginal utility of income, consumers benefit from more competition along all dimensions as prices fall while quality increases.

Conclusions

We have investigated the effect of competition on quality under a range of assumptions which characterises the hospital sector. A key insight is that altruistic preferences, cost structure, profit constraints and other features are important in shaping the effect of competition on quality. We have also highlighted how competition can have different meaning; for example, it can be related to the number of providers or to the cost for the patient of exercising choice (eg choosing a provider that is not close from home).

The current empirical literature makes use of two main measures of market structure: the number of hospitals within a catchment area with a fixed radius or the Herfindahl index, which is given by the sum of the square of the (predicted) market shares. The first measure corresponds precisely to one of the interpretations we have given to the competition parameters. The second measure, ie the Herfindahl index, is useful when hospitals have different market shares. If market shares in a hospital catchment area are identical, the Herfindahl index is simply the inverse of the number of hospitals in the catchment area and conveys no additional information. Most of the current theoretical literature assumes symmetric markets for tractability reasons. Developing closer links between theoretical models and empirical measures of market concentration with asymmetric market shares is an interesting venue for possible future research. A third measure related to competition in the empirical literature is the extent of patients' choice policies and how these have affected hospitals' incentive to compete. Patients' choice policies can be interpreted in our theoretical model as a reduction of costs (transportation and other) from switching from one provider to another one, and are therefore closely connected to the models covered in this review.

The empirical evidence on the effect of hospital competition from the US under fixed prices is somewhat mixed. Kessler and McClellan (2000) for example find a positive effect of competition on quality in the healthcare sector (with fixed prices), Gowrinsankaran and Town (2003) find a negative effect, Shen (2003) finds mixed effects, and Shortell and Hughes (1988) and Mukamel, Zwanziger and Tomaszewski (2001) find no effect. Colla *et al*. (2018) find that competition had no effect on 30-day emergency readmission rates for Medicare hip and knee replacement patients and reduced quality for dementia patients. The recent evidence from the England generally finds support for a positive effect of competition on quality when prices are fixed (Cooper *et al*., 2011; Bloom *et al*., 2011; Gaynor *et al*., 2013). This is in contrast to some older evidence which suggests that competition reduces quality when prices are not fixed (Propper *et al*., 2004; Burgess *et al*., 2008). The empirical evidence is generally scant for other OECD and European countries. A recent exception is Berta *et al*. (2016) who find that competition had no effect on quality in Italy.

An alternative approach to investigate whether hospitals compete is by looking at hospital strategic interaction. Gravelle *et al*. (2014) employ a spatial econometrics approach to test whether hospitals have incentive to increase quality when rival hospitals increase quality. They find that in England quality responds positively to rivals' quality for seven out of sixteen indicators, and are otherwise insignificant. These methods have been previously applied in the US to test for strategic substitution in hospital prices (Mobley, 2003; see Moscone *et al*., 2014 for a review of empirical spatial methods in health economics).

The models presented in this chapter can be adapted to capture the institutional features of other countries which are likely to differ, and to derive theoretical predictions of the effect of competition on quality under a range of institutional settings. In turn, this can guide further empirical research in other OECD countries that intend to encourage competition in the hospital.

Appendix

Suppose that the benefit for a potential patient is $mq - k$ where m is morbidity and k is the cost (monetary or non-monetary) of being treated. m varies across the population with distribution function $F(m, \theta)$ and potential patients with $m \geq m^o \equiv k/q$ demand treatment, so that, normalising the total population to 1, demand is $D = 1 - F(m^o, \theta)$. Total patient benefit is

$$B^o = q\int_{m^o} mdF(m,\theta) - k[1 - F(m^o,\theta)]$$

We can write this as a function of θ and D only by using $D - 1 + F(m^o, \theta) = 0$ to solve for $m^o = g(D, \theta)$ and getting

$$\begin{aligned} B^{oo}(D,q) &= q\int_{g(D,\theta)} mdF(m,\theta) - k[1 - F(g(D,\theta),\theta)] \\ &= q\int_{d(D,\theta)} mdF(m,\theta) - kD \end{aligned}$$

We have:

$$B_q^{oo} = \int_{g(D,\theta)} m\, dF(m,\theta) > 0 \quad \text{and} \quad B_D^{oo} = -(qm^o - k)g_D f(m^o,\theta) = 0.$$

Or write $m^o = k/q = m^o(q, k)$ and totally differentiate total patient benefit with respect to q

$$\begin{aligned} \frac{dB^o}{dq} &= \frac{d}{dq}\left\{q\int_{m^o(q,k)} mdF(m,\theta) - k[1 - F(m^o(q,k),\theta)]\right\} \\ &= \int_{m^o} mdF(m,\theta) - (q\hat{m} - k)f\frac{\partial m^o}{\partial q} \\ &= \int_{m^o} mdF(m,\theta) = \frac{\partial B^o}{\partial q} \end{aligned}$$

So actual patient benefit Bo depends only on q and θ, and not on D.

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