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# Quality Differentiation under Mixed Competition in Hospital Markets

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**Abstract**

We use a Hotelling-type model of two hospitals, one for-profit (FP) and the other not-for-profit (NFP) using quality to compete for patients. In an equilibrium that constrains the NFP to zero profits, the NFP share of the market decreases as fixed costs or patient's marginal utility of quality increase, or as transportation and marginal quality costs decrease, conditions that make quality a more effective tool for attracting patients, improving the ability of the FP to compete for market share. We also show that a NFP hospital cannot take the entire market without significant fundraising ability. The market shares predicted by our model are consistent with what is presently observed in Europe and the US.

Keywords: Hospital, Not-for-profit, Mixed competition.

JEL Classification: L1, L3, I1.

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Quality Differentiation under Mixed Competition in Hospital Markets

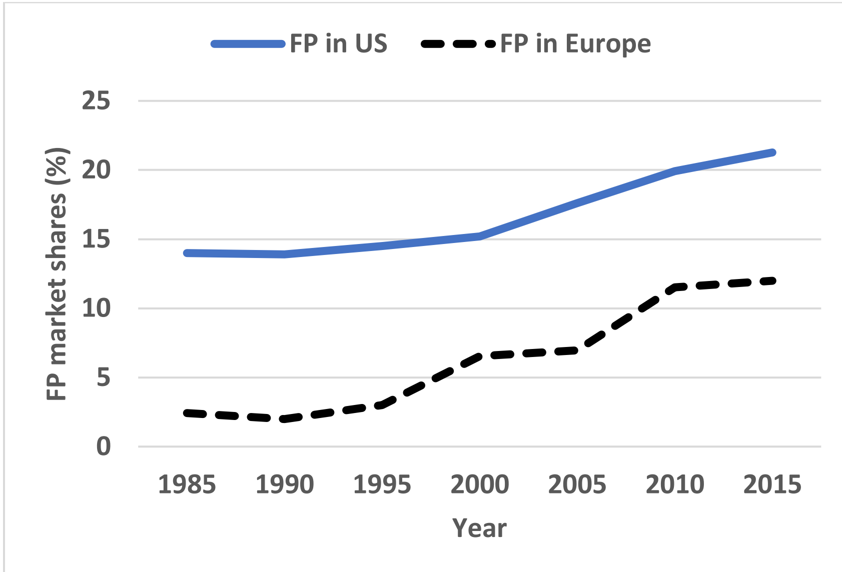
## Introduction

Although not-for-profit hospitals (NFP) still have the largest share of the US market for hospital services, for-profit (FP) hospitals now account for more than 21% of the market, gaining about 1% per year in the 5 years up to 2012 (David, 2009; Lee and Rosenman, 2013; Henderson, 2009; Selvam, 2012). In 2015, 1034 of 4862 community hospitals in the US were investor-owned (AHA, 2015). When government hospitals are excluded, the FP share of private hospitals climbs to over 26 percent. This trend towards the privatization of hospital services in investor hands is being seen in Europe as well. FP hospital beds in eight European countries grew from about 15.68 percent in 2005 to 18.42 percent in 2013 (Jeurissen, et al, 2016). In France 37% of all hospitals are FP, as are 40% in Spain and 18% in Germany (Chevalier and Levitan, 2009). Figure 1 shows that the trend towards FP hospitals has been steady since 2000 or before.

In this paper, we use Montefiori's (2005) model of quality competing hospitals to analyze mixed competition in the hospital industry, and provide a foundation that explains some of the changes in market share that are being observed. In fact, market shares suggested by our model are close to what is observed in present European and US health care markets. In addition, we tie the trend towards FP hospitals to implications for the quality of healthcare services.

Figure 1

Health Care Market in US and Europe*




**Note:* US FP includes the share of for-profit community hospitals in total number of community hospitals in the United States. Europe NFP includes the share of for-profit hospitals in the European Union.
*Source:* AHA (2015) for US, WHO (2016) for European Union.

The next section presents the model and derives different outcomes from varying parameter values. We then discuss the role of fundraising for determining the NFP share of the market. The final section offers discussion and conclusions.

## A two hospital model of mixed competition

Our model is derived from Montefiori (2005), which has two hospitals, *A* and *B* competing on a unit line. One hospital is located at each end of the unit line, and each point represents a patient who buys one unit of care from one hospital or the other.[1] A patient located

[1] Patient costs are paid by a third-party, and patients incur no direct cost for care.

at point $z$ on the line derives utility $U_z = \alpha q_A - \gamma d$ if she goes to hospital $A$ and $U_z = \alpha q_B - \gamma(1-d)$ if she goes to hospital $B$. Here $q_A$ and $q_B$ are the levels of service quality offered respectively by hospitals $A$ and $B$, $d$ is the distance from $z$ to hospital $A$, and $\alpha, \gamma > 0$ describe the preference for quality and the unit transportation cost, respectively. The patient indifferent between the two hospitals is thus located where $\alpha q_A - \gamma d = \alpha q_B - \gamma(1-d)$. Given the density of the unit line equal to 1 we obtain the demand for hospital $A$

$$d_A = \frac{\alpha}{2\gamma}(q_A - q_B) + \frac{1}{2} \tag{1}$$

Total demand is normalized to one so the demand for hospital $B$ is $d_B = 1 - d_A$. Hospitals attract patients by having a higher quality than its competitor.[2]

We change Montefiori's model by letting hospital $A$ be not-for-profit (NFP) while hospital $B$ remains for-profit (FP).[3] Hospitals receive a fixed price $M$ per patient treated (determined exogenously) and have costs $C_i = cd_iq_i + F, i = (A, B)$ where $c, F > 0$ and $F$ is fixed cost which for simplicity we assume is the same for both hospitals.[4] Costs are linear in quality and the number of patients served, although as quality increases, the cost of serving each patient goes up. Profit for hospital $i$ is $\Pi_i = Md_i - cd_iq_i - F$ where again $i = (A, B)$. Since hospital $A$ is not-for-profit, we constrain its profit to 0, hence,[5]

$$\Pi_A = Md_A - cd_Aq_A - F = 0 \Rightarrow q_A = \frac{M}{c} - \frac{F}{cd_A}. \tag{2}$$

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[2] If $\alpha$=0, quality doesn't matter to patients, each hospital gets a market share of ½.

[3] Montefiori has both hospitals FP.

[4] Payment is prospective – that is, irrespective of actual quantity, although in the context our setup, each patient consumes the same amount. Payment is decided exogenous to the firm, making the model most applicable to single payer European markets and Medicare in the US.

[5] We assume that the zero-profit constraint is binding on an unspecified utility function for hospital $A$ which has as its arguments the hospital's market share, and possibly, the quality of care provided, both positively adding to utility. Montefiori briefly alludes to a public (NFP) hospital turning all payment into quality but does not take this line further to explore mixed competition.

Montefiori shows that the reaction function of a FP hospital, $B$ in this case, is

$$q_B(q_A) = \frac{1}{2}\left[q_A + \frac{M}{c} - \frac{\gamma}{\alpha}\right] \tag{3}$$

Equations (1), (2) and (3) together define the relationship that comes from competition between the FP and NFP hospital. Although we characterize it with only $B's$ reaction function, the outcome is *jointly* determined through $A's$ demand, consistent with studies that show NFP hospitals respond to the presence of FP hospitals in their market.[6]

*Equilibrium market share*

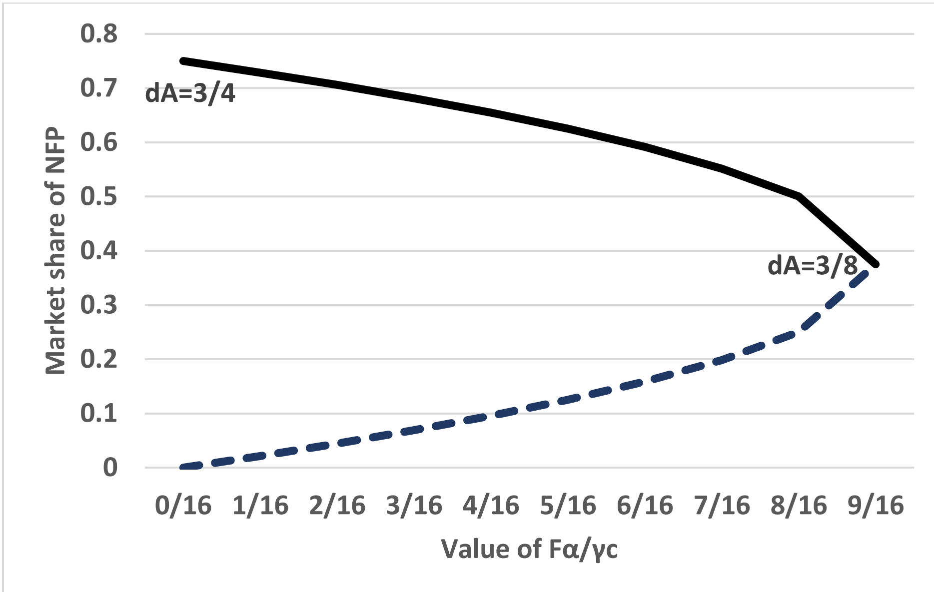
Solving (1), (2) and (3) together gives $d_A = \frac{3}{8} \pm \frac{\sqrt{\frac{9}{16} - \frac{F/c}{\gamma/\alpha}}}{2} = \frac{3}{8} \pm \frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2}$ so there is a real solution only if $\frac{9}{16} \geq \frac{F\alpha}{\gamma c}$.[7] Notice that if we constrain ourselves to real solutions, which we do for the remainder of the paper, if $F = 0$ then $d_A = \frac{3}{8} \pm \frac{3}{8}$; if there are no fixed costs the NFP has either the ¾ of the market or none of the market. Moreover, if $0 < d_A < 1$ then either $\frac{3}{8} - \frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2} > 0$ or $\frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2} < 1$. Assuming the radical exists, with the signs of the parameters both of these conditions hold, although the former only if $\frac{9}{16} > \frac{F\alpha}{\gamma c}$. As $\frac{F\alpha}{\gamma c} \to \frac{9}{16}$ from below, the NFP share converges on 3/8, while as $\frac{F\alpha}{\gamma c} \to 0$, this time from above, the NFP share converges to its extreme values 0 or ¾ (See Figure 2).

[6] Hughes and Luft (1990) and Cutler and Horowitz (2000) find the influence is mainly on cost; in the spirit of this finding we assume the same cost structure for both hospitals. This approach is also consistent with Lakdawalla and Philipson (2006) and Chakravarty, Gaynor, and Klepper et al. (2006) who find evidence that FPs are the marginal firms in a market.

[7] This condition is briefly discussed in Appendix 1. The derivation of solutions is given in Appendix 2.

Figure 2

Market shares of NFP under different scenario




This means the NFP share converges to its extreme values as the marginal utility of quality goes to zero, transportation costs get large or the marginal cost of quality gets large. Each of these makes quality less effective or more costly in the competition for patients, making it harder for the FP hospital to react to the quality offered by the NFP. In the same spirit, if fixed costs go to zero the zero-profit condition is less constraining – if hospital $A$ has a zero share of the market, the condition is met, and it need not worry about covering costs, or it can take on the largest number of patients it can handle (at a given quality level) without worrying about covering fixed costs.

*Equilibrium quality*

Quality is used by the hospitals to attract market share, hence, by looking at market share, we can discern some information about the quality offered. More concretely, we can link quality to market share. Solving equations (1)-(3) and using $d_A^* = \frac{3}{8} - \frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2}$ we find

$$q_A^* = \frac{M}{c} - \left(\frac{F}{c}\right)\left(\frac{3}{8} - \frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2}\right)^{-1} \text{ and } q_B^* = \frac{M}{c} - \left(\frac{F}{c}\right)\left(\frac{3}{4} - \sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}\right)^{-1} - \frac{\gamma}{2\alpha}$$

while if $d_A^{**} = \frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2}$,

$$q_A^{**} = \frac{M}{c} - \left(\frac{F}{c}\right)\left(\frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2}\right)^{-1} \text{ and } q_B^{**} = \frac{M}{c} - \left(\frac{F}{c}\right)\left(\frac{3}{4} + \sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}\right)^{-1} - \frac{\gamma}{2\alpha}$$

Note that in all cases quality is increasing in the capitated payment, $M$, at a rate of $1/c$, so each additional dollar spent on health care increases quality by $1/c$ units.

Obviously, $d_A^{**} \geq d_A^*$. Comparing $q_A^*$ and $q_A^{**}$, as shown in Appendix 2, $q_A^* - q_A^{**} = -\frac{8\gamma}{\alpha}\phi \leq 0$, where $\phi = \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}$. Quality from hospital $A$ is lower when it has the smaller market share. Similarly comparing $q_B^*$ and $q_B^{**}$ we find $q_B^* - q_B^{**} = -\frac{2\gamma}{\alpha}\lambda \leq 0$, where $\lambda = \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}$, so quality from hospital $B$ is also smaller when $A$ has the smaller market share – that is, average market quality is lower. One wonders why the quality of *both* hospitals is lower when the NFP has the smaller share of the market. If hospital $A$ has the lower market share, $d_A^*$, it needs less quality to attract the share of patients it desires. Meanwhile, the FP hospital, $B$, offers only the quality necessary to attract its profit maximizing share as given by its reaction function;

with $q_A$ smaller, $q_B$ is as well. Essentially, hospital $A's$ share determines how much quality competition there will be.

Comparing the qualities of the two hospitals is in one sense straightforward because the hospital with a larger market share has the higher quality.[8] Hence since $d_A^* < \frac{1}{2}$ we know that $d_A^* < d_B^*$. Comparing quality at $d_A^{**}$ is less clear because we do not know how $d_A^{**}$ compares to ½. From (1), however, $d_A^{**} > \frac{1}{2}$ implies $\frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2} > \frac{1}{8} \Rightarrow \frac{1}{2} > \frac{F\alpha}{\gamma c}$. From this last relationship, the NFP hospital is more likely to have better quality than its FP competitor if fixed costs are lower, consumers value quality less, or transportation or quality costs are high, all characteristics that make it hard for the FP hospital to use quality to compete for patients.

*The Subgame Perfect Nash Equilibrium (SPNE)*

We assumed the zero profit constraint is binding for an unspecified NFP utility function which, when combined with the demand conditions and the FP reaction function gives the system of equations (1)-(3) that define our model. The solution for $d_A$ is quadratic, giving a Pareto-coordination game with two Nash equilibria. With the (reasonable) assumption that hospital $A's$ unspecified utility function increases in both market share and quality, it will prefer $d_A^{**}$; it yields a higher utility because $d_A^* < d_A^{**}$ and $q_A^* < q_A^{**}$. In fact, even if the NFP goal is to maximize total market consumer surplus (which is positive in quality) rather than its own utility, it would prefer $d_A^{**}$ over $d_A^*$ because the quality from both hospitals is higher with that choice. Hence, a social regulator, presumably the group paying the per patient cost $M$, would prefer,

[8] See equation (1).

and thus encourage, an outcome with the NFP having a larger share. In any case, if the game were altered slightly so the NFP chooses its quality first, we would expect an outcome where it chooses $q_A^{**}$. At that point neither hospital can make a move to increase its goal outcome.

**Fundraising and the not-for-profit share**

Lakdawalla and Philipson (2006) argue that with sufficient NFP preferences FP firms cannot compete. At issue, then, is under what circumstances do we achieve a similar outcome. We again go to the demand for the NFP hospital, looking only at the solution with the larger market share to better match what is observed in the market. Giving the NFP the entire market means $d_A = \frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}}}{2} = 1$ which requires $\sqrt{\frac{9}{16} - \frac{F\alpha}{\gamma c}} = \frac{5}{4}$ implying $\frac{F\alpha}{\gamma c} = -1$. All the parameters on the left-hand side of the last equation are positive, so it would appear our model is inconsistent with Lakdawalla and Philipson. However, if we allow fundraising as an additional source of revenue for the NFP, its zero profit constraint becomes

$$\Pi_A = Md_A - cd_Aq_A - F + R_A = Md_A - cd_Aq_A - F_A^*$$

where $R_A$ is the amount of fundraising done by the NFP and $F_A^* = F - R_A$. With this substitution we can write the condition for the NFP having the entire market as $\frac{F_A^*\alpha}{\gamma c} = \frac{(F-R_A)\alpha}{\gamma c} = -1$.[9] Solving for $R_A$ gives $R_A = \frac{\alpha F + \gamma c}{\alpha} = F + \frac{\gamma c}{\alpha}$. By fundraising this amount, a situation equivalent to Lakdawalla and Philipson's identifying "sufficient" NFP preferences, the NFP will have the entire market. The amount of fundraising necessary to take the entire market is directly related to fixed, transportation and quality costs, but is inversely related to the value patients place on

[9] $F$ enters into our model only through the zero-profit constraint, so we get the same formula using $F$ or $F_A^*$.

quality. Appendix 3 provides some further analysis of this issue, simulating the NFP share and relative quality on changes in fundraising compared to fixed costs and the ratio $\frac{\alpha}{\gamma c}$.

**Discussion and Conclusions**

We build on Montefiori's (2005) model to assess the market shares and quality of FP and NFP hospitals competing for patients with quality as the tool. Constraining our results to parameter values that yield real-valued solutions, we show that the NFP share will vary directly with transportation costs and the marginal cost of quality, and inversely with fixed cost and the value patients place on quality. Moreover, overall market quality is higher as the NFP share of the market increases. In addition, the ability of the NFP to dominate the market depends somewhat on its fundraising ability – the amount needed varies directly with fixed costs and the marginal cost of quality.

These findings somewhat help explain the growth of FP hospitals over the past few decades. Hospital costs are increasingly tied up with technology, which adds to fixed costs. This has a direct impact on the NFP hospital's optimal market share, making it smaller, and also increases the fundraising necessary to take its share beyond that which results from a zero operating margin. In short, part of the growth of FP hospitals may be attributable to technology demands of modern hospital services.

For the same reason, our results are consistent with the "profit-deviating" NFP firm of Lakdawalla and Philipson (2006). In their model the NFP hospital has negative economic profits, reflected lower NFP opportunity costs in a willingness to accept returns in a nonpecuniary form. This is directly reflected in our model by the ability of the NFP to take the entire market only by raising sufficient funds from sources outside the market – a signal of

Lakdawalla and Philipson's "sufficient" NFP preferences. In fact, Malani, Philipson, & David (2003) argue, as we do, that for-profit firms produce only where donations cannot sustain enough non-profit firms to satisfy the entire market demand.

Our results explain more than just the existence of mixed competition. We show that more competitive NFP hospitals will increase quality in the entire market, and if their share exceeds 50 percent, offer more quality to patients than does the FP hospital. This finding is consistent with the empirical evidence that NFP hospitals provide higher welfare to patients (Gowrisankaran & Town, 1999; Dafny, 2005) and have lower mortality rates (Mukamel, Zwanziger & Bamezai, 2002; Picone, Chou, and Sloan, 2002; and Farsi, 2004).

Finally, the results about quality have implications for policymakers, especially those responsible for paying patients' expenses. First, consumer surplus is directly related to the NFP share of the market, hence policymakers who care about consumer surplus should encourage NFP over FP hospitals, especially since the NFP has zero profits, it extracts no rents and imposes no welfare loss in the market. Additionally, the NFP share of the market, and thereby the FP share, is independent of the per patient payment, varying instead, directly with the marginal costs of quality and transportation, and inversely with fixed costs and patients' marginal valuation of quality. From the perspective of payment as a policy tool, what the policymaker can influence is the level of quality.

**Appendix 1: The existence of a real solution**

It is not obvious what interpretation to put on the condition $\frac{9}{16} \geq \frac{F\alpha}{\gamma c}$ which ensures a real solution in our model. Rearranging the inequality we get $\frac{9}{16F} \geq \frac{\alpha}{\gamma c}$ where the right-hand-side is the patients' marginal valuation of quality relative to its marginal cost and the cost to the patient of getting quality. The more patients value quality relative to the cost of providing it, the less likely there is to be a real solution in the market. Analogously, if the cost of providing quality gets too low relative to patients' value of it, the market breaks down. The same happens if fixed costs get too large or transportation costs too low.

## Appendix 2: Mathematical Appendix[10]

*Deriving equilibrium values*

The demand for hospital A (NFP) is given by, $d_A = \frac{\alpha}{2\gamma}(q_A - q_B) + \frac{1}{2}$. Therefore for hospital B (FP) has the demand, $d_B = 1 - d_A$. For hospital A we have,

$$\Pi_A = Md_A - cd_A q_A - F = 0 \Rightarrow q_A = \frac{M}{c} - \frac{F}{cd_A}$$

The reaction function of hospital B is $q_B = \frac{1}{2}\left[q_A + \frac{M}{c} - \frac{\gamma}{\alpha}\right]$.

Plugging $q_A$ into $q_B$

$$q_B = \frac{1}{2}\left[\frac{M}{c} - \frac{F}{cd_A} + \frac{M}{c} - \frac{\gamma}{\alpha}\right] = \frac{1}{2}\left[\frac{2M}{c} - \frac{F}{cd_A} - \frac{\gamma}{\alpha}\right] = \frac{M}{c} - \frac{F}{2cd_A} - \frac{\gamma}{2\alpha}$$

Plug the values of $q_A$ and $q_B$ into $d_A$

$$d_A = \frac{\alpha}{2\gamma}\left[\frac{M}{c} - \frac{F}{cd_A} - \frac{1}{2}q_A - \frac{1}{2}\frac{M}{c} + \frac{\gamma}{2\alpha}\right] + \frac{1}{2}$$

[10] Detail is provided here for review. We expect that this appendix should be shortened or put on-line when the paper is published.

$$= \frac{\alpha}{2\gamma}\left[\frac{M}{c} - \frac{F}{cd_A} - \frac{1}{2}\frac{M}{c} + \frac{1}{2}\frac{F}{cd_A} - \frac{1}{2}\frac{M}{c} + \frac{\gamma}{2\alpha}\right] + \frac{1}{2}$$

$$= \frac{\alpha}{2\gamma}\left[\frac{\gamma}{2\alpha} - \frac{F}{2cd_A}\right] + \frac{1}{2}$$

$$= \frac{\alpha}{2\gamma}\frac{\gamma}{2\alpha} - \frac{\alpha}{2\gamma}\frac{F}{2cd_A} + \frac{1}{2}$$

$$= \frac{1}{4} + \frac{1}{2} - \frac{\alpha}{2\gamma}\frac{F}{2cd_A}$$

$$= \frac{3}{4} - \frac{\alpha}{2\gamma}\frac{F}{2cd_A}$$

$$\Rightarrow d_A + \frac{\alpha F}{4\gamma c d_A} - \frac{3}{4} = 0$$

$$\Rightarrow \frac{4\gamma c d_A^2 + \alpha F - 3\gamma c d_A}{4\gamma c d_A} = 0$$

$$\Rightarrow 4\gamma c d_A^2 - 3\gamma c d_A + \alpha F = 0$$

$$\Rightarrow d_A = \frac{-(-3\gamma c) \pm \sqrt{9\gamma^2 c^2 - 16\gamma c \alpha F}}{8\gamma c}$$

$$= \frac{3}{8} \pm \frac{\sqrt{\gamma c(9\gamma c - 16\alpha F)}}{8\gamma c}$$

$$= \frac{3}{8} \pm \frac{\sqrt{16(\gamma c)^2\left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)}}{8\gamma c}$$

$$= \frac{3}{8} \pm \frac{\sqrt{\left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)}}{2}$$

The range of market share for NFP hospital is,

$$\therefore d_A \in \left\{ \frac{3}{8} - \frac{\sqrt{\left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)}}{2}, \frac{3}{8} + \frac{\sqrt{\left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)}}{2} \right\}$$

The case where NFP gets the entire market, $d_A = 1$:

$$d_A = \frac{3}{8} \pm \frac{\sqrt{\left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)}}{2}$$

$$\Rightarrow 1 = \frac{3}{8} \pm \frac{\sqrt{\left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)}}{2}$$

$$\Rightarrow \frac{5}{8} = \pm \frac{\sqrt{\left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)}}{2}$$

$$\Rightarrow \frac{10}{8} = \pm \sqrt{\left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)}$$

$$\Rightarrow \frac{100}{64} = \left(\frac{9}{16} - \frac{\alpha F}{\gamma c}\right)$$

$$\Rightarrow \frac{100}{64} - \frac{9}{16} = -\frac{\alpha F}{\gamma c}$$

$$\Rightarrow \frac{\alpha F}{\gamma c} = -1$$

$$\Rightarrow F = -\frac{\gamma c}{\alpha}$$

*Finding $q_A^*$, $q_A^{**}$, $q_B^*$ and $q_B^{**}$*

$$d_A = \frac{3}{8} \pm \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}$$

$$q_A = \frac{M}{c} - \frac{F}{c d_A}$$

$$q_B = \frac{M}{c} - \frac{\gamma}{2\alpha} - \frac{F}{2c d_A}$$

Plug $d_A$ into $q_A$ to get

$$q_A = \frac{M}{c} - \frac{F}{c}\left(\frac{3}{8} \pm \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}\right)^{-1}$$

If $d_A^* = \frac{3}{8} - \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}$, $q_A^* = \frac{M}{c} - \frac{F}{c}\left(\frac{3}{8} - \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}\right)^{-1}$

If $d_A^{**} = \frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}$, $\qquad q_A^{**} = \frac{M}{c} - \frac{F}{c}\left(\frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}\right)^{-1}$

For hospital B's quality, plug $d_A$ into $q_B$

$$q_B = \frac{M}{c} - \frac{\gamma}{2\alpha} - \frac{F}{2c}\left(\frac{3}{8} \pm \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}\right)^{-1}$$

$$= \frac{M}{c} - \frac{\gamma}{2\alpha} - \frac{F}{2c}\left[\frac{1}{2}\left(\frac{3}{4} \pm \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}\right)\right]^{-1}$$

$$= \frac{M}{c} - \frac{\gamma}{2\alpha} - \frac{F}{c}\left(\frac{3}{4} \pm \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}\right)^{-1}$$

$$\text{If } d_A^* = \frac{3}{8} - \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}, \qquad q_B^* = \frac{M}{c} - \frac{F}{c}\left(\frac{3}{4} - \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}\right)^{-1} - \frac{\gamma}{2\alpha}$$

$$\text{If } d_A^{**} = \frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}, \qquad q_B^{**} = \frac{M}{c} - \frac{F}{c}\left(\frac{3}{4} + \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}\right)^{-1} - \frac{\gamma}{2\alpha}$$

*The differences in qualities*

$$q_A^* - q_A^{**} = \frac{M}{c} - \frac{F}{c}\left(\frac{3}{8} - \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}\right)^{-1} - \frac{M}{c} + \frac{F}{c}\left(\frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}\right)^{-1}$$

$$Let, \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2} = \phi$$

$$\therefore\ q_A^* - q_A^{**} = \frac{F}{c}\left(\frac{3}{8} + \phi\right)^{-1} - \frac{F}{c}\left(\frac{3}{8} - \phi\right)^{-1}$$

$$= \frac{F}{c\left(\frac{3}{8} + \phi\right)} - \frac{F}{c\left(\frac{3}{8} - \phi\right)}$$

$$= \frac{F\left(\frac{3}{8} - \phi\right) - F\left(\frac{3}{8} + \phi\right)}{c\left(\frac{3}{8} + \phi\right)\left(\frac{3}{8} - \phi\right)}$$

$$= \frac{\frac{3}{8}F - \phi F - \frac{3}{8}F - \phi F}{c\left(\frac{9}{64} - \phi^2\right)}$$

$$= -\frac{2\phi F}{c\left(\frac{9}{64} - \phi^2\right)}$$

$$= -\frac{2F}{c}\,\frac{\phi}{\frac{9}{64} - \phi^2}$$

$$= -\frac{2F}{c}\frac{\frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}}{\frac{9}{64} - \frac{\frac{9}{64} - \frac{\alpha F}{\gamma c}}{4}}$$

$$= -\frac{2F}{c}\frac{\frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}}{\frac{9}{64} - \frac{9}{16 * 4} + \frac{\alpha F}{4\gamma c}}$$

$$= -\frac{2F}{c}\frac{\frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}}{\frac{9}{64} - \frac{9}{64} + \frac{\alpha F}{4\gamma c}}$$

$$= -\frac{2F}{c}\,\frac{4\gamma c}{\alpha F}\,\frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}$$

$$= -\frac{4\gamma}{\alpha}\,\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}$$

$$\therefore\; q_A^* - q_A^{**} = -\frac{8\gamma}{\alpha}\phi, \qquad where, \qquad \phi = \frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{2}$$

$$q_B^* - q_B^{**} = \frac{M}{c} - \frac{\gamma}{2\alpha} - \frac{F}{c}\left(\frac{3}{4} - \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}\right)^{-1} - \frac{M}{c} + \frac{\gamma}{2\alpha} + \frac{F}{c}\left(\frac{3}{4} + \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}\right)^{-1}$$

$$= \frac{F}{c}\left(\frac{3}{4} + \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}\right)^{-1} - \frac{F}{c}\left(\frac{3}{4} - \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}\right)^{-1}$$

$$Let, \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}} = \lambda$$

$$\therefore\ q_B^* - q_B^{**} = \frac{F}{c}\left(\frac{3}{4} + \lambda\right)^{-1} - \frac{F}{c}\left(\frac{3}{4} - \lambda\right)^{-1}$$

$$= \frac{F}{c\left(\frac{3}{4} + \lambda\right)} - \frac{F}{c\left(\frac{3}{4} - \lambda\right)}$$

$$= \frac{F\left(\frac{3}{4} - \lambda\right) - F\left(\frac{3}{4} + \lambda\right)}{c\left(\frac{3}{4} + \lambda\right)\left(\frac{3}{4} - \lambda\right)}$$

$$= \frac{\frac{3}{4}F - \lambda F - \frac{3}{4}F - \lambda F}{c\left(\frac{9}{16} - \lambda^2\right)}$$

$$= -\frac{2F}{c}\frac{\lambda}{\left(\frac{9}{16} - \lambda^2\right)}$$

$$= -\frac{2F}{c}\frac{\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}}{\frac{9}{16} - \frac{9}{16} + \frac{\alpha F}{\gamma c}}$$

$$= -\frac{2F}{c}\frac{\gamma c}{\alpha F}\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}$$

$$= -\frac{2\gamma}{\alpha}\sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}$$

$$\therefore q_B^* - q_B^{**} = -\frac{2\gamma}{\alpha}\lambda, \quad where,\ \lambda = \sqrt{\frac{9}{16} - \frac{\alpha F}{\gamma c}}$$

**Appendix 3: Simulating market outcomes on NFP fundraising**

In this appendix, we simulate our model to evaluate market share and quality as fundraising by the NFP changes when $d_A = \frac{3}{8} + \frac{\sqrt{\frac{9}{16} - \frac{\alpha F_A^*}{\gamma c}}}{2}$ where $F_A^* = F - R_A$ assuming the NFP has zero profit so service quality is $q_A = \frac{M}{c} - \frac{F_A^*}{c}\left(d_A^{**}\right)^{-1}$. We use three levels of parameter values that affect overall market: (1) $\frac{\alpha}{\gamma c} = \frac{9}{16}$, (2) $\frac{\alpha}{\gamma c}$ decreases by 50%, and (3) $\frac{\alpha}{\gamma c}$ increases by 50%. An increase in the term implies an increase in patients' quality preference ($\alpha$), and/or a decrease in transportation cost of patients ($\gamma$), and/or a decrease in the marginal cost of treatment quality borne by the hospitals (c). We assume M to be sufficiently high to serve the market under all three cases. We use MS Excel 2016 to run the simulation.

Key findings from simulation:

1. Fundraising increases the market share of NFP hospitals, however it has a decreasing return on market share of NFP hospital. The curve is concave (Figure A1).
2. An increase in quality preference increases the marginal return of donations (in terms of NFP market share), whereas an increase in transportation cost or in the marginal cost of

quality makes the marginal return of donations lower. Both transportation cost and marginal cost of quality have the same effect on NFP market share in our model.

3. Irrespective of parameter values, NFP market share is 75% when the entire fixed cost is covered by donations.
4. NFP's quality is slightly increasing in fundraising. In general, the NFP hospital provides slightly higher quality—about one percent more than the FP hospital. However, the NFP may provide lower quality under certain values of parameters if fundraising is less than about 15% of the fixed cost so it has less than 50% of the market (See Figure A2).
5. An increase in quality preference (or decrease in costs) lead to a decrease in the NFP to FP quality ratio because the competitive FP hospital tries to increase its treatment quality when quality preference increases. On the contrary, an increase in market-wide marginal cost or transportation cost increases the ratio of NFP to FP quality as there is less incentive for the FP hospital to increase its treatment quality.

Figure A1

Market shares of NFP under different fundraising scenario

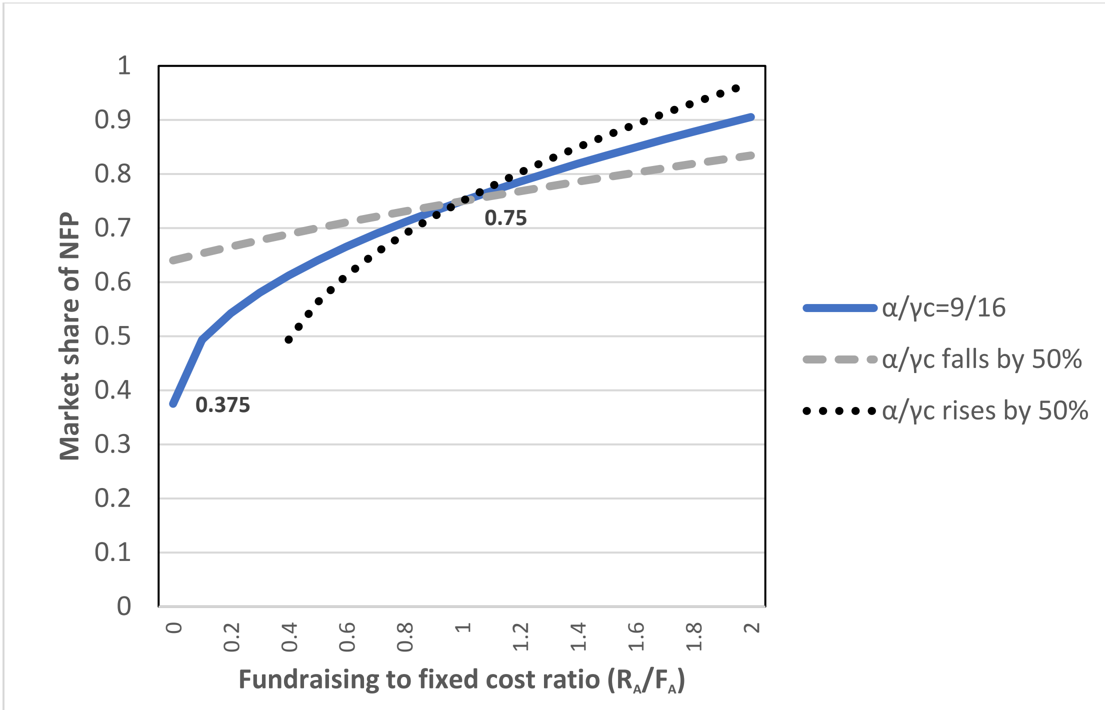
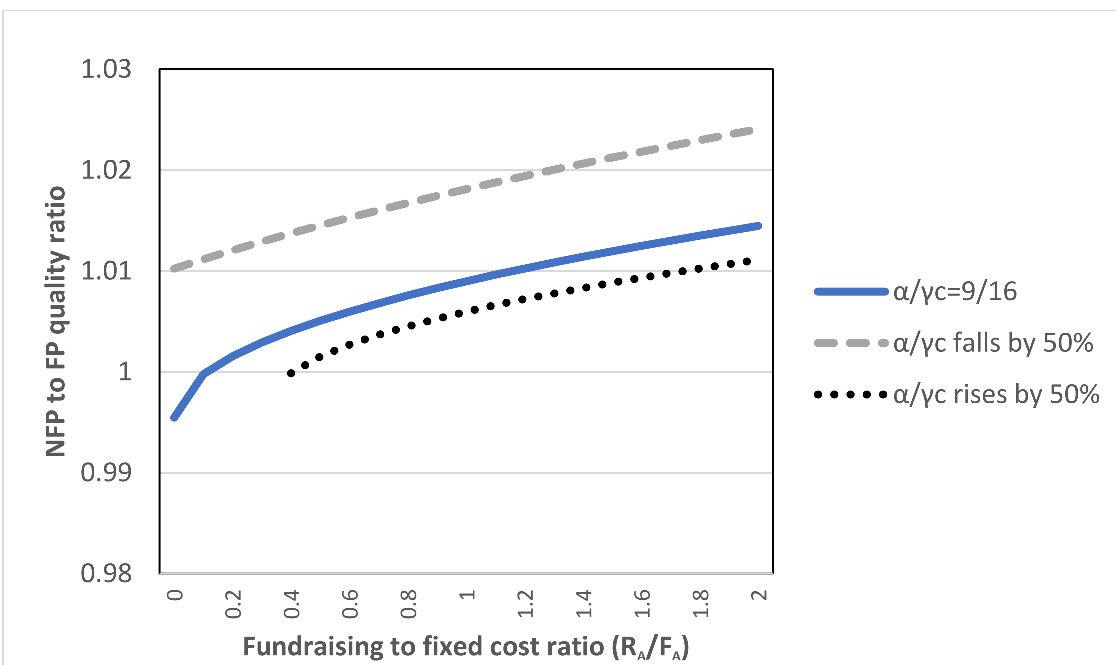



Figure A2

NFP to FP quality ratio, $q_A/q_B$



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