

Documentos de Trabalho  
Working Paper Series

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**URL:**

<http://www.eeg.uminho.pt/economia/nipe>



# Hospital Mergers: A Spatial Competition Approach

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April 2013

## Abstract

Using a spatial competition framework with three ex ante identical hospitals, we study the effects of a hospital merger on quality, price and welfare. The merging hospitals always reduce quality, but the non-merging hospital responds by reducing quality if prices are fixed and increasing quality if not. The merging hospitals increase prices if demand responsiveness to quality is sufficiently low, whereas the non-merging hospital always increases its price. If prices are endogenous, a merger leads to higher average prices and quality in the market. A merger is harmful for total patient utility but can improve social welfare under price competition.

*Keywords:* Hospital mergers; Spatial Competition; Antitrust

*JEL Classification:* I11, I18, L13, L44

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# 1 Introduction

The hospital industry has undergone substantial consolidation during the last decades both in the US and in Europe. In the US, the consolidation is due to several waves of mergers and acquisitions, whereas in Europe consolidation is often more a result of governmental policy, especially in countries with a National Health Service.<sup>1</sup> The stated motives for hospital mergers are usually that they facilitate efficiency gains (e.g., economies of scale, cost synergies, less duplication of services) and enhance the quality of care. However, there is a growing concern that the continuing consolidation in the hospital industry increases market power and leads to higher prices, lower quality, and higher health care expenditures.<sup>2</sup> The concern that mergers may harm quality applies not only when hospitals compete on prices (e.g., in the US outside of Medicare), but also when prices are regulated (e.g., in the US within Medicare and in several OECD countries).

What does the empirical evidence tell us? According to a recent survey by Gaynor and Town (2012) most empirical studies tend to find that hospital mergers result in higher prices. However, the estimated price effects vary substantially from negligible to 40-50 percent price increases. Considering the impact of hospital mergers on quality, empirical studies find either no effects or very small effects. These findings suggest that the efficiency gains, if they are present, are not shared with patients or insurers, but instead captured by the hospitals through the exercise of market power. The policy implications appear trivial, and it seems like a puzzle why governments, antitrust authorities or courts tend to approve most hospital mergers.<sup>3</sup>

In this paper we ask the following questions: What are the mechanisms that can explain the empirical findings on the effects of hospital mergers? How will the merging hospitals optimally adjust their prices and qualities? How do competing hospitals (not part of the merger) respond to the merger? Do the effects of hospital mergers on quality depend on whether prices are regulated

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<sup>1</sup>A description of the consolidation and corresponding changes in concentration in the US and UK hospital markets can be found in the recent survey by Gaynor and Town (2012).

<sup>2</sup>In Forbes, Avik Roy (Senior Fellow at the Manhattan Institute for Policy Research and healthcare adviser to Mitt Romney's presidential campaign) claims that hospital mergers are the biggest driver of US healthcare costs due to increased market power and higher prices; see the articles "Hospital Monopolies: The Biggest Driver of Health Costs That Nobody Talks About" (dated 8/22/2011) and "How Hospital Mergers Increase Health Costs, and What to Do About It" (dated 3/1/2012).

<sup>3</sup>However, there is a tendency towards a more strict regulation of hospital mergers. The US Federal Trade Commission (FTC) has recently been more aggressive *and successful* in challenging hospital mergers. In the UK, NHS hospitals were exempted by fiat from oversight by the competition authorities. However, in 2009 the government established the Cooperation and Competition Panel (CCP), which has been given the authority of approving NHS hospital mergers.

or not? How do potential efficiency gains influence the price and quality effects of hospital mergers? What are the policy implications? What type of hospital mergers should be approved?

In order to answer these questions, we use a spatial competition framework with three hospitals symmetrically located on the Salop circle.<sup>4</sup> Hospitals choose quality and price (if not regulated) of their services, and patients decide which hospital to be treated at based on travelling distance, quality and price (copayments). We assume that hospitals are *ex ante* identical before the merger takes place. In the benchmark model we focus on the anticompetitive effects of hospital mergers by assuming the merger implies coordination of supply (quality and price) among the merging hospitals. In this case the only motive for the merger is to obtain higher profits through the exercise of market power. In an extension to the benchmark model we also allow for two types of efficiency gains. First, we assume the hospital merger results in closure of one of the hospitals and thus savings of fixed costs. Second, we allow for variable-cost synergies, where the merger makes the merging hospitals more cost efficient by reducing their treatment costs.

We consider two different institutional settings: (i) quality competition with regulated prices, and (ii) competition on both quality and price. The case of regulated prices is relevant for US Medicare and most European countries, where activity-based funding of the Diagnosis Related Groups (DRG) type is the norm: each hospital receives a fixed price for each patient treated. In the United Kingdom, where prices are regulated, hospital mergers have to be approved by the Co-operation & Competition Panel. Mergers are allowed only if there remains sufficient choice and competition for patients.<sup>5</sup> The case of price and quality competition is mostly relevant for the US market and private markets in Europe where prices are decided by providers.

Our analysis offers five sets of results. First, the merging hospitals always reduce quality (irrespective of whether prices are fixed or endogenous). However, the non-merging hospital responds by reducing quality if prices are regulated and by *increasing* quality if prices are set by providers. Whereas the first part of the result is quite intuitive, the second part is more surprising: under price competition, the outside hospital responds to a quality reduction at the merged hospitals by increasing its quality level. The reason is that the outside hospital also responds to the merger by increasing prices, and a higher profit margin makes it profitable to increase quality, thus making qualities *net*

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<sup>4</sup>A similar framework has been used by Gravelle (1999) and Nuscheler (2003) to study competition among physicians, and Brekke et al. (2011) for competition among hospitals with regulated prices.

<sup>5</sup>For further details, see [www.ccp-panel.org.uk](http://www.ccp-panel.org.uk).

*strategic substitutes* among hospitals. In fact, the quality response by the outside hospital is sufficiently strong to ensure an increase in *average* quality (weighted by the number of patients) in the market as a result of the merger.

Second, whereas the non-merging hospital always responds to the merger by increasing prices (if not regulated), the merging hospitals increase prices only if demand responsiveness to quality is sufficiently low. The possibility that prices of merging hospitals may decrease for high demand responsiveness is at first glance surprising and results from an intricate strategic relationship between price and quality – *within* and *between* hospitals. A quality reduction by the merging hospitals is met by a quality increase by the non-merging hospital, which in turn dampens the merging hospitals’ incentives to increase prices. If this effect is sufficiently strong – which requires sufficiently quality-elastic demand – the overall effect of the merger is a price reduction by the merging hospitals.

Third, the non-merging hospital always benefits more from the merger than the merging hospitals. Thus, the well-known ‘merger paradox’ is present also in our framework with quality competition. This result holds irrespective of whether prices are regulated or not. A hospital merger is profitable for the merging hospitals with one exception; under price competition, if demand responsiveness to quality is sufficiently high, a merger triggers a quality increase by the non-merging hospital that is sufficiently strong to make the merger unprofitable. This is an interesting result considering that prices are strategic complements, which tends to make mergers profitable under *Bertrand* competition (with differentiated products).<sup>6</sup>

Fourth, under price regulation the welfare effects of hospital mergers are straightforward. Patients are worse off for two reasons: quality is lower at all hospitals and average travelling distance is higher because of asymmetric quality provision. In the absence of any cost savings, the merger is also harmful for social welfare under price regulation (unless quality levels were too high before the merger). Under price competition, the welfare effects are less clear because of the non-uniform effects of a merger on quality and price. We show that patients’ utility is reduced on average, although some patients may actually be better off: if demand is sufficiently quality-elastic, the utility gain of the quality increase outweighs the utility loss of the price increase for patients attending the non-merging hospital. Surprisingly, we also find that a hospital merger might in fact improve social welfare even

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<sup>6</sup>See the seminal work by Denecker and Davidson (1985). Assuming Cournot competition, Salant et al. (1983) reported the striking result that mergers are usually not profitable for the merging firms unless sufficiently many firms take part in the merger.

in the absence of any direct cost synergies, if demand is sufficiently responsive to quality and co-insurance rates are sufficiently high. The reason is that a hospital merger might indirectly lead to savings of (endogenous) fixed quality costs.

Finally, the effects of a hospital merger might crucially rely on the presence (and *type*) of cost synergies. Under price regulation, fixed-cost savings through hospital closure lead to lower quality at all hospitals, which is in line with the results from our benchmark model without explicit cost synergies. However, in the case of price competition, we show that all hospitals increase price *and* quality. Thus, under price-quality competition the effects of a hospital merger rely crucially on whether the merger involves closure or not. Considering variable-cost synergies, we show that, if these synergies are sufficiently large, the results of the benchmark model are reversed under price regulation: merging hospitals increase quality because of cost synergies despite the reduction in competition and the non-merging hospital responds by increasing quality because qualities are strategic complements. Obviously the merger is beneficial for patients, hospitals, and thus society. Not surprisingly, an equivalent reversal of results is also possible when prices are endogenous.

Our paper is related to the existing empirical literature on hospital consolidation. Considering the impact on *prices*, the vast amount of research reports that hospital consolidation leads to higher prices.<sup>7</sup> The reported price effects vary quite a lot, but more recent studies tend to report stronger price effects. Gaynor and Vogt (2003) estimate a structural model of demand and pricing using data from California and simulate the effects of a (near monopoly) merger, finding that this results in price increases by up to 53%. Dafny (2009) estimates the price response by rival hospitals that did not take part in the merger and reports price increases of 40 percent. Our analysis might provide a possible theoretical explanation for the large variation in the price effects for the merging hospitals, namely that the incentive (or scope) for increasing prices is linked to the reduction in quality. Thus, if the merger results in lower quality for the merging hospitals, the corresponding price effects are likely to be softened. The reduction in quality because of a merger is linked to the demand responsiveness to quality. If the demand responsiveness is low (high), then mergers are likely to lead to large (small) price increases.<sup>8</sup> This may explain why some studies find small price effects, whereas others find

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<sup>7</sup>See Vogt and Town (2006) and Gaynor and Town (2012) for reviews of the evidence.

<sup>8</sup>The responsiveness of providers' demand to quality has been tested empirically by Folland (1983), Luft et al. (1990), Burns and Wholey (1992), Hodgkin (1996), Tay (2003), Howard (2005) and Sivey (2012). These studies model hospital patients' choice using conditional logit models. They find that higher quality and shorter distance increase the probability of choosing a provider. Demand elasticities with respect to quality are positive but relatively small for

large price effects of hospital mergers.

A key implication of our model is that empirical analyses testing the effect of mergers on prices need to adequately control for quality differences in order to isolate the price effect. Similarly, studies that test the effect of mergers on quality need to control for price changes. An alternative (complementary) empirical approach is to simultaneously test the effect of mergers on both prices and quality (the current dominant approach being instead to focus on either quality or price): a small reduction in price following a merger can be explained by a reduction in quality. Our study emphasises the importance of (i) testing the effect of mergers on price and quality jointly, and (ii) taking into account the response of rival hospitals.

The empirical findings on the effects of hospital mergers on *quality* are more limited. Ho and Hamilton (2000) find that mergers in California have no effect on the quality of care as measured by mortality rates for patients with heart attack and stroke, though readmission rates and early discharges for newborns increased in some cases. Capps (2005) focuses on mergers in the New York state during 1995-2000 and also find no effects for most quality indicators. Romano and Balan (2011) focus on two mergers in the Chicago suburbs and find little evidence that the mergers led to any quality improvements. Gaynor et al. (2012a) examine the impact of a large number of mergers in England, where prices are regulated, on a range of outcomes including financial performance, productivity, waiting times and clinical quality. They find little evidence that mergers had any effect except for some reductions in activity. Overall, the evidence seems to support little or no effects of mergers on quality.

Our analysis indicates that one possible explanation for the above-described results may be that price and quality are complementary strategies for each hospital. For given prices, the merging hospitals have an incentive to reduce quality. However, because the merging hospitals also would like to increase prices (for given quality), the incentive to reduce quality is mitigated. We show that the relative strength of the price and quality effects depends on how responsive demand is to quality changes. If demand is relatively *quality-inelastic*, a merger will mainly affect prices, with relatively little effect on the quality offered by the merging hospitals. An alternative explanation for rationalising the empirical results is that the effect on quality is the sum of two effects going in opposite directions: mergers can generate cost synergies with respect to quality provision, which

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most procedures and conditions.

tends to increase quality, but also reduces competition which tends to reduce quality. These two effects might well cancel each other out, as emphasised in an extension to our main analysis.<sup>9</sup>

It is worth emphasising, though, that identification is particularly challenging when empirically evaluating hospital mergers. Merging hospitals are not random: hospitals may merge precisely because of low quality (generating a positive correlation between quality and probability to merge, therefore biasing downwards the estimate of the merger effect on quality). Moreover, we show that under price regulation non-merging hospitals may respond also by lowering quality. If non-merging hospitals are included in the control group, this may also bias downwards estimates of the effect of mergers on quality. The opposite holds when prices are endogenous: the non-merging hospitals increase quality; if included in the control group, this may bias upwards the effect of mergers on quality.

Although not directly related to mergers, our results on quality are in line with studies that find that reductions in competition, as measured by concentration indices, reduce quality for markets with regulated prices. For the US Medicare market, Kessler and McClellan (2000) and Kessler and Geppert (2005) find that market concentration significantly increases mortality. Recent studies on the English National Health Service (NHS) reforms in 2006 introducing patient choice and regulated prices report similar findings (see Cooper et al., 2010; Gaynor et al., 2010). The effects of hospital concentration under price competition vary in all directions (see Gaynor and Vogt, 2012).

The rest of the paper is organised as follows. In Section 2 we present the benchmark model and derive the pre- and post-merger equilibria under two different institutional settings: price regulation and price competition. In Section 3 we conduct a welfare analysis focusing both on patient and total welfare. In Section 4 we consider two different extensions to the model – hospital closure and variable-cost synergies – and discuss how each of these extensions affect our main results. Finally, in Section 5 we summarise our findings and offer some concluding reflections.

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<sup>9</sup>Beckert et al. (2012) simulate the effect of mergers on hospital quality estimating a conditional logit choice model for hip replacement patients as a function of mortality rates (quality), waiting times and distance. Their simulation of a merger suggests that hospital demand would be substantially less sensitive to quality, which in turn could have adverse effects on patients.

## 2 Model

Consider a market for health care services where three providers (hospitals), denoted by  $i = 1, 2, 3$ , are equidistantly located on a circle with circumference equal to 1.<sup>10</sup> A total mass of 1 consumers (patients) are uniformly distributed on the same circle. Each patient demands one unit of treatment from the most preferred provider. The net utility of a patient located at  $z$  and seeking treatment at Hospital  $i$ , located at  $x_i$ , is given by

$$u_{z,x_i} = v + bq_i - \gamma p_i - t(z - x_i)^2, \quad (1)$$

where  $q_i$  and  $p_i$  are the quality offered and the price charged, respectively, by Hospital  $i$ ;  $b > 0$  is the marginal utility of quality;  $\gamma \in (0, 1)$  is the coinsurance rate (i.e., the share of the treatment price paid by the consumer), and  $t > 0$  is a travelling cost parameter.<sup>11</sup>

Each patient chooses the preferred hospital based on quality, price and travelling costs. The demand for each hospital is therefore a function of its own price and quality, and the prices and qualities of its two neighbours. When each patient makes a utility-maximising choice, the demand for Hospital  $i$  is given by

$$D_i(p_i, p_{i-1}, p_{i+1}, q_i, q_{i-1}, q_{i+1}) = \frac{1}{3} + \frac{3b[(q_i - q_{i+1}) + (q_i - q_{i-1})] - 3\gamma[(p_i - p_{i+1}) + (p_i - p_{i-1})]}{2t}. \quad (2)$$

Several of our results rely on the relative size of the parameters  $b$  and  $t$ . As we can see from (2), a high (low) value of  $b$  relative to  $t$  implies a high (low) *demand responsiveness to quality*, and we will subsequently use this terminology when describing the relative size of  $b$  and  $t$ .

All hospitals are assumed to have *ex ante* identical costs. The cost function of Hospital  $i$  is given by

$$C_i(q_i, D_i) = cq_i D_i + \frac{k}{2} q_i^2 + F, \quad (3)$$

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<sup>10</sup>The assumption of three instead of  $n$  hospitals is made in order to make the analysis tractable. In a market with  $n$  hospitals there would be *ex post* differences among the non-merging hospitals, where the incentives for a non-merging hospital with respect to quality and price setting in the post-merger game depend on its relative positioning in space vis-à-vis the merged hospitals. However, as competition is localised, the strongest responses to a merger will always come from the merged hospitals' closest neighbours. Therefore, the assumption of three hospitals is without too much loss of generality.

<sup>11</sup>The hospital choice literature referred to in the introduction also shows that distance is a key predictor of hospital choice.

where  $c \in (0, b)$ ,  $k > 0$  and  $F > 0$ . Notice that there are both variable and fixed costs of quality provision, implying that treatment quality and treatment volume are cost substitutes ( $\partial^2 C_i / \partial q_i \partial D_i > 0$ ). This is a natural assumption. It is 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. The restriction  $c < b$  is made to ensure interior solutions with strictly positive equilibrium quality levels in all versions of the game considered. Each hospital is assumed to maximise profits, given by

$$\pi_i = (p_i - cq_i) D_i - \frac{k}{2} q_i^2 - F. \quad (4)$$

We will analyse the effects of a merger between two of the hospitals in this market, under two different scenarios: price regulation and price competition. In this main part of the analysis we will concentrate on the purely (anti-)competitive effects of a merger.

## 2.1 Price regulation

Suppose that hospitals are subject to price regulation, making quality the only choice variable, with prices being fixed at a uniform level  $p$ . As mentioned in the Introduction, prices are fixed within Medicare in the US and in many other OECD countries, where DRG-type activity-based payment is employed. In the *pre-merger* game, Hospital  $i$  chooses  $q_i$  to maximise profits, which are given by (4) with  $p_i = p$ . From the profit-maximisation problem of Hospital  $i$  we can derive its best-response function, which is given by

$$q_i = \frac{18bp - 2ct + 9bc \sum_{j \neq i} q_j}{6(6bc + kt)}. \quad (5)$$

We see that qualities are *strategic complements*; i.e.,  $\partial q_i / \partial q_j > 0$ . If a hospital increases its quality, the competing hospitals lose demand, which in turn reduces their marginal cost of quality provision. These hospitals will therefore respond by increasing their quality. Notice that this strategic complementarity is caused by the presence of variable quality costs. In contrast, if there are only fixed costs of quality provision (i.e., if  $c = 0$ ), the hospitals' optimal quality choices are strategically independent.

In the symmetric Nash equilibrium, each hospital offers a quality level given by

$$q_i^* = \frac{9bp - ct}{3(3bc + kt)}. \quad (6)$$

The relationships between the key parameters of the model and equilibrium quality are intuitive and quite standard. A higher price or more quality-responsive demand will increase quality provision ( $\partial q_i^*/\partial b = t(c^2 + 3kp)/(3bc + kt)^2$ ). We assume that the regulated price is sufficiently high to ensure an interior solution with quality above the minimum level:  $q_i^* > 0$  if  $p > ct/9b$ . In equilibrium, each hospital serves one third of the market and earns a profit of

$$\pi_i^* = \frac{3kp(2kt^2 + 12bct - 27b^2p) + (6bc + kt)c^2t}{18(3bc + kt)^2} - F. \quad (7)$$

Now consider a merger between two of the hospitals. Throughout the analysis in this section we assume that a merger does not lead to any hospital closures, either because a closure would not be approved by the regulator or because the potential fixed-cost synergies are too small. In the *post-merger* game, the hospital that does not take part in the merger (the ‘outsider’) chooses quality, denoted  $q_o$ , to maximise its profits, whereas the merged entity, which now consists of two hospitals, chooses quality at each of its hospitals, denoted  $q_m$ , to maximise their joint profits.

In the asymmetric Nash equilibrium, the outsider provides quality

$$q_o^* = \frac{9bp(9bc + 2kt) - 2ct(6bc + kt)}{3(27b^2c^2 + 2k^2t^2 + 18bckt)}, \quad (8)$$

whereas each of the merger participants offers quality

$$q_m^* = \frac{9bp(9bc + kt) - ct(15bc + 2kt)}{3(27b^2c^2 + 2k^2t^2 + 18bckt)}. \quad (9)$$

The expressions for equilibrium profits are a bit more involved and therefore only reported in the appendix (in the proof of Proposition 1).

**Proposition 1** *Under price regulation, a hospital merger leads to lower quality provision for all hospitals in the market, with the largest drop in quality for the merging hospitals. A merger is always profitable, and more so for the hospital not taking part in the merger.*

The intuition for these results is fairly straightforward. A merger allows the participants to internalise a negative competition externality by reducing their quality provision.<sup>12</sup> As qualities are

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<sup>12</sup>This is the mechanism highlighted by Katz (forthcoming) in his brief discussion of hospital merger (from duopoly

strategic complements, the outside hospital will respond by reducing quality as well, although by a smaller amount than the merger participants. Thus, the merger leads to a reduction in total demand for the merger participants. Such a merger is profitable, but there is a ‘merger paradox’ in the sense that the outside hospital reaps higher benefits from the merger. Therefore, although the reduction in quality (and the corresponding reduction in profits for a given demand) is smaller for the outside hospital, the higher demand is such that the outside hospital gains ultimately higher profits than the merging ones.

## 2.2 Price competition

Suppose now that the hospitals can choose both the price and the quality of their services. This case is relevant for hospitals in the US market (outside of Medicare) and private markets in Europe where prices are decided by providers. Game-theoretically, we assume that these choices are made simultaneously.<sup>13</sup> In the *pre-merger* game, Hospital  $i$  chooses  $q_i$  and  $p_i$  to maximise (4). The first-order conditions for optimal quality and price, respectively, are given by<sup>14</sup>

$$\frac{\partial \pi_i}{\partial q_i} = \frac{3(b + c\gamma)p_i - (6bc + kt)q_i}{t} + \frac{3c\sum_{j \neq i}(bq_j - \gamma p_j)}{2t} - \frac{c}{3} = 0 \quad (10)$$

and

$$\frac{\partial \pi_i}{\partial p_i} = \frac{1}{3} + \frac{3(b + c\gamma)q_i - 6\gamma p_i}{t} + \frac{3\sum_{j \neq i}(\gamma p_j - bq_j)}{2t} = 0. \quad (11)$$

At this point it is instructive to analyse the strategic interaction between the quality and price decisions, both *within* each hospital and *between* hospitals, as this is crucial for understanding the merger effects on prices and qualities which will be derived below. From (10), the best-quality-

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to monopoly).

<sup>13</sup>In the Appendix, we show that our main results are qualitatively similar if we instead assume that quality and price decisions are made sequentially.

<sup>14</sup>The second-order conditions are

$$\frac{\partial^2 \pi_i}{\partial q_i^2} = -\left(\frac{6bc + kt}{t}\right) < 0, \quad \frac{\partial^2 \pi_i}{\partial p_i^2} = -\frac{6\gamma}{t} < 0$$

and

$$\left(\frac{\partial^2 \pi_i}{\partial p_i^2}\right) \left(\frac{\partial^2 \pi_i}{\partial q_i^2}\right) - \left(\frac{\partial^2 \pi_i}{\partial q_i \partial p_i}\right)^2 = 3 \left(\frac{2kt\gamma - 3(b - \gamma c)^2}{t^2}\right) > 0,$$

which are satisfied if  $t > \frac{3}{2k\gamma}(b - \gamma c)^2$ .

response function of Hospital  $i$  is given by

$$q_i(p_i, p_j, q_j) = \frac{3(b + c\gamma)p_i}{(6bc + kt)} + \frac{3c\sum_{j \neq i}(bq_j - \gamma p_j)}{2(6bc + kt)} - \frac{ct}{3(6bc + kt)}, \quad (12)$$

whereas the best-price-response function is given by

$$p_i(q_i, q_j, p_j) = \frac{(b + c\gamma)q_i}{2\gamma} + \frac{\sum_{j \neq i}(\gamma p_j - bq_j)}{4\gamma} + \frac{t}{18\gamma}. \quad (13)$$

We see that both qualities and prices are *gross strategic complements* between competing hospitals; i.e.,  $\partial q_i / \partial q_j > 0$  for given prices and  $\partial p_i / \partial p_j > 0$  for given qualities. The intuition for the (gross) strategic complementarity between qualities was given in the previous subsection. The strategic complementarity of the hospitals' pricing decisions is standard. All else equal, a unilateral price increase by one hospital leads to higher demand for the competing hospitals. Their marginal revenues (measured as a function of output) are consequently reduced and they will optimally respond by increasing their prices as well.

However, the strategic relationships described above are *partial* in the sense that one of the choice variables (price or quality) is taken to be fixed. How do quality and price decisions interact strategically? From (12) and (13) we see that *quality and price are strategic complements within hospitals*; i.e.,  $\partial q_i / \partial p_i > 0$  and  $\partial p_i / \partial q_i > 0$ . Abstracting from any strategic responses by competing hospitals, a price increase has two effects on incentives for quality provision. It increases the hospital's profit margin and also reduces the marginal cost of quality provision through lower demand. Both effects contribute to a higher optimal level of quality. Vice versa, a higher quality level leads to higher demand and also increases marginal treatment costs, and both effects contribute to a higher optimal price. On the other hand, *quality and price are strategic substitutes between hospitals*; i.e.,  $\partial q_i / \partial p_j < 0$  and  $\partial p_i / \partial q_j > 0$ . All else equal, a unilateral price increase by one hospital leads to higher demand for competing hospitals. As a result, their marginal costs of quality provision increase and they will optimally respond by reducing their qualities. Similarly, if a hospital increases its quality, competing hospitals will have lower demand and their profits are therefore maximised, all else equal, at a lower price.

We can internalise the strategic relationship between quality and price within each hospital by

simultaneously solving (12)-(13) with respect to  $q_i$  and  $p_i$ , yielding

$$p_i(p_j, q_j) = \frac{(kt + 3c(b - c\gamma))(2t + 9\sum_{j \neq i}(\gamma p_j - bq_j))}{18(2kt\gamma - 3(b - c\gamma)^2)} \quad (14)$$

and

$$q_i(p_j, q_j) = \frac{(b - c\gamma)(2t + 9\sum_{j \neq i}(\gamma p_j - bq_j))}{6(2kt\gamma - 3(b - c\gamma)^2)}. \quad (15)$$

Whereas the strategic complementarity between prices remains, we see that the strategic relationship between qualities changes when we take the optimal price adjustments into account. In other words, *qualities are net strategic substitutes*; i.e.,  $\partial q_i / \partial q_j < 0$  when  $p_i$  is optimally adjusted. As explained above, the direct (gross) effect of higher quality by a hospital is that rival hospitals will increase their qualities and lower their prices. However, as quality and price are strategic complements within each hospital, a lower price implies that the quality should be optimally adjusted downwards. This indirect effect outweighs the direct effect, making qualities net strategic substitutes.

Simultaneously solving the three pairs of best-response functions given by (14)-(15), the symmetric Nash equilibrium in the *pre-merger* game is characterised by the following qualities and prices:

$$q_i^* = \frac{b - c\gamma}{3k\gamma}, \quad (16)$$

$$p_i^* = \frac{t}{9\gamma} + \frac{c(b - c\gamma)}{3k\gamma}. \quad (17)$$

The corresponding profits are

$$\pi_i^* = \frac{t}{27\gamma} - \frac{(b - c\gamma)^2}{18k\gamma^2} - F. \quad (18)$$

In the *post-merger* game, the outside hospital chooses quality and price, denoted  $q_o$  and  $p_o$ , to maximise its profits, whereas the merger participants choose quality and price at each of the merged hospitals, denoted  $q_m$  and  $p_m$ , to maximise the sum of the two hospitals' profits. In the asymmetric Nash equilibrium, qualities and prices are given by

$$q_m^* = \frac{(b - \gamma c)(5kt\gamma - 9(b - c\gamma)^2)}{9k\gamma(2kt\gamma - 3(b - c\gamma)^2)} \quad (19)$$

and

$$p_m^* = \frac{(5kt\gamma - 9(b - c\gamma)^2)(2kt + 3c(b - c\gamma))}{27k\gamma(2kt\gamma - 3(b - c\gamma)^2)} \quad (20)$$

for each of the merged hospitals, and

$$q_o^* = \frac{(b - c\gamma)(8kt\gamma - 9(b - c\gamma)^2)}{9k\gamma(2kt\gamma - 3(b - c\gamma)^2)} \quad (21)$$

and

$$p_o^* = \frac{(kt + 3c(b - c\gamma))(8kt\gamma - 9(b - c\gamma)^2)}{27k\gamma(2kt\gamma - 3(b - c\gamma)^2)} \quad (22)$$

for the outside hospital. Equilibrium profits for the outsider and each of the merged hospitals, respectively, are given by

$$\pi_o^* = \frac{(8kt\gamma - 9(b - c\gamma)^2)^2}{486k\gamma^2(2kt\gamma - 3(b - c\gamma)^2)} - F \quad (23)$$

and

$$\pi_m^* = \frac{(4kt\gamma - 3(b - c\gamma)^2)(5kt\gamma - 9(b - c\gamma)^2)^2}{486k\gamma^2(2kt\gamma - 3(b - c\gamma)^2)^2} - F. \quad (24)$$

Before analysing the effects of a hospital merger on qualities and prices, let us first derive a condition for merger profitability. A straightforward comparison of (24) and (18) yields:

**Lemma 1** *Under price competition, a hospital merger is profitable for the participants if*

$$t > \frac{9(b - c\gamma)^2}{4k\gamma},$$

*and unprofitable otherwise.*

This result is perhaps surprising. Even if a merger is always profitable when quality is the only competition variable (Proposition 1) or when price is the only competition variable (which is a standard result from the merger literature, the seminal paper being Deneckere and Davidson, 1985), a merger might not be profitable when competition occurs simultaneously along both dimensions. The intuition for this result will be discussed below, after deriving the equilibrium price and quality responses to the merger.

For the remainder of the analysis, we will assume that the condition in Lemma 1 is satisfied; i.e., we restrict attention to profitable mergers only. This condition, along with the condition  $b > c$ , also ensures existence and uniqueness of both Nash equilibria (before and after the merger).

**Proposition 2** *Under price competition, a hospital merger leads to*

(i) *lower quality at the merged hospitals, higher quality at the outside hospital, and higher average quality in the market;*

(ii) *higher (lower) price at the merged hospitals if the demand responsiveness to quality is sufficiently low (high), higher price at the outside hospital, and higher average price in the market;*

(iii) *smaller market share for the merged hospitals.*

In contrast to the case of price regulation, the effect of a hospital merger on quality is not uniform across all hospitals in the market. A merger leads to lower quality at the merging hospitals, but *higher* quality at the hospital not taking part in the merger. Similarly, the price responses to a merger might also be qualitatively different across merging and non-merging hospitals. Perhaps counterintuitively, a merger might lead to a *price reduction* for the merging hospitals.

In order to sort out the intuition behind these results, which are not straightforward, we need to keep in mind the strategic relationships between qualities and prices – within and across hospitals – which we previously analysed in detail. When two hospitals merge they have an incentive to internalise the negative competition externality that existed between them in the pre-merger game. All else equal, they can increase their joint profits by increasing the price and reducing the quality provided. Such price and quality adjustments will trigger a response from the outside hospital, which in turn triggers feedback effects on the merging hospitals’ optimal quality and price decisions. As qualities are net strategic substitutes whereas prices are net strategic complements across hospitals, the direct response of the non-merging hospital is to increase both the quality and the price. The net strategic substitutability of qualities explains why a hospital merger may lead to quality increases – but only for non-merging hospitals. Furthermore, the increase in quality and market share for the non-merging hospital implies that the (volume-weighted) *average quality* in the market goes up as a result of the merger. In other words, the ‘average patient’ enjoys a higher quality of health care as a result of the merger.

The *feedback effects* of higher price and quality at the outside hospital are in general ambiguous

with respect to the pricing decision of the merged hospitals. As prices are strategic complements across hospitals, the price response of the outside hospital will reinforce the initial price increase by the merger participants. However, from (14) we see that  $\partial p_i / \partial q_j < 0$ . Thus, the positive quality response by the outside hospital will counteract the initial price increase by the merged entity. If this particular feedback effect is sufficiently strong, it might outweigh the merged hospitals' initial incentive to raise prices, implying that a merger might lead to lower prices at the merged hospitals. This will happen if the demand responsiveness to quality is sufficiently high.<sup>15</sup> However, even if a merger might lead to lower prices at the merged hospitals, the net effect of the quality and price responses to the merger implies a loss of market share for the merger participants. Regardless of the sign of the price effect at the merged hospitals, the increase in price and market share for the non-merging hospital also implies that the merger leads to an increase in the (volume-weighted) *average market price* for hospital services.

The intricate strategic relationships between the optimal price and quality decisions also explains the profitability result in Lemma 1. The possibility of unprofitable mergers arises from the fact that qualities are net strategic substitutes. If demand responds sufficiently strongly to quality changes, the positive quality response by the outside hospital is sufficiently strong to make the merger unprofitable for the participants.<sup>16</sup> As under price regulation, it is easily confirmed that the 'merger paradox' also applies when hospitals compete on prices, i.e., a merger is more profitable for the hospital not taking part in the merger.

As mentioned in the introduction, the empirical literature typically finds that prices tend to increase after a merger, and that demand responsiveness to quality is relatively low, which is consistent with the second part of Proposition 2.

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<sup>15</sup>From (14), the feedback effect of higher quality at Hospital  $j$  on the optimal price of Hospital  $i$  is given by

$$\frac{\partial p_i}{\partial q_j} = -\frac{(kt + 3c(b - \gamma c))b}{2(2kt\gamma - 3(b - \gamma c)^2)} < 0.$$

We see that the magnitude (in absolute value) of this effect is increasing in  $b$ .

<sup>16</sup>From (15),

$$\frac{\partial q_i}{\partial q_j} = -\frac{3(b - \gamma c)b}{2(2kt\gamma - 3(b - \gamma c)^2)}.$$

The magnitude (in absolute value) of this effect is increasing in  $b$ .

### 3 Welfare

In this section we analyse the welfare effects of a hospital merger under price regulation and price competition, respectively. For completeness, we will apply different criteria for evaluating the welfare effect of a merger: (i) the effect on patient utility only, and (ii) the effect on social welfare, defined as the sum of total patient utility and total profits net of third-party payments.

In order to derive an expression for total patient utility, notice that Hospital  $i$ 's demand function, given by (2), can alternatively be expressed as

$$D_i(p_i, p_{i-1}, p_{i+1}, q_i, q_{i-1}, q_{i+1}) = \hat{x}_i^{i+1}(p_i, p_{i+1}, q_i, q_{i+1}) + \hat{x}_i^{i-1}(p_i, p_{i-1}, q_i, q_{i-1}), \quad (25)$$

where

$$\hat{x}_i^{i+1} = \frac{1}{6} + \frac{3(b(q_i - q_{i+1}) - \gamma(p_i - p_{i+1}))}{2t} \quad (26)$$

is the location (measured *clockwise* from Hospital  $i$ ) of the patient who is indifferent between Hospital  $i$  and Hospital  $i + 1$ , and

$$\hat{x}_i^{i-1} = \frac{1}{6} + \frac{3(b(q_i - q_{i-1}) - \gamma(p_i - p_{i-1}))}{2t} \quad (27)$$

is the location (measured *anticlockwise* from Hospital  $i$ ) of the patient who is indifferent between Hospital  $i$  and Hospital  $i - 1$ . With a slight abuse of notation, total patient utility is then given by<sup>17</sup>

$$U = \sum_{i=1}^3 \left( \int_0^{\hat{x}_i^{i+1}} (v + bq_i - \gamma p_i - ts) ds + \int_0^{\hat{x}_i^{i-1}} (v + bq_i - \gamma p_i - ts) ds \right). \quad (28)$$

Social welfare also includes hospital profits and third-party payments, and is given by

$$W = U + \sum_{i=1}^3 \pi_i - \sum_{i=1}^3 (1 - \gamma) p_i D_i, \quad (29)$$

which can be re-written as

$$W = \sum_{i=1}^3 \left( \int_0^{\hat{x}_i^{i+1}} (v + bq_i - ts) ds + \int_0^{\hat{x}_i^{i-1}} (v + bq_i - ts) ds - cq_i D_i - \frac{k}{2} q_i^2 \right) - 3F. \quad (30)$$

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<sup>17</sup>Notice that, if  $i = 1$ , then  $i - 1 = 3$ , and if  $i = 3$ , then  $i + 1 = 1$ .

### 3.1 Price regulation

When hospital prices are regulated, the effects of a hospital merger on patient utility and total welfare are quite straightforward to derive:<sup>18</sup>

**Proposition 3** *Under price regulation, a hospital merger reduces the utility for all consumers in the market whereas the effect on social welfare is negative (positive) if the regulated price is below (above) a certain threshold level.*

Under price regulation, the effect of a hospital merger on patient utility is straightforward. As a merger leads to lower quality at all hospitals in the market, all patients suffer a utility loss. The reduction in total patient utility is made up of two components: (i) a reduction in treatment quality for all patients, and (ii) an increase in total travelling costs because of the asymmetric nature of the post-merger equilibrium, with a larger number of patients travelling to the hospital that does not take part in the merger.

The effect of a hospital merger on social welfare, on the other hand, is *a priori* ambiguous. As a merger leads to lower quality in the market, a welfare gain is possible only if the quality was too high in the first place. There is a real resource cost of providing treatment quality, which implies that quality can in principle be too high from utilitarian perspective. As the hospitals' incentives for providing quality depend positively on the regulated price, there will be overprovision of quality in the market if the price is sufficiently high. If the price is so high that the welfare gain from lower quality outweighs the welfare loss from increased travelling costs, the overall welfare effect of a hospital merger will be positive.

### 3.2 Price competition

When hospitals compete on both quality and price, total patient utility and social welfare in the pre-merger equilibrium are given by, respectively,

$$U(q_i^*, p_i^*) = v - \left( \frac{13kt\gamma - 36(b - c\gamma)^2}{108k\gamma} \right) \quad (31)$$

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<sup>18</sup>The explicit expressions for total patient utility and total welfare, in the pre- and post-merger equilibria, are rather involved and therefore only reported in the Appendix (in the proof of Proposition 3).

and

$$W(q_i^*, p_i^*) = v - \left( \frac{kt\gamma^2 + 18(b(1-2\gamma) + c\gamma)(b-c\gamma)}{108k\gamma^2} \right), \quad (32)$$

whereas the corresponding expressions in the post-merger equilibrium are

$$U(q_m^*, p_m^*, q_o^*, p_o^*) = v - \left( \frac{kt\gamma \left( 5589(b-c\gamma)^4 + 4kt\gamma \left( 175kt\gamma - 873(b-c\gamma)^2 \right) \right) - 2916(b-c\gamma)^6}{972k\gamma \left( 2kt\gamma - 3(b-c\gamma)^2 \right)^2} \right) \quad (33)$$

and

$$W(q_m^*, p_m^*, q_o^*, p_o^*) = v - \left( \frac{1458(b(1-2\gamma) + c\gamma)(b-c\gamma)^5 + kt\gamma\Phi}{972k\gamma^2 \left( 2kt\gamma - 3(b-c\gamma)^2 \right)^2} \right), \quad (34)$$

where

$$\Phi := 4kt\gamma \left( 11kt\gamma^2 + 9(b-c\gamma)(19b - 41b\gamma + 19c\gamma + 3c\gamma^2) \right) - 81 \left( 24(b+c\gamma) + c\gamma^2 - 49b\gamma \right) (b-c\gamma)^3.$$

The welfare implications of a hospital merger under price competition are summarised as follows:

**Proposition 4** *Under price competition, a hospital merger leads to*

- (i) *lower total patient utility;*
- (ii) *higher utility for more than a third of all patients in the market if the demand responsiveness to quality is sufficiently high;*
- (ii) *higher social welfare if  $\gamma > \frac{2}{3}$  and the demand responsiveness to quality is sufficiently high; otherwise, welfare drops.*

If we consider total patient utility, or the utility of the ‘average patient’ in the market, a hospital merger has three different effects: (i) the average quality goes up, which is positive; (ii) the average price also goes up, which is negative; and (iii) total travelling costs go up (because of the asymmetry of the post-merger equilibrium), which is also negative. In our model, the second and third effects always outweigh the first effect, implying that a hospital merger has a negative effect on total patient utility. However, some of the patients in the market might still benefit from the merger. The patients attending the non-merging hospital benefit from higher quality as a result of the merger. If the demand responsiveness to quality is sufficiently high, the quality response of the outside hospital is sufficiently strong to make these patients enjoy a net benefit from the hospital merger in spite

of the corresponding price increase. As these net benefits also apply (due to continuity) to some of the patients who switch hospitals as a result of the merger, more than a third of the patients in the market might potentially benefit from the hospital merger.

Perhaps the most surprising result of our analysis is that a purely anti-competitive hospital merger (i.e., a merger with no direct cost synergies) might improve social welfare. A welfare-improving merger requires that two conditions are met: (i) patients must pay a sufficiently large share of the price and (ii) demand must respond sufficiently strongly to quality changes.

The intuition behind this apparently counterintuitive result is the following. Social welfare depends on a trade-off between patient benefits of quality and two types of costs: (i) the cost of travelling and (ii) the cost of quality provision. Interestingly, social welfare is not necessarily maximised with symmetric supply of quality across all hospitals in the market. The reason is that there are fixed costs of quality provision (given by the term  $(k/2)q_i^2$  in the hospital cost function). Starting from a situation with symmetric quality provision, the costs of providing a given level of average quality can be reduced by increasing the quality at some hospital(s) and reducing it at others, and letting more patients be treated at the high-quality hospital(s). In fact, the costs of providing a given level of average quality is minimised if there is only one hospital offering this quality level, whereas all other hospitals offer zero quality (at zero costs) and have zero demand. If there are no travelling costs, such an outcome would clearly maximise social welfare for any given average quality level (including the socially optimal one).

However, in the presence of travelling costs, the cost savings from a more asymmetric quality provision must be weighed against the increase in total travelling costs that would occur in a more asymmetric outcome. If the cost of travelling is sufficiently low and the marginal utility of quality is sufficiently high, social welfare can be increased with a more asymmetric quality provision.<sup>19</sup> The effect of a hospital merger under price competition is precisely to make quality provision more asymmetric. Quality increases at the non-merging hospital and more patients attend this hospital in the post-merger equilibrium. Such a merger can therefore increase social welfare because of increased allocational efficiency with respect to fixed quality costs, if the demand responsiveness to quality is sufficiently high (i.e., if  $b$  is sufficiently high relative to  $t$ ).

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<sup>19</sup>Notice that the cost savings from a more asymmetric quality provision would increase the socially optimal level of quality provision. More asymmetric quality provision could therefore increase social welfare if the patients value the higher average quality level to a sufficient degree.

Notice, however, that the possibility of a welfare-improving merger requires that the patients pay a sufficiently large share of the price. The reason is the following. If the patients pay a smaller share of the treatment price, demand becomes less price-elastic, resulting in higher equilibrium prices and (as price and quality are strategic complements within hospitals) also higher equilibrium qualities. Thus, a lower coinsurance rate increases the potential for overprovision of quality and, as a hospital merger increases the average quality in the market even further, this reduces the scope for the allocative efficiency gains from a more asymmetric quality provision to be large enough to make the merger welfare-improving. In our model, welfare-improving (and profitable) mergers are possible only if  $\gamma > 2/3$ .<sup>20</sup>

## 4 Extensions

All the previous results have been derived under the assumption that there are no direct cost synergies associated with a hospital merger. Here we relax this assumption by briefly looking at two different types of merger synergies: (i) fixed-cost synergies that can be realised through hospital closure, and (ii) variable-cost synergies that reduce the marginal cost of both treatment and quality provision.

### 4.1 Hospital closure

Suppose that the merging hospitals decide to close down one of its two hospitals and allocate all production to the remaining hospital. Hospital closure allows the merging parties to realise fixed-cost savings and will be profitable if  $F$  is sufficiently large. Thus, the analysis in this extension applies to cases where the realisation of fixed-cost savings is an important motivation for the hospital merger.

In the case of hospital closure, a merger implies that the market structure changes from a symmetric triopoly to a symmetric duopoly.<sup>21</sup> The post-merger demand function for Hospital  $i$  is given by

$$D_i(p_i, p_j, q_i, q_j) = \frac{1}{2} + \frac{9(b(q_i - q_j) - \gamma(p_i - p_j))}{4t}; \quad i = m, o; \quad j = m, o; \quad i \neq j, \quad (35)$$

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<sup>20</sup>Since co-insurance rates for hospital care are typically low, and empirical hospital choice models suggest that the demand responsiveness to quality is relatively low, the two conditions identified for hospital mergers to increase welfare are perhaps less likely to be satisfied.

<sup>21</sup>The post-merger duopoly is, in a sense, asymmetric in terms of locations. However, with only two hospitals in the market, the equilibrium outcome in a Salop model will be symmetric regardless of how the firms are located.

whereas the profit function is given by (4). As before, we distinguish between the cases of price regulation and price competition. Furthermore, as a merger is always profitable for sufficiently high values of  $F$  with closure, we neglect the issue of merger profitability and focus only on the effects on quality and potentially price.

#### 4.1.1 Price regulation

Setting  $p_m = p_o = p$  and letting the (merged and non-merged) hospitals simultaneously choose quality to maximise profits, the Nash-equilibrium outcome of the post-merger game with closure is given by:

$$q_m^* = q_o^* = \frac{9bp - 2ct}{9bc + 4kt}, \quad (36)$$

$$D_m(q_m^*, q_o^*) = D_o(q_m^*, q_o^*) = \frac{1}{2}, \quad (37)$$

$$\pi_m^* = \pi_o^* = \frac{kp(16kt^2 + 72bct - 81b^2p) + 2c^2t(9bc + 2kt)}{2(9bc + 4kt)^2} - F. \quad (38)$$

As the post-merger game is symmetric, the merged and non-merged hospitals choose the same level of quality, obtain equal market shares, and therefore earn the same profit. The effect on equilibrium quality is unambiguous:

**Proposition 5** *Under price regulation, a hospital merger with closure leads to lower quality at both the merged and the non-merged hospitals.*

As in the benchmark model with no closure, under price regulation a hospital merger leads to lower quality provision for all hospitals also in the case where one of the merging hospitals is closed down. The reason for this is two-fold, as a reduction in the number of hospitals has two different effects on incentives for quality provision (although both effects go in the same direction). First, the increase in the distance from the ‘average patient’ to the nearest hospital means that the intensity of quality competition is relaxed. Second, whereas each hospital treated one third of the patients before the merger, in the post-merger equilibrium the remaining two hospitals now treat half of the market each. This increases the variable quality costs, which in turn reduces the profit margin from treating patients. When the profit margin is lower, the hospitals optimally respond by reducing their quality in order to obtain higher profits. Thus, our previous result (Proposition 1) that hospital merger leads

to lower quality under price regulation does not depend on whether a merger leads to closure or not. For patients, though, a hospital closure is particularly bad, because not only is quality reduced, but also average travelling distance will be higher.

#### 4.1.2 Price competition

In the post-merger game under price competition, assuming simultaneous decision-making, Hospital  $i$  chooses  $p_i$  and  $q_i$  to maximise profits,  $i = m, o$ . The symmetric Nash-equilibrium outcome of the post-merger game with hospital closure is given by

$$q_m^* = q_o^* = \frac{b - c\gamma}{2k\gamma}, \quad (39)$$

$$p_m^* = p_o^* = \frac{2t}{9\gamma} + \frac{c(b - c\gamma)}{2k\gamma}, \quad (40)$$

$$D_m(p_m^*, p_o^*, q_m^*, q_o^*) = D_o(p_m^*, p_o^*, q_m^*, q_o^*) = \frac{1}{2}, \quad (41)$$

$$\pi_m^* = \pi_o^* = \frac{t}{9\gamma} - \frac{(b - c\gamma)^2}{8k\gamma^2} - F. \quad (42)$$

As under price regulation, the effects (on price and quality) of a hospital merger with closure are unambiguous:

**Proposition 6** *Under price competition, a hospital merger with closure leads to higher quality and price at both the merging and the non-merging hospitals.*

Comparing Propositions 5 and 6 it is evident that the effect on equilibrium quality of a hospital merger with closure depends crucially on whether hospitals compete on prices or not. In case of price competition, a merger (with closure) leads to higher quality for all firms in the market. The key to understanding the effects of hospital closure is the initial demand response for the remaining hospital in the market. All else equal, a hospital closure leads to higher demand for the remaining hospitals. This makes hospital-specific demand less elastic and the remaining hospitals will respond by increasing their prices. The effect of hospital closure on quality provision is determined by two counteracting incentives. On the one hand, a higher price implies a higher profit margin, which stimulates quality provision. On the other hand, the initial demand increase (because of the hospital

closure) leads to higher variable quality costs and gives the hospitals an incentive to reduce their quality provision. Under price regulation, only the latter effect is present and hospital closure leads to lower quality provision. However, when prices are endogenous the former effect dominates, yielding higher equilibrium quality provision as a result of the hospital closure.<sup>22</sup>

Interestingly, this finding is not consistent with our previous results on hospital merger without closure (cf. Proposition 2), where we found that the merging hospitals reduce quality whereas the non-merging hospital increases quality. In case of closure, the post-merger game is symmetric and all hospitals have the same incentives for quality provision. Because of the initial demand effect of hospital closure, the positive price response is sufficiently strong to ensure higher quality provision (as price and quality are strategic complements within hospitals) in the post-merger equilibrium. Thus, an important insight from the analysis in this section is that the effect of a hospital merger on quality provision is likely to depend crucially on whether the merger implies hospital closure or not.

## 4.2 Variable-cost synergies

A hospital merger might also yield variable cost synergies, for example through improved resource utilisation. Dranove and Lindrooth (2003) find that in the US mergers reduce hospital costs by about 14% during the two-three years following the merger. Previous studies did not find much evidence of cost savings, with the exception of Alexander et al. (1996) which found cost reductions of 33%. Here we briefly explore this possibility by assuming that a merger implies a reduction of variable costs by a fraction  $\delta \in [0, 1)$ . For clarity of analysis, we now assume that a merger will not lead to hospital closure. The profit of each of the merger participants is then given by

$$\pi_m = (p - c(1 - \delta)q_m) D_m - \frac{k}{2} q_m^2 - F. \quad (43)$$

Under *price regulation*, equilibrium qualities in the post-merger Nash equilibrium are given by

$$q_m^* = \frac{9bp(kt + 3bc(3 - \delta)) - ct(1 - \delta)(15bc + 2kt)}{81b^2c^2(1 - \delta) + 6kt(kt + 3bc(3 - \delta))} \quad (44)$$

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<sup>22</sup>This result is also found by Economides (1993) who report an inverse relationship between firm density and equilibrium quality in a Salop model with quality and price competition. However, Brekke et al. (2010) show that this result could be reversed if utility is non-linear in income.

and

$$q_o^* = \frac{9bp(+2kt + 3bc(3 - 2\delta)) - 2ct(kt + 6bc(1 - \delta))}{81b^2c^2(1 - \delta) + 6kt(kt + 3bc(3 - \delta))}. \quad (45)$$

The effects of a hospital merger on equilibrium qualities are easily characterised:

**Proposition 7** *Under price regulation, a hospital merger leads to lower (higher) quality for all hospitals in the market if the size of the variable cost synergies are below (above) a certain threshold level. The quality response is always stronger for the merged hospitals.*

Thus, compared with the benchmark case of no merger synergies (Proposition 1), the quality effects of a hospital merger are turned around if there are sufficiently larger cost synergies. This is fairly intuitive. All else equal, a reduction in variable costs increases the profit margin on each treatment and therefore makes it more profitable to attract patients by providing higher quality. If this effect is sufficiently large, it will outweigh the anticompetitive effect of the merger and lead to an overall increase in quality. Because of strategic complementarity, the quality response of the outsider is always in the same direction as the quality adjustment of the merger participants, implying that a merger leads to lower or higher quality for *all* hospitals in the market, depending on the magnitude of the cost synergies. The presence of variable cost synergies obviously makes the merger even more profitable and, if these synergies are sufficiently large, the total demand for the merger participants will also increase.

Under *price competition*, the equilibrium prices and qualities in the post-merger game are given by<sup>23</sup>

$$p_m^* = \frac{(5kt\gamma - 9(b - c\gamma)^2)(2kt + 3c(1 - \delta)(b - c\gamma(1 - \delta)))}{27k\gamma(2kt\gamma - 3(b - c\gamma)^2 - c\gamma\delta(2(b - c\gamma) + c\gamma\delta))}, \quad (46)$$

$$p_o^* = \frac{(kt + 3c(b - c\gamma))(8kt\gamma - 9(b - c\gamma(1 - \delta))^2)}{27k\gamma(2kt\gamma - 3(b - c\gamma)^2 - c\gamma\delta(2(b - c\gamma) + c\gamma\delta))}, \quad (47)$$

$$q_m^* = \frac{(b - c\gamma(1 - \delta))(5kt\gamma - 9(b - c\gamma)^2)}{9k\gamma(2kt\gamma - 3(b - c\gamma)^2 - c\gamma\delta(2(b - c\gamma) + c\gamma\delta))}, \quad (48)$$

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<sup>23</sup>Equilibrium existence with profitable mergers requires that the following condition is satisfied:

$$t > \max \left\{ \frac{9(b - c\gamma)^2}{4k\gamma}, \frac{9(b - c\gamma(1 - \delta))^2}{8k\gamma}, \frac{3(b - c\gamma)^2}{2k\gamma} + \frac{c\gamma\delta(2(b - c\gamma) + c\gamma\delta)}{2k\gamma} \right\}.$$

$$q_o^* = \frac{(b - c\gamma) \left( 8kt\gamma - 9(b - c\gamma(1 - \delta))^2 \right)}{9k\gamma \left( 2kt\gamma - 3(b - c\gamma)^2 - c\gamma\delta(2(b - c\gamma) + c\gamma\delta) \right)}. \quad (49)$$

Clearly, due to continuity, the results stated in Proposition 2 also holds for sufficiently small values of  $\delta$ . If there are sizeable cost synergies, the effects of a merger in terms of quality and price responses are generally hard to characterise. Depending on the exact parameter configuration, a number of different outcomes are possible, including a complete reversal of price and quality responses, where a merger leads to lower prices and higher quality for the merging hospitals, and a reduction of both price and quality for the non-merging hospital.

## 5 Concluding remarks

In this paper we have used a spatial competition framework to study the effects of hospital mergers under two different institutional settings: price regulation and price competition. The main part of the analysis focuses exclusively on anticompetitive effects, where a hospital merger implies coordination of quality provision and (if not regulated) prices. The benchmark model is subsequently extended to consider efficiency gains, either through variable-cost savings or hospital closure.

We have shown that the effects of hospital mergers on quality depend crucially on whether hospital prices are regulated or not. Under price regulation, the merging hospitals reduce quality in order to increase their profit margin. The non-merging hospital responds by also reducing quality, reflecting that quality decision are strategic complements under price regulation. The merger is profitable for all hospitals, but there is a ‘merger paradox’ in the sense that the non-merging hospital gains more from the merger than the merging hospitals. Clearly, under price regulation, a hospital merger (without efficiency gains) is always harmful for patients, but also for society (unless quality was too high before the merger took place).

Under price competition, the effects of a hospital merger are more involved due to the strategic relationship between quality and price. We report some quite surprising results. The non-merging hospital *increases* quality as a response to the quality reduction by the merging hospitals, which is in contrast to the results under price regulation. This arises because mergers also induce an increase in price, which in turn increases the mark up and the returns from higher quality. This result holds regardless of how strongly demand responds to quality changes. Under the assumption that demand

responsiveness to quality is sufficiently high, we obtain some additional surprising results. First, the merging hospitals might *reduce* prices if the quality increase by the non-merging hospitals is sufficiently strong. This, in turn, might make the merger *unprofitable*. Finally, the merger might be socially beneficial (even in absence of direct cost synergies) if both the coinsurance rate and the demand responsiveness to quality are sufficiently high.

By way of conclusion, we would like to make some further reflections on the ambiguity of some of our results. As explained above, our analysis has revealed that, at least when prices are endogenous, the effects of a hospital merger often rely crucially on the demand responsiveness to quality. If this responsiveness is relatively low (which is suggested by existing empirical evidence), a hospital merger leads to a higher price for the merging hospitals, lower utility for all patients in the market and lower total welfare. In theory, each of these results are turned around if demand is sufficiently responsive to changes in hospital quality. An interesting point we would like to make in this respect is that, although the demand responsiveness to quality is to some extent determined by preferences which are more or less stable over time, it is also likely to be influenced by public policy to a considerable degree. Governments in several countries have in recent years taken various measures to increase patient information about hospital quality, for example by publishing quality indicators on a regular basis, and more countries are likely to follow suit. The intended effect of such policy measures is precisely to make demand more quality-elastic.<sup>24</sup> A potentially important implication of our analysis is that policies to increase the demand responsiveness to hospital quality might also fundamentally change the effects of hospital mergers, sometimes in surprising ways.

## Appendix

The proofs of all Propositions are offered in Section A.1, whereas the subgame perfect Nash equilibrium with sequential quality and price choices is derived in Section A.2.

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<sup>24</sup>Indeed, Gaynor et al. (2012b) find that a recent reform relaxing patient constraints on hospital choice in the English National Health Service led to a substantial increase in the demand elasticity with respect to clinical quality.

## A.1. Proofs

**Proof of Proposition 1.** A comparison of (9) and (6) yields,

$$q_m^* - q_i^* = -\frac{bt(3kp + c^2)(6bc + kt)}{(3bc + kt)(9bc(3bc + 2kt) + 2k^2t^2)} < 0, \quad (\text{A1})$$

a comparison of (8) and (6) yields

$$q_o^* - q_i^* = -\frac{3b^2ct(3kp + c^2)}{(3bc + kt)(9bc(3bc + 2kt) + 2k^2t^2)} < 0, \quad (\text{A2})$$

whereas a comparison of (9) and (8) yields

$$q_m^* - q_o^* = -\frac{bt(3kp + c^2)}{9bc(3bc + 2kt) + 2k^2t^2} < 0. \quad (\text{A3})$$

In the post-merger game with price regulation, equilibrium profits are given by

$$\pi_m^* = \frac{\left[ \begin{array}{c} c^2t(3bc + kt)(15bc + 2kt)^2 \\ -3kp(81b^2p(27b^2c^2 + k^2t^2 + 11bckt) - 2t(3bc + kt)(15bc + 2kt)^2) \end{array} \right]}{18(27b^2c^2 + 2k^2t^2 + 18bckt)^2} \quad (\text{A4})$$

and

$$\pi_o^* = \frac{4c^2t(6bc + kt)^3 - 3kp(81b^3cp(27bc + 4kt) - 8t(6bc + kt)^3)}{18(27b^2c^2 + 2k^2t^2 + 18bckt)^2} \quad (\text{A5})$$

A comparison of (A4) and (7) yields

$$\pi_m^* - \pi_i^* = \frac{b^2t(21bc(3bc + kt)^2 + k^3t^3)(3kp + c^2)^2}{2(3bc + kt)^2(27b^2c^2 + 2k^2t^2 + 18bckt)^2} > 0, \quad (\text{A6})$$

whereas a comparison of (A4) and (A5) yields

$$\pi_m^* - \pi_o^* = -\frac{3b^2t(3kp + c^2)^2(7bc + kt)}{2(27b^2c^2 + 2k^2t^2 + 18bckt)^2} < 0. \quad (\text{A7})$$

*Q.E.D.*

**Proof of Proposition 2.** (i): Comparing (19) and (16) yields

$$q_m^* - q_i^* = -\frac{(b - c\gamma)t}{9(2kt\gamma - 3(b - c\gamma)^2)} < 0. \quad (\text{A8})$$

Comparing (21) and (16) yields

$$q_o^* - q_i^* = \frac{2t(b - c\gamma)}{9(2kt\gamma - 3(b - c\gamma)^2)} > 0. \quad (\text{A9})$$

The average quality in the market in the post-merger equilibrium is

$$\begin{aligned} \bar{q} & : = 2D_m(q_m^*, p_m^*, q_o^*, p_o^*)q_m^* + D_o(q_m^*, p_m^*, q_o^*, p_o^*)q_o^* \\ & = \frac{\left(81(b - c\gamma)^4 + 2kt\gamma(19kt\gamma - 54(b - c\gamma)^2)\right)(b - c\gamma)}{27k\gamma(2kt\gamma - 3(b - c\gamma)^2)^2}. \end{aligned} \quad (\text{A10})$$

Comparing (A10) and (16) yields

$$\bar{q} - q_i^* = \frac{2kt^2\gamma(b - c\gamma)}{27(2kt\gamma - 3(b - c\gamma)^2)^2} > 0. \quad (\text{A11})$$

(ii): Comparing (20) and (17) yields

$$p_m^* - p_i^* = t \left( \frac{4kt\gamma - 3(3b - 2c\gamma)(b - c\gamma)}{27\gamma(2kt\gamma - 3(b - c\gamma)^2)} \right) > (<) 0 \quad \text{if} \quad t > (<) \frac{3(3b - 2c\gamma)(b - c\gamma)}{4k\gamma}. \quad (\text{A12})$$

Merger profitability requires  $t > \frac{9(b - c\gamma)^2}{4k\gamma}$ . As  $\frac{3(3b - 2c\gamma)(b - c\gamma)}{4k\gamma} - \frac{9(b - c\gamma)^2}{4k\gamma} = \frac{3c(b - c\gamma)}{4k} > 0$ , the parameter space defined by  $t < \frac{3(3b - 2c\gamma)(b - c\gamma)}{4k\gamma}$  is non-empty. Regarding the non-merging hospital, comparing (22) and (17) yields

$$p_o^* - p_i^* = \frac{2t(kt + 3c(b - c\gamma))}{27(2kt\gamma - 3(b - c\gamma)^2)} > 0. \quad (\text{A13})$$

The average price in the market in the post-merger equilibrium is

$$\begin{aligned}\bar{p} & : = 2D_m(q_m^*, p_m^*, q_o^*, p_o^*)p_m^* + D_o(q_m^*, p_m^*, q_o^*, p_o^*)p_o^* \\ & = \frac{729c(b-c\gamma)^5 + kt \left( \begin{array}{c} 81(5b-17c\gamma)(b-c\gamma)^3 \\ + 2kt\gamma(82kt\gamma - 9(28b-47c\gamma)(b-c\gamma)) \end{array} \right)}{243k\gamma(2kt\gamma - 3(b-c\gamma)^2)^2}.\end{aligned}\quad (\text{A14})$$

Comparing (A14) and (17) yields

$$\bar{p} - p_i^* = \frac{2t \left( 81(b-c\gamma)^4 + kt\gamma(28kt\gamma - 9(b-c\gamma)(10b-11c\gamma)) \right)}{243\gamma(2kt\gamma - 3(b-c\gamma)^2)^2}.\quad (\text{A15})$$

The numerator is monotonically increasing in  $t$  for all  $t > \frac{9(b-c\gamma)^2}{4k\gamma}$ . Setting  $t$  at the lowest level that still guarantees profitable mergers,  $t = \frac{9(b-c\gamma)^2}{4k\gamma}$ , the numerator in (A15) reduces to  $\frac{729b(b-c\gamma)^3(b-c\gamma)^2}{8k\gamma} > 0$ . Thus,  $\bar{p} > p_i^*$ . (iii): Inserting the equilibrium values of qualities and prices into (2) and comparing the pre- and post-merger equilibria, yields

$$D_m(q_m^*, p_m^*, q_o^*, p_o^*) - D_i(q_i^*, p_i^*) = -\frac{tk\gamma}{9(2kt\gamma - (b-c\gamma)^2)} < 0.\quad (\text{A16})$$

*Q.E.D.*

**Proof of Proposition 3.** In the pre-merger equilibrium with price regulation, total patient utility and welfare are given by, respectively,

$$U(q_i^*) = v - \gamma p + \frac{324pb^2 - t(39bc + kt)}{108(3bc + kt)}\quad (\text{A17})$$

and

$$W(q_i^*) = v + \frac{162b^2p(6c(b-c) - 9kp + 2kt) - 9bc^2t(13b-12c) - kt^2(6c(7b-3c) + kt)}{108(3bc + kt)^2},\quad (\text{A18})$$

whereas in the post-merger equilibrium, the corresponding expressions are

$$U(q_m^*, q_o^*) = v - \gamma p + \frac{\left[ \begin{array}{l} 54b^2p(1458b^3c^3 + 16k^3t^3 + 252bck^2t^2 + 1206b^2c^2kt + 27b^2k^2pt) \\ -t(14175b^4c^4 + 4k^4t^4 + 2736b^2c^2k^2t^2 + 216bck^3t^3 + 11988b^3c^3kt) \end{array} \right]}{108(27b^2c^2 + 2k^2t^2 + 18bckt)^2} \quad (\text{A19})$$

and

$$W(q_m^*, q_o^*) = v + \frac{\left[ \begin{array}{l} 54b^2p \left( \begin{array}{l} 1458b^2c^3(b-c) + 16k^3t^3 \\ +18ckt(bc(67b-26c) + 2kt(7b-c)) \\ -27kp(81b^2c^2 + kt(2kt + b(26c-b))) \end{array} \right) \\ -t \left( \begin{array}{l} 81b^3c^4(175b-164c) + 4k^4t^4 \\ +36ckt \left( \begin{array}{l} 9b^2c^2(37b-23c) \\ +2kt(2bc(19b-9c) + kt(3b-c)) \end{array} \right) \end{array} \right) \end{array} \right]}{108(27b^2c^2 + 2k^2t^2 + 18bckt)^2}. \quad (\text{A20})$$

As a merger leads to lower quality for all hospitals ( $q_i^* > q_o^* > q_m^*$ ), it follows straightforwardly that utility decreases for all patients in the market; thus  $U(q_m^*, q_o^*) < U(q_i^*)$ . Regarding total welfare, a comparison of (A18) and (A20) reveals that

$$\begin{aligned} & W(q_m^*, q_o^*) - W(q_i^*) \\ = & b^2t(3kp + c^2) \frac{\left[ \begin{array}{l} 27kp(9b^3c^2(b+28c) + kt(3b^2c(2b+59c) + kt(34bc+2kt+b^2))) \\ -3ckt(9b^2c^2(100b-59c) + kt(3bc(115b-34c) + 2kt(26b-3c))) \\ -81b^3c^4(29b-28c) - 8k^4t^4 \end{array} \right]}{6(3bc+kt)^2(27b^2c^2 + 2k^2t^2 + 18bckt)^2} \quad (\text{A21}) \end{aligned}$$

< (>) 0 if

$$p < (>) \frac{\left[ \begin{array}{l} 8k^4t^4 + 81b^3c^4(29b-28c) \\ +3ckt(9b^2c^2(100b-59c) + kt(3bc(115b-34c) + 2kt(26b-3c))) \end{array} \right]}{27k(9b^3c^2(b+28c) + kt(3b^2c(2b+59c) + kt(b(b+34c) + 2kt)))}.$$

*Q.E.D.*

**Proof of Proposition 4.** (i): Comparing (31) and (33) yields

$$U(q_m^*, p_m^*, q_o^*, p_o^*) - U(q_i^*, p_i^*) = -2t \left( \frac{kt\gamma \left( 29kt\gamma - 99(b - c\gamma)^2 \right) + 81(b - c\gamma)^4}{243 \left( 2kt\gamma - 3(b - c\gamma)^2 \right)^2} \right). \quad (\text{A22})$$

The sign of (A22) is determined by the sign of the numerator, which is monotonically increasing in  $t$  for  $t > \frac{9(b-c\gamma)^2}{4k\gamma}$ . Setting  $t = \frac{9(b-c\gamma)^2}{4k\gamma}$ , the numerator is  $\frac{81(b-c\gamma)^4}{16} > 0$ . Thus,  $U(q_m^*, p_m^*, q_o^*, p_o^*) < U(q_i^*, p_i^*)$  for all parameter configurations that yield profitable mergers.

(ii): Patients attending the non-merging hospital in the pre-merger equilibrium (these patients constitute one third of the market) can potentially benefit from the merger due to higher quality (if the quality increase outweighs the utility loss of higher prices). The individual utility effect of the merger for each of these patients is

$$\Delta u := b(q_o^* - q_i^*) - \gamma(p_o^* - p_i^*) = -\frac{2t \left( kt\gamma - 3(b - c\gamma)^2 \right)}{27 \left( 2kt\gamma - 3(b - c\gamma)^2 \right)} < (>) \quad \text{if } t > (<) \frac{3(b - c\gamma)^2}{k\gamma}. \quad (\text{A23})$$

If  $\Delta u > 0$ , the merger will also increase the utility of some patients who switch from the merged hospitals to the outside hospital as a result of the merger, and who are located sufficiently close to the patients who were indifferent between a merged and a non-merged hospital in the pre-merger equilibrium. (iii) Comparing (32) and (34) yields

$$\begin{aligned} W(q_m^*, p_m^*, q_o^*, p_o^*) - W(q_i^*, p_i^*) &= -\frac{(2kt\gamma^2 - 9(b - c\gamma)(b(2\gamma - 1) - c\gamma))kt^2}{243 \left( 2kt\gamma - 3(b - c\gamma)^2 \right)^2} \quad (\text{A24}) \\ &< (>) 0 \quad \text{if } t > (<) \frac{9(b(2\gamma - 1) - c\gamma)(b - c\gamma)}{2k\gamma^2}. \end{aligned}$$

Notice that

$$\frac{9(b(2\gamma - 1) - c\gamma)(b - c\gamma)}{2k\gamma^2} - \frac{9(b - c\gamma)^2}{4k\gamma} = \frac{9(b - c\gamma)(b(3\gamma - 2) - c\gamma(2 - \gamma))}{4k\gamma^2}.$$

This expression is always negative if  $\gamma < \frac{2}{3}$ . If  $\gamma > \frac{2}{3}$ , the expression is positive if  $b$  is sufficiently high. Thus,  $W(q_m^*, p_m^*, q_o^*, p_o^*) > W(q_i^*, p_i^*)$  if  $\gamma > \frac{2}{3}$  and  $b$  is sufficiently large relative to  $t$ .

*Q.E.D.*

**Proof of Proposition 5.** Comparing (6) and (36) yields

$$q_m^* - q_i^* = q_o^* - q_i^* = -\frac{t(9bc^2 + 9bkp + 2ckt)}{3(3bc + kt)(9bc + 4kt)} < 0. \quad (\text{A25})$$

*Q.E.D.*

**Proof of Proposition 6.** Comparing (16)-(17) and (39)-(40) yields

$$q_m^* - q_i^* = q_o^* - q_i^* = \frac{b - c\gamma}{6k\gamma} > 0 \quad (\text{A26})$$

and

$$p_m^* - p_i^* = p_o^* - p_i^* = \frac{t}{9\gamma} + \frac{c(b - c\gamma)}{6k\gamma} > 0. \quad (\text{A27})$$

*Q.E.D.*

**Proof of Proposition 7.** Comparing (6) and (44) yields

$$q_m^* - q_i^* = \frac{(6bc + kt)(c\delta(27b^2p + 2kt^2 + 3bct) - 3bt(3kp + c^2))}{3(3bc + kt)(27b^2c^2(1 - \delta) + 6bckt(3 - \delta) + 2k^2t^2)} > (<) 0 \quad \text{if } \delta > (<) \widehat{\delta}, \quad (\text{A28})$$

comparing (6) and (45) yields,

$$q_o^* - q_i^* = \frac{bc(c\delta(27b^2p + 2kt^2 + 3bct) - 3bt(3kp + c^2))}{(3bc + kt)(27b^2c^2(1 - \delta) + 6bckt(3 - \delta) + 2k^2t^2)} > (<) 0 \quad \text{if } \delta > (<) \widehat{\delta}, \quad (\text{A29})$$

and comparing (44) and (45) yields

$$q_m^* - q_o^* = \frac{c\delta(27b^2p + 2kt^2 + 3bct) - 3bt(3kp + c^2)}{3(27b^2c^2(1 - \delta) + 6bckt(3 - \delta) + 2k^2t^2)} > (<) 0 \quad \text{if } \delta > (<) \widehat{\delta}, \quad (\text{A30})$$

where

$$\widehat{\delta} := \frac{3bt(3kp + c^2)}{c(27pb^2 + 2kt^2 + 3bct)}. \quad (\text{A31})$$

*Q.E.D.*

## A.2. Sequential choices of quality and price

Here we show that the price and quality effects of a hospital merger reported in Section 2.2 are qualitatively similar if quality and price decisions are made sequentially instead of simultaneously. Consider the following two-stage game:

1. Each hospital chooses its quality.
2. Each hospital chooses its price, observing the qualities chosen in the previous stage.

In the pre-merger game, the optimal price chosen by Hospital  $i$  at the second stage of the game is given by

$$p_i(q_i, q_{i+1}, q_{i-1}) = \frac{t}{9\gamma} + \frac{1}{5} \left( (2b + 3c\gamma) q_i - \sum_{j \neq i} (b - c\gamma) q_j \right). \quad (\text{A32})$$

In the first-stage of the game, each hospital chooses its optimal quality level to maximise profits, anticipating the prices that will subsequently be chosen. In the subgame perfect Nash equilibrium, prices and qualities are given by

$$p_i^* = \frac{t}{9\gamma} + \frac{4c(b - c\gamma)}{15\gamma k} \quad (\text{A33})$$

and

$$q_i^* = \frac{4(b - c\gamma)}{15k\gamma}. \quad (\text{A34})$$

As in the simultaneous-move game, an interior solution requires  $b > c$  (for all  $\gamma \in (0, 1)$ ).

In the post-merger game, the optimal prices set at the second stage by the each of the merged hospitals and the outside hospital are given by, respectively,

$$p_m(q_m, q_o) = \frac{5t}{27\gamma} + \frac{(5b + 7c\gamma)}{12\gamma} q_m - \frac{(b - c\gamma)}{3\gamma} q_o, \quad (\text{A35})$$

$$p_o(q_m, q_o) = \frac{4t}{27\gamma} - \frac{(b - c\gamma)}{6\gamma} q_m + \frac{(b + 2c\gamma)}{3\gamma} q_o. \quad (\text{A36})$$

In the subgame perfect Nash equilibrium, prices and qualities are given by

$$p_m^* = \frac{\left( 5kt\gamma - 6(b - c\gamma)^2 \right) (kt + c(b - c\gamma))}{27\gamma k \left( kt\gamma - (b - c\gamma)^2 \right)}, \quad (\text{A37})$$

$$p_o^* = \frac{(4kt\gamma - 3(b - c\gamma)^2)(kt + 2c(b - c\gamma))}{27\gamma k (kt\gamma - (b - c\gamma)^2)}, \quad (\text{A38})$$

$$q_m^* = \frac{(b - c\gamma)(5kt\gamma - 6(b - c\gamma)^2)}{27k\gamma (kt\gamma - (b - c\gamma)^2)}, \quad (\text{A39})$$

$$q_o^* = \frac{2(b - c\gamma)(4kt\gamma - 3(b - c\gamma)^2)}{27k\gamma (kt\gamma - (b - c\gamma)^2)}. \quad (\text{A40})$$

Equilibrium existence requires

$$t > \frac{6(b - c\gamma)^2}{5k\gamma}.$$

Comparing (16) and (A39)-(A40), the effects of the merger on equilibrium quality provided by the merged and non-merged hospitals, respectively, are given by

$$q_m^* - q_i^* = -\frac{(b - c\gamma)(11kt\gamma - 6(b - c\gamma)^2)}{135k\gamma (kt\gamma - (b - c\gamma)^2)} < 0 \quad (\text{A41})$$

and

$$q_o^* - q_i^* = \frac{2(b - c\gamma)(2kt\gamma + 3(b - c\gamma)^2)}{135k\gamma (kt\gamma - (b - c\gamma)^2)} > 0. \quad (\text{A42})$$

Comparing (17) and (A37)-(A38), the effects of the merger on equilibrium prices set by the merged and non-merged hospitals, respectively, are

$$p_m^* - p_i^* = \frac{6c(b - c\gamma)^3 + kt(10kt\gamma - (15b - 4c\gamma)(b - c\gamma))}{135k\gamma (kt\gamma - (b - c\gamma)^2)} \quad (\text{A43})$$

and

$$p_o^* - p_i^* = \frac{6c(b - c\gamma)^3 + kt\gamma(5kt + 4c(b - c\gamma))}{135k\gamma (kt\gamma - (b - c\gamma)^2)} > 0. \quad (\text{A44})$$

The sign of (A43) is determined by the sign of the numerator and it is easy to see that the sign is negative if  $b$  is sufficiently high relative to  $t$ . It remains to show that the sign is ambiguous for parameter configurations that are compatible with equilibrium existence. Notice that the numerator is monotonically increasing in  $t$ . Setting  $t$  equal to the lower bound,  $t = \frac{6(b-c\gamma)^2}{5k\gamma}$ , the numerator reduces to in (A43) reduces to  $-\frac{18(b+c\gamma)(b-c\gamma)^3}{5\gamma} < 0$ . Thus,  $p_m^* > (<)p_i^*$  if  $b$  is sufficiently low (high)

relative to  $t$ .

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