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Abstract

New empirical evidence shows substantial heterogeneity in the altruism of healthcare providers. Spurred by this evidence, we build a spatial quality competition model with altruism heterogeneity. We find that more altruistic healthcare providers supply relatively higher quality levels and position themselves closer to the center. Whether the social planner prefers more or less horizontal differentiation is in general ambiguous and depends on the level of altruism. The more altruistic healthcare providers are, the more likely it is that the social planner prefers greater horizontal differentiation to offset costly quality competition.

JEL Classification: H42, I11, I18, L13

Keywords: healthcare provider altruism and heterogeneity; quality competition

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1 Introduction

Quality is a major concern in healthcare. Recent and ongoing reforms in several countries aim to stimulate quality competition and to promote patient choice among healthcare providers (e.g. physicians, nurses, healthcare managers in hospitals) in order to generate better quality of care at constant costs. The idea behind reforms of this kind in various OECD countries, such as the US, the UK, Norway, Denmark and Germany, is to introduce two different types of incentives; financial incentives such as pay-for-performance ("P4P") schemes as well as non-financial incentives such as public quality reporting initiatives. Evidence on the effect of both types of incentives is, however, mixed; cf. Borowitz et al. (2010) and Maynard (2012) for surveys. One explantion for this discrepancy may be the lack of acknowledgement of heterogeneity in physician preferences in the incentive design. In particular, this includes the weight healthcare providers place on patients' well-being, meaning their individual degrees of altruism. The necessity of accounting for altruism heterogeneity in the design of future incentive schemes is underlined by recent empirical evidence documenting substantial heterogeneity in physicians' altruism levels, cf. Godager and Wiesen (2013) and Brosig-Koch et al. (2013).

There is a long tradition in the theoretical literature of analyzing quality competition within a spatial competition framework à la Hotelling (1929) or Salop (1979). Brekke et al. (2006) were the first to study a healthcare provider's endogenous choice of medical treatment quality and location choice (horizontal differention) within a spatial competition framework. The "standard" result of such a framework is that competition increases quality, as healthcare providers can attract more patients by providing higher quality levels.[1] The initial seminal contribution by Brekke et al. (2006) stirred various authors to study variations of the model. However, none of those studies considers the effect of altruism heterogeneity.[2]

Arrow (1963) already highlighted the importance of altruism in healthcare markets. Later, various other authors[3] emphasized that healthcare providers are to some extent altruistic. Thus, a healthcare provider's objective function may include the own profit and

[1]A positive relationship between competition and quality is found by Ma and Burgess (1993), Calem and Rizzo (1995), Wolinsky (1997), Gravelle (1999) Gravelle and Masiero (2000), Nuscheler (2003),Beitia (2003), Brekke et al. (2006), Brekke et al. (2007), Matsumura and Matsushima (2007), Karlsson (2007).

[2]E.g., Brekke et al. (2007) study the effect of general practioners' gatekeeping function, Brekke et al. (2008) analyze how competition in the hospital market affects patients' waiting times and Brekke at al. (2010) generalize results with respect to non-linear income and cost functions.

[3]E.g., Ellis and McGuire (1986), Chalkley and Malcomson (1998), Eggleston (2005), Heyes (2005), Jack (2005), Chone and Ma (2007), and Kaarboe and Siciliani (2011).

the patient benefit, cf. McGuire (2000).[4] Although the assumption of altruistic healthcare providers has been a pivotal element in the theoretical health economics literature, Brekke et al. (2011) were only recently the first to study the effect of altruism within a spatial quality competition framework.[5]

In light of the emerging literature exploring the relationship between competition and quality under the assumption of altruistic behavior, little is yet known about the effect of altruism heterogeneity. While some authors allow for heterogeneity in the levels of altruism (cf. Jack (2005), Siciliani (2009), Kairies (2013)), none of the authors has studied the effect of altruism heterogeneity in a spatial quality competition framework. Only recently empirical evidence taken from laboratory experiments has reinforced the importance of altruism heterogeneity in healthcare markets. The data from a laboratory experiment by Hennig-Schmidt et al. (2011) was utilized by Godager and Wiesen (2013) to estimate physicians' degrees of altruism. Their results show that nearly all prospective physicians put a positive weight on the health benefit of the patient. However, the authors report substantial heterogeneity in the degree of altruism. Based on their estimation technique and altruism clustering, the overwhelmig majority (73 precent) attach an equal or greater weight on patients' benefits vis-a-vis their own profit. This result is confirmed by Brosig-Koch et al. (2013), who in a different laboratory experiment find that the majority of participants (62 percent) belong to the two highest altruism clusters.

Within a spatial competition framework, the toughness of competition can be modelled either through an increase in the number of healthcare providers or via a decrease in transportation costs. The latter case can be interpreted as an increase in transparency, meaning it is easier for patients to differentiate between quality levels.[6] Thus, recent healthcare reforms actively try to increase the level of transparency by introducing public quality reporting schemes.[7] However, in light of the new empirical evidence on altruism heterogeneity, little is theoretically known about the interactions between transparency, altruism heterogeneity, and medical treatment quality.

[4]The empirical evidence also suggests that altruism is important for healthcare providers, cf. Page (1996) and Le Grand (2003); and job satisfaction depends on pecuniary and non-pecuniary aspects, cf. Shields and Ward (2001), Antonazzo et al. (2003), Ikenwilo and Scott (2007), Leonard and Masatu (2010).

[5]In Brekke et al. (2011), competition increases the incentive of healthcare providers to deploy a higher quality for altruistic reasons but competition simultaneously reinforces the incentive to reduce quality in order to dampen demand from financially unprofitable patients. Thus, in contrast to the standard prediction, the effect of competition on quality is ambiguous.

[6]Brekke et al. (2007) have shown that an increase in information is qualitatively equivalent to lower transportation costs.

[7]The evidence on public quality reporting in medical care is mixed, e.g. Kolstad (2013) reports that physicians change their behavior while the effect on quality is ambigious, cf. Marshall (2000).

We introduce a model of spatial quality competition in which healthcare providers are heterogeneous in their degree of altruism. Our results can be summarized as follows: First, we study homogeneous degrees of altruism. Besides the standard positive relationship between competition and quality, we find that more altruistic, or more agglomerated healthcare providers increase quality. The latter result is in line with Holmstrom and Milgrom (1991), who find that horizontal and vertical differentiation are strategic substitutes. Second, we consider altruism and location heterogeneity. Our model predicts that more altruistic healthcare providers deliver higher quality of care which induces other less altruistic suppliers to increase quality provision (i.e. quality levels are strategic complements). This result is in line with recent evidence by Gravelle et al. (2013), who find that a hospital's quality is positively associated with the quality of its rivals. Furthermore, our results are consistent with recent evidence of quality heterogeneity as provided by Gravelle and Sivey (2010). They report that the UK Healthcare Commission performance data for 2004/5 shows a wide disparity in quality indicators. While it is difficult to explain this with homogeneous agents, assuming altruism heterogeneity can rationalize quality dispersion. Third, we study endogeneous location choices. Healthcare providers first choose locations anticipating quality choices in the second stage. If one physician positions himself closer to the other this intensifies quality competition (negative "strategic effect"), but also increases the own demand (positive "demand stealing effect"). In a standard price competition model, firms locate on extreme points (maximum degree of horizontal differentiation) since the negative strategic effect dominates. However, with altruism heterogeneity, this is not necessarily the case. In fact, the negative strategic effect is weakened for the more altruistic physician as this physician derives greater benefit from higher quality. This results in a market outcome where physicians choose a "medium" degree of horizontal differentiation with the more altruistic physician closer to the center.

From a social perspective, considering average transportation costs as well as average patient benefit and physicians' costs, this outcome is not necessarily optimal. In fact, whether the social planner prefers more or less horizontal differentiation is dependent on the level of altruism. The higher the altruism levels, the more likely it is that the social planner prefers more horizontal differentiation to offset costly quality competition. Related to this, the social planner positions the more altruistic physician closer to the center as this stimulates quality provision relatively more.

The paper is organized as follows: Section 2 introduces the model set-up and derives the results. Section 3 discusses the results and the ensuing healthcare policy implications.

2 Model

2.1 Demand Side: Patients

We utilize a textbook model of horizontal differentiation along the line of Hotelling (1929) with a unit mass of consumers, hereafter referred to as patients, uniformly distributed on a unit intervall ("linear city"). Patients are treated by healthcare providers, hereafter referred to as physicians. Patients face quadratic transportation costs τ that can either be interpreted in a geographical dimension (e.g. time to travel to a particular physician) or in a "taste" dimension meaning a particular physician is preferred due to certain non-quality criteria (e.g. gender, age, cultural background, family history, ability to cure certain diseases).[8,9] We assume that a patient located at $x \in [\alpha, 1-\beta]$ with $\alpha < 1-\beta$ and $\alpha, \beta \in [0,1]$ bears quadratic transportation costs of $\tau(x-\alpha)^2$ to visit a physician located at α and $\tau\,(1-\beta-x)^2$ for a physician located at $1-\beta$.[10]

We combine this model's approach towards horizontal differentiation with vertical quality differentiation induced by different quality levels of physicians. For a given patient, a physician i can choose to provide the quality level q_i. The patient benefit function is $B\,(q_i) = b\,q_i$ and linear in q_i, i.e. $B_{q_i} = b > 0$ and $B_{q_i q_i} = 0$. Similar to Ellis and McGuire (1986), we assume that quality is in principle perfectly observable by patients. Thus, we do not assume, as Siciliani (2009), that patients can discretely judge whether a physician is "good" or "bad".

A patient located at x is indifferent between a physician located at α and $1-\beta$ if

$$B\,(q_1) - \tau\,(x-\alpha)^2 = B\,(q_2) - \tau\,(1-\beta-x)^2 \tag{1}$$

holds. The indices 1 and 2 represent the physician located at α and $1-\beta$, respectively.

[8]Anecdotical evidence by Bardey et al. (2012) shows that physicians actively try to accentutate horizontal differentiation, e.g. by posting advertisements in newspapers.

[9]Notice that τ can be thought of as a policy variable. For example, in Norway, patients' travel costs are partially reimbursed by the public payer. In many countries, there is also an increased (policy-induced) availability of performance indicators on quality, which facilitates comparison across healthcare providers.

[10]With a broad interpretation of transportation costs, we include all disutility associated with being far from the point of medical treatment. There is also strong empirical evidence that distance is a major predictor of patients' choice of hospital, cf. Kessler and McClellan (2000) and Tay (2003).

The "share" x_i of patients that prefer physician i can be written as

$$x_1(q_1,q_2) = \underbrace{\alpha}_{\text{Left part}} + \underbrace{\frac{1-\alpha-\beta}{2}}_{\text{Half distance between } \alpha \text{ and } \beta} + \underbrace{\frac{B(q_1)-B(q_2)}{2\tau(1-\alpha-\beta)}}_{\text{Gain/loss due to quality competition}} \tag{2}$$

and $x_2(q_1,q_2) = 1 - x_1(q_1,q_2)$.

It follows from Eq. (2) that a higher quality increases (decreases) own (competitor's) patient demand. The lower the transportation costs or the more transparent quality differentials are (lower τ), the greater the intensity of quality competition.

2.2 Supply Side: Physicians

Physician i earns an exogeneously given fee-for-service per medical treatment q_i which is denoted by p.[11] The provision of medical treatment quality q_i involves costs per patient $C(q_i) = cq_i^2$. The cost function is assumed to be convex in the provision of q_i, i.e $C_{q_i} = 2cq_i > 0$ and $C_{q_iq_i} = 2c > 0$.[12]

Moreover, physicians are heterogeneous in their degree of altruism denoted by $\theta > 0$. Thus, physicians heterogeneously benefit from their patients' wellbeing. The degree of altruism is captured in physician i's utility function by the term $\theta_i B(q_i)$ for the provision of q_i.[13,]

The utility function of a physician i given the own provision q_i and the rival's quality level q_j can then be written as

$$\Pi_i(q_i,q_j) = x_i(q_i,q_j)\ \pi_i(q_i) = x_i(q_i,q_j)\ \left(p\,q_i + \theta_i B(q_i) - C(q_i)\right) \tag{3}$$

where $\pi_i(q_i)$ denotes the profit per patient, while the demand $x_i(q_i,q_j)$ is given by Eq. (2).

[11] As a particularity of the healthcare market, the price per treatment p is exogeneously given by a third party institution, e.g. by the government.

[12] Some model approaches, e.g. Economides (1989), Economides (1993), Calem and Rizzo (1995), Lyon (1999), Gravelle and Masiero (2000), Barros and Martinez-Giralt (2002), assume that costs are separable in quality and quantity, i.e. quality is a public good for all patients. We follow Siciliani (2009) and assume that each quality level has opportunity costs (e.g. in not treating another patient), which motivates our assumption that quality and quantity are not separable.

[13] We assume that physicians have altruistic preferences only towards their own patients. This can be justified by experimental evidence which shows that decreasing social distance affects the benevolent behavior, c.f. Bohnet and Frey (1999), Burnham (2003), and Charness et al. (2007), Charness and Gneezy (2008).

2.3 Monopoly

Before introducing competition, we first study the maximization problem of a monopolistic healthcare provider. Assuming that such a monopolistic healthcare provider would be located in the middle of the "linear city" at $x = 1/2$ and naturally captures the unit mass of consumers, the first-order condition (hereafter "FOC") and optimal treatment quantity $q_M^*(\theta, p)$ are given by:

$$\Pi_q = p + \theta\, b - 2\, c\, q = 0 \quad \text{and} \quad q_M^*(\theta, p) = \frac{p + \theta\, b}{2\, c}. \tag{4}$$

All else equal, a higher fee-for-service p, more altruistic physicians (higher θ), more quality sensitive patients (higher b), and lower costs (lower c) all increase the quality of care.[14]

2.4 Altruism Homogeneity and Symmetric Locations

We now consider the case of two physicians who are symmetrically located at α and $1 - \beta$ with $\ell = \alpha = \beta$. They are assumed to have identical degrees of altruism, i.e. $\theta = \theta_1 = \theta_2$. In contrast to the previous monopolistic case, physicians now compete for patients via quality levels. As illustrated in Eq. (2), a physician can attract more patients by a relatively higher quality level.

The profit function of a physician i is given by Eq. (3) and the corresponding FOC can be written as:

$$\frac{\partial \Pi_i(q_i, q_j)}{\partial q_i} = \Pi_{i,q_i}(q_i, q_j) = \underbrace{\pi_i(q_i) \frac{B_{q_i}}{2\tau(1 - \alpha - \beta)}}_{\text{new patients due to higher quality}} + \underbrace{x_i(q_i, q_j) \frac{\partial \pi_i(q_i)}{\partial q_i}}_{\text{treatment of existing patients}} = 0. \tag{5}$$

The first part of the FOC ("new patients due to higher quality") is the earnings from a marginal patient that switches from rival physician j to physician i and positive. The second part ("treatment of existing patients") is in principle the FOC from the monopolistic scenario, which sets marginal revenue (given by the price per treatment p) plus marginal patient benefit weighted by the degree of altruism ($\theta_i B_{q_i}$) against marginal costs (i.e. C_{q_i}) for the share of patients treated. In order to satisfy the FOC, the second part must be negative. Due to the convex cost assumption, it follows that the quality q_D^* in this symmetric duopoly scenario must be higher than in the monopolistic scenario. This is the case since the second part of the FOC is equal to zero for $q = q_M^*$ and negative for

[14] Note that $\Pi_{qq}(q = q_M^*) < 0$ such that this specification fulfills a profit maximum at q_M^*.

$q > q_M^*$. Thus, from a per patient perspective and compared to the monopolistic scenario, physicians are "overtreating" patients, i.e. providing a quality level which has a negative marginal return per patient. The rationale behind this result is that by overtreating some patients, physicians can attract additional patients (this is reflected in the first part of the FOC). Solving the FOCs for $q_1^* = q_2^* = q_D^*$ yields (cf. Proof 1 in the Appendix):

$$q_D^* = \frac{\sqrt{4\,c^2\tau^2\,(1-2\,\ell)^2 + b^2\,(p+b\,\theta)^2} - 2\,c\,\tau\,(1-2\,\ell)}{2\,b\,c} + q_M^* > q_M^*. \tag{6}$$

By comparing quality levels, it unambiguously follows that $q_M^* < q_D^*$. Thus, introducing competition in this framework via an additional healthcare provider induces physicians to offer higher quality levels to patients. Analogeously, increasing competition via greater transparency (lower transportation costs τ) as well as a stronger marginal benefit of quality (higher b) also increases the quality of care. From a horizontal differentation (location) perspective, centralizing healthcare providers (higher ℓ) also increases quality.

2.5 Altruism Heterogeneity and Asymmetric Locations

We now relax the assumption of symmetric locations and allow for altruism heterogeneity. Physicians choose profit maximizing quality levels $q_1^*\,(\alpha, \beta, \theta_1, \theta_2)$ and $q_2^*\,(\alpha, \beta, \theta_1, \theta_2)$, respectively, given their locations α and β, as well as altruism levels θ_1 and θ_2. We now explore (i) whether quality levels are strategic substitutes or complements (i.e. if an increase in one physician's quality level yields the rival's quality level to decrease or increase), (ii) whether more proximate (less horizontally differentiated) physicians increase or decrease quality levels, (iii) the effect of altruism heterogeneity, and (iv) the effect of increasing competition through an increase in transparency (lower transportation costs).

(i) Strategic complements or substitutes?

First, we explore whether quality levels are strategic substitutes or complements. In principle, the FOCs (for $i = 1, 2$) as given in Eq. (5), determine the best response function ("RF_i") of physician i given any quality level q_j of physician j. To determine whether an increase in q_2 by physician 2 yields an optimal increase or decrease in q_1 of physician 1, we consider:

$$\mathrm{RF}_1 : \frac{\partial q_1\,(q_2)}{\partial q_2} = -\left(\frac{\partial \Pi_{1,q_1}}{\partial q_2}\right)\left(\frac{\partial \Pi_{1,q_1}}{\partial q_1}\right)^{-1}; \quad \mathrm{RF}_2 : \frac{\partial q_2\,(q_1)}{\partial q_1} = -\left(\frac{\partial \Pi_{2,q_2}}{\partial q_1}\right)\left(\frac{\partial \Pi_{2,q_2}}{\partial q_2}\right)^{-1}. \tag{7}$$

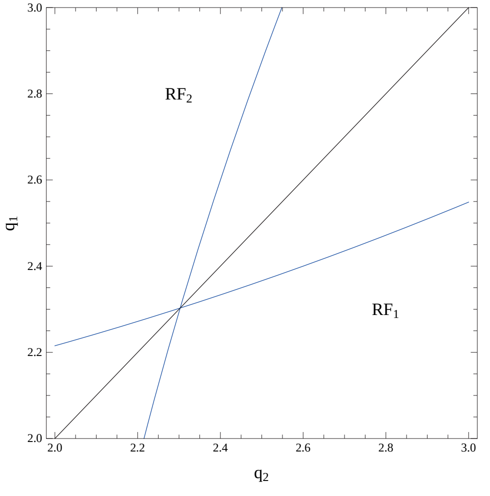

Figure 1: Reaction functions in (q_2, q_1)-space

The signs of both derivatives are the slopes of the RFs of physician 1 and 2. In fact, it can be shown (see Proof 2 in the Appendix) that

$$\mathrm{RF}_1 : \quad \frac{\partial q_1(q_2)}{\partial q_2} > 0 \quad \text{and} \quad \mathrm{RF}_2 : \quad \frac{\partial q_2(q_1)}{\partial q_1} > 0 \tag{8}$$

such that an increase in q_j of physician j is best responded by physician i with an increase in q_i, i.e. optimal quality levels are strategic complements. Figure 1 illustrates the result.[15] The strategic complement nature of quality levels is in line with recent empirical evidence by Gravelle et al. (2013), who show that a hospital's quality is positively associated with the quality of its rivals.[16]

(ii) Effect of locations?

Second, we study the effect of the location parameter α and β. An increase in α or β mirrors a lower degree of horizontal differentiation. Again, the optimal $q_1^*(\alpha, \beta, \theta_1, \theta_2)$ and $q_2^*(\alpha, \beta, \theta_1, \theta_2)$ solve the FOCs. We are now interested in the comparative statics with

[15] The chosen model parameters are: $\alpha = \beta = 0$, $p = 2$, $b = c = \tau = \theta_1 = \theta_2 = 1$.

[16] More precisely, Gravelle et al. (2013) find that a hospital's quality is positively associated with the quality of its rivals for seven out of the sixteen quality measures and that in no case is there a negative association.

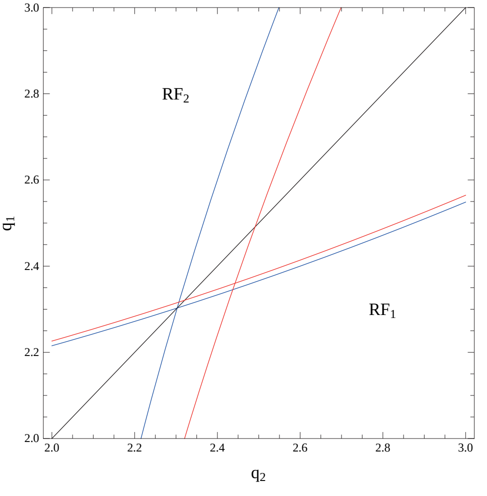

Figure 2: Higher α

respect to α and β. It can be shown (cf. Proof 3 in the Appendix) that:

$$\frac{\partial q_1^*\left(\alpha,\beta,\theta_1,\theta_2\right)}{\partial\alpha}>0,\quad \frac{\partial q_2^*\left(\alpha,\beta,\theta_1,\theta_2\right)}{\partial\beta}>0,\quad \frac{\partial q_1^*\left(\alpha,\beta,\theta_1,\theta_2\right)}{\partial\beta}>0,\quad \frac{\partial q_2^*\left(\alpha,\beta,\theta_1,\theta_2\right)}{\partial\alpha}>0.$$

Thus, a physician will intensify the quality competition if the rival moves towards him ($\partial q_1^*\left(\alpha,\beta,\theta_1,\theta_2\right)/\partial\beta > 0$, $\partial q_2^*\left(\alpha,\beta,\theta_1,\theta_2\right)/\partial\alpha > 0$), or if the physician for itself locates more proximate to the rival ($\partial q_1^*\left(\alpha,\beta,\theta_1,\theta_2\right)/\partial\alpha > 0$, $\partial q_2^*\left(\alpha,\beta,\theta_1,\theta_2\right)/\partial\beta > 0$). Intuitively, the greater the distance between the physicians, the smaller the market share captured by a marginal increase in quality. Thus, greater horizontal differentiation softens quality competition (vertical differentiation). Figure 2 illustrates the result.[17] This result is similar to a multitasking setting à la Holmstrom and Milgrom (1991) in which horizontal and vertical differentiation are strategic substitutes. An increase in horizontal differentiation leads to a decrease in quality as locating further apart allows providers to relax quality competition.

(iii) Effect of altruism heterogeneity

Third, we study the effect of altruism heterogeneity. The comparative static results are

[17]The model parameters are: $\beta = 0$, $p = 2$, $b = c = \tau = \theta_1 = \theta_2 = 1$ and $\alpha = 0$ for the blue graphs and $\alpha = 0.2$ for the red graph.

(cf. Proof 4 in the Appendix) are given by:

$$\frac{\partial q_1^*(\alpha,\beta,\theta_1,\theta_2)}{\partial\theta_1} > \frac{\partial q_2^*(\alpha,\beta,\theta_1,\theta_2)}{\partial\theta_1} > 0. \tag{9}$$

Thus, an increase in physician i's altruism level θ_i increases both physicians' quality levels. However, the increase is stronger in the "own" quality level q_i^* of physician i and less pronounced for the rival's quality level q_j^*. The strategic complement nature of quality levels implies that a unilaterally higher altruism level increases both quality levels and the toughness of quality competition. Intuitively, the more altruistic physician "suffers" comparatively less from an increase in quality. Figure 3 illustrates the result.[18]

Beyond the empirical evidence of laboratory experiments on altruism heterogeneity as described in the introduction, evidence for quality heterogeneity is provided by Gravelle and Sivey (2010). They report that the UK Healthcare Commission performance data for 2004/5 shows a wide disparity in its quality indicators.[19] Furthermore, Gravelle et al. (2013) show for a different dataset that in those cases where quality levels are strategic complements, a 10% increase in a rival's quality level increases the hospital's own quality by 1.7% to 2.9%. In our model, this quality heterogeneity could be a direct result of either altruism or location heterogeneity. It is notable that quality heterogeneity is difficult to be explained when physicians are homogeneous in their level of altruism.

(iv) Effect of transparency

Fourth, we study an increase in transparceny (i.e. a decrease in transportation costs). The comparative static results with respect to τ are given by (cf. Appendix 5):

$$\frac{\partial q_1^*(\tau)}{\partial\tau} > 0 \quad \text{and} \quad \frac{\partial q_2^*(\tau)}{\partial\tau} > 0. \tag{10}$$

Hence, an increase in transparency (a decrease in transportation costs) can be interpreted as an increase in competition, yielding an increase in the overall quality level. Figure 4 illustrates this result.[20]

Similar to the relationship between quality and location, a parallel argument applies

[18] Parameters: $\alpha=\beta=0$, $p=2$, $b=c=\tau=\theta_2=\theta_1=1$ for the blue graph, $\theta_1=1.5$ for the red graph.

[19] For example, the percentage of patients with heart attacks who thrombolysed within one hour of their first call for medical help had a coefficient of variation across acute hospital trusts of 0.29 and decile ratio of 2.29. The number of patients diagnosed with MRSA bacteraemia per 10,000 bed-days had a coefficient of variation of 0.35 and a decile ratio of 2.66. The 173 Acute Hospital Trusts were awarded overall star ratings of performance: 73 obtained 3 stars, 53 had 2 stars, 38 had 1 star and 9 had no stars.

[20] Parameters: $\alpha=\beta=0$, $p=2$, $b=c=\theta_1=\theta_2=\tau=1$ for the blue graph, $\tau=0.8$ for the red graph.

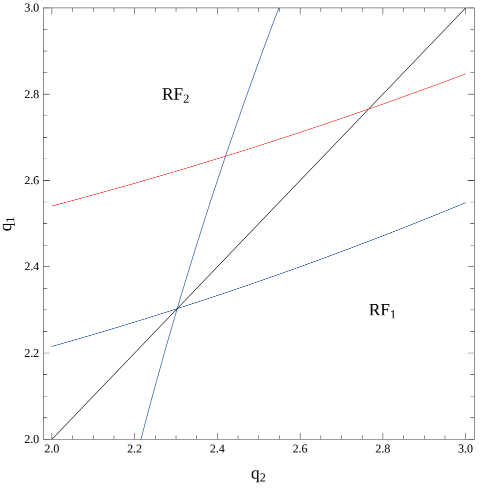

Figure 3: Higher θ_1

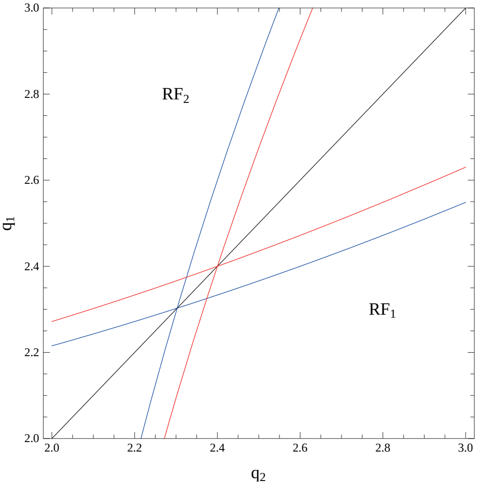

Figure 4: Lower τ

to the negative relationship between quality and transparency. The more costly it is for patients to "travel", the less pronounced the benefits, in terms of increased market share for either physician investing in quality improvements. This implies that the local "monopoly" power of physicians increases as τ increases, which in turn permits to decrease quality levels. The predicted positive relationship between competition and quality can be tested empirically by using hospital market shares. While Propper et al. (2004, 2008) find a significant, albeit small negative relationship based on UK data, the majority of studies find a positive relationship between competition and quality in healthcare markets.[21]

2.6 Endogeneous Location Choice

We now relax the assumption of exogeneous locations and allow physicians to endogeneously choose their locations according to the following two stage game.

1st Stage: In the first stage of the game, physicians choose their locations. Physician 1 (2) chooses α (β) in order to maximize profit as given in Eq. (3) anticipating optimal quantity choices $q_1^*(\alpha, \beta, \theta_1, \theta_2)$ and $q_2^*(\alpha, \beta, \theta_1, \theta_2)$ in the second stage. The first stage optimal location choices are denoted by $\alpha^*(\theta_1, \theta_2)$ and $\beta^*(\theta_1, \theta_2)$.

2nd Stage: In the second stage, physicians choose the profit maximizing quality levels

$$q_1^*\left(\alpha^*(\theta_1, \theta_2), \beta^*(\theta_1, \theta_2), \theta_1, \theta_2\right) \quad \text{and} \quad q_2^*\left(\alpha^*(\theta_1, \theta_2), \beta^*(\theta_1, \theta_2), \theta_1, \theta_2\right)$$

where $\alpha^*(\theta_1, \theta_2)$ and $\beta^*(\theta_1, \theta_2)$ denote the optimal locations chosen in the first stage. We will first solve for the market outcome using backward induction and afterwards derive the social planner's optimum.

(i) Market outcome

2nd Stage: In the second stage, the FOCs are given in Eq. (5). The optimal $q_1^*(\alpha, \beta, \theta_1, \theta_2)$ and $q_2^*(\alpha, \beta, \theta_1, \theta_2)$ solve the FOCs and the comparative statics with respect to first stage location choices α and β which have been derived in the previous section:

$$\frac{\partial q_1^*(\alpha, \beta, \theta_1, \theta_2)}{\partial \alpha} > 0, \quad \frac{\partial q_2^*(\alpha, \beta, \theta_1, \theta_2)}{\partial \beta} > 0, \quad \frac{\partial q_1^*(\alpha, \beta, \theta_1, \theta_2)}{\partial \beta} > 0, \quad \frac{\partial q_2^*(\alpha, \beta, \theta_1, \theta_2)}{\partial \alpha} > 0.$$

[21] Based on US data, a positive relationship is found by Dranove et al. (1992), Sari (2002), Gowrinsankaran and Town (2003), Howard (2005) and Araham et al. (2007).

1st Stage: Physician 1 maximizes its location α in stage 1 given its rival's location β and in anticipation of the second stage optimal quality levels $q_1^*(\alpha,\beta,\theta_1,\theta_2)$ and $q_2^*(\alpha,\beta,\theta_1,\theta_2)$, that is

$$\max_{\alpha} \Pi_1\left(q_1^*(\alpha), q_2^*(\alpha), \alpha\right) = x_1\left(q_1^*(\alpha), q_2^*(\alpha), \alpha\right) \ \ \pi_1\left(q_1^*(\alpha)\right). \tag{11}$$

By using the envelope theorem the corresponding FOC is given by

$$\frac{\mathrm{d}\Pi_1}{\mathrm{d}\alpha} = \left(\frac{\partial x_1}{\partial \alpha} + \frac{\partial x_1}{\partial q_1^*}\frac{\partial q_1^*}{\partial \alpha} + \frac{\partial x_1}{\partial q_2^*}\frac{\partial q_2^*}{\partial \alpha}\right)\pi_1 + x_1\frac{\partial \pi_1}{\partial q_1^*}\frac{\partial q_1^*}{\partial \alpha} = \left(\frac{\partial x_1}{\partial \alpha} + \frac{\partial x_1}{\partial q_2^*}\frac{\partial q_2^*}{\partial \alpha}\right)\pi_1 = 0 \tag{12}$$

where $\partial x_1/\partial\alpha > 0$ represents the "direct stealing effect" and $(\partial x_1/\partial q_2^*)(\partial q_2^*/\partial\alpha) < 0$ the "strategic effect". The "direct stealing effect" refers to the increase in physician 1's demand by positioning closer to the rival. The "strategic effect" is negative since $\partial x_1/\partial q_2^* < 0$ (a higher rival's quality attracts more patients) and $\partial q_2^*/\partial\alpha > 0$ (meaning physician 2 increases his optimal quality if physician 1 positions himself closer). Thus, locating oneself closer to the rival increases the rival's quality level, which reinforces the quality overprovision by both physicians. The latter has a negative effect on both physicians' profit levels. Taking into account the positive direct stealing effect and the negative strategic effect, the total effect of positioning oneself closer to the rival is at first ambiguous.[22]

In Figure 5 (cf. blue graphs), the optimal $\alpha^*(\beta,\theta_1,\theta_2)$ for variations in β (we refer to this as the "RF_1"), vice versa $\beta^*(\alpha,\theta_1,\theta_2)$, for variations in α ("RF_2") and identical degrees of altruism (i.e. $\theta_1 = \theta_2$) are plotted.[23] The intersection of both RFs is the optimal $\alpha^*(\theta_1,\theta_2)$ and $\beta^*(\theta_1,\theta_2)$, as chosen by the physicians in the first stage. As it follows from Figure 5, there exists an equilibrium such that $\alpha^*(\theta_1,\theta_2) > 0$ and $\beta^*(\theta_1,\theta_2) > 0$.[24] Thus, in contrast to the standard prediction of complete specialization in a Hotelling price competition model, a medium horizontal differentiation strategy is chosen by physicians.

The underlying intuition behind this result is straightforward. First, the major difference between this quality competition set up and a standard Hotelling price competition model is the role of altruism. Physicians (possibly heterogeneously) care about patients' benefits and are therefore providing, ceteris paribus, higher quality of care if the individual level of altruism is higher. Moving closer to the rival in turn induces him to increase quality

[22]It is noted that in a standard text book price competition version of Hotelling's model with endogeneous location choice, the negative strategic effect dominates and thus firms locate at extreme points (i.e. $\alpha = 0$, $\beta = 0$). This maximum degree of horizontal differentiation is greater compared to the social planner's preferred outcome, which minimizes transportation costs (i.e. $\alpha = \beta = 1/4$).

[23]Paramters: $\tau = c = 1$, $b = 2$, $\theta_2 = 0.005$, $\theta_1 = 0.005$ for the blue graphs, $\theta_1 = 0.35$ for the red graphs.

[24]For physician 1 there exists a α-domain where the direct stealing effect dominates while for higher α the strategic effect is stronger.

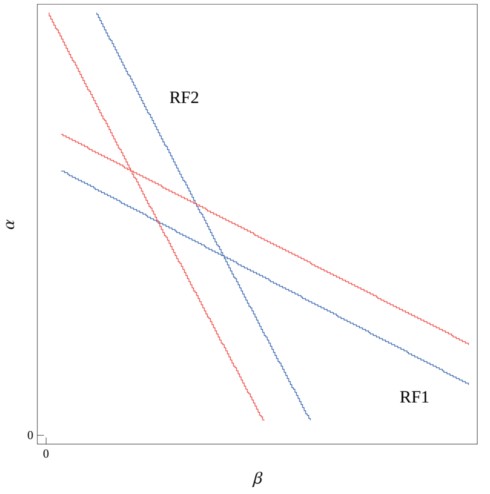

Figure 5: Reaction functions: $\theta_1 = \theta_2$ (blue) and $\theta_1 > \theta_2$ (red)

(decrease prices in a price competition model). Second, quality levels (prices) are strategic complements (in the second stage), profits per patient are effectively lowered as quality levels increase (prices decrease). In the standard price competition model, this negative effect dominates. However, in our case, this negative strategic effect is partly offset by physicians caring about patient wellbeing, i.e. their level of altruism.

To substantiate this intuition, we have also simulated variations in the individual level of altruism, i.e. altruism heterogeneity. If we consider physician 1 to be the one with the higher level of altruism (i.e. $\theta_1 > \theta_2$), we already know that for symmetrical locations, he provides a higher quality of care as compared to physician 2 in the second stage. In the first stage, this effect is intensified as the more altruistic physician also positions himself closer to the center (i.e. $\alpha^* (\theta_1, \theta_2)$ increases), while the less altruistic rival dampens the quality competition race by recoiling from the center (i.e. $\beta^* (\theta_1, \theta_2)$ decreases). The red RFs in Figure 5 illustrate this result.

Nevertheless, we find that symmetrically increasing altruism levels introduces a "centrifugal" type force[25] and implies that physicians endogeneously choose higher degrees of horizontal differentiation. Increasing horizontal differentiation allows for softening quality competition and in turn weakening costly quality overprovision. Evaluating direct stealing vis-a-vis strategic effect, the latter is magnified by simultaneously increasing altruism levels

[25] Brekke et al. (2006) also find that quality competition introduces a centrifugal-type force.

as this yields an overproportional increase in costs.

Whether the overall quality level (taking both the first and second stage effect together) increases or decreases in altruism is ambiguous, as higher altruism levels increase quality levels in the second stage. Regardless, for sufficiently high symmetric levels of altruism physicians locate at extreme points. Therefore, physicians cannot soften quality competition further by increasing horizontal differentiation. In such an instance, any further increase in altruism levels will unambiguously increase quality levels (due to the increase in the second stage).

(ii) Social planner's perspective

The patient, who is indifferent between consulting physician 1 and physician 2, is located at $\tilde{x} = x_1(q_1, q_2)$ as given by Eq. (2). Averaging over all patients yields total welfare[26] of

$$\begin{aligned} W &= \underbrace{\int_0^{\tilde{x}} B(q_1) - C(q_1) - \tau (z-\alpha)^2 \, \mathrm{d}z}_{\text{consultation of physician 1}} + \underbrace{\int_{\tilde{x}}^1 B(q_2) - C(q_2) - \tau (\beta - z)^2 \, \mathrm{d}z}_{\text{consultation of physician 2}} \\ &= \underbrace{\int_0^{\tilde{x}} B(q_1) - C(q_1) \, \mathrm{d}z + \int_{\tilde{x}}^1 B(q_2) - C(q_2) \, \mathrm{d}z}_{\equiv W_B} + \underbrace{\int_0^{\tilde{x}} \tau (z-\alpha)^2 \, \mathrm{d}z + \int_{\tilde{x}}^1 \tau (\beta - z)^2 \, \mathrm{d}z}_{\equiv W_\tau}. \end{aligned}$$

The social planner maximizes $W = W_B + W_\tau$ by choosing optimal α^W and β^W in the first stage and anticipating the physicians' choices $q_1^*\left(\alpha^W, \beta^W, \theta_1, \theta_2\right)$ and $q_2^*\left(\alpha^W, \beta^W, \theta_1, \theta_2\right)$ in the second stage.

It is well-known that W_τ is maximized (i.e. average transportation costs are minimized) for $\ell_\tau^W = \alpha_\tau^W = \beta_\tau^W = 1/4$ and indepdent of altruism. Thus, in the standard price competition framework where $W = W_\tau$ since $W_B = 0$, the social planner prefers less horizontal differentiation than the market outcome yields.

However, in our case the social planner's optimum is not necessarily achieved by choosing locations for which W_τ is maximized, as this does not necessarily imply that $W = W_B + W_\tau$ is maximized. In order to investigate the latter, we integrate W_B, which yields:

$$W_B = (B(q_1) - C(q_1))\, \tilde{x} + (B(q_2) - C(q_2))\,(1 - \tilde{x}). \tag{13}$$

[26]It is worth noting that the price per treatment p is a lump-sum transfer between patients and physicians. The altruistic component is excluded in the welfare function as it is discussed in the literature that the inclusion would lead to double-counting, c.f. Chalkley and Malcomson (1998). Notably, our results will not be qualitatively affected by this assumption.

If both physicians are symmetrically altruistic, i.e. $\theta = \theta_1 = \theta_2$, the social planner will choose $\ell^W = \alpha^W = \beta^W$ which implies $q_1^*\left(\ell^W, \theta\right) = q_2^*\left(\ell^W, \theta\right)$ in the physicians' second stage choices. In this case, the optimal ℓ_B^W, which maximizes W_B (i.e. the average difference between patient benefit and physicians' costs), can be explicitly derived (cf. Proof 6 in the Appendix). It can be shown that ℓ_B^W monotonically decreases in θ. Taking our results for ℓ_B^W and ℓ_τ^W together, we can conclude that ℓ^W monotonically decreases in altruism. Figure 6 illustrates this result.[27] Furthermore, in Figure 7 the intersection of the blue graphs illustrates the optimal $\ell^W = \alpha^W(\theta_1, \theta_2) = \beta^W(\theta_1, \theta_2)$ that maximize W for the symmetric case $\theta_1 = \theta_2$.[28] The intuition behind this result is that the social planner's maximization problem takes into account cost-efficient quality levels and transportation costs. Related to cost-efficient quality, the social planner positions more altruistic physicians further apart, as they for themselves provide higher quality than less altruistic physicians. Thus, increasing horizontal differentiation softens quality competition and dampens costly quality overprovision.

If physician 1 is more altruistic than physician 2 ($\theta_1 > \theta_2$), physician 1 is providing a higher quality of care for given symmetric locations. This effect is reinforced the more centrally positioned physician 1 is. Simulations indicate that it is easier for the social planner to stimulate quality provision from physician 1 and leverage this physician to increase average quality provision. As such, a social planner positions the more (less) altruistic physician 1 (2) closer to (further apart from) the center as this physician benefits more (less) from higher quality levels. The red RFs in Figure 7 illustrate this result.

Whether the social planner prefers more or less horizontal differentiation compared to the market outcome is ambiguous and depends on the altruism levels of the physicians. If altruism levels are sufficiently high, the social planner's optimal degree of horizontal differentiation is greater than the market outcome (cf. blue graphs in Figure 6). Vice versa, lower altruism levels may yield less horizontal differentiation from the perspective of a social planner (cf. red graphs in Figure 6). Faced with altruism heterogeneity, analogeously the social optimum yields more or less horizontal differentiation depending on the altruism levels. The more altruistic physicians are, the more likely it is that the social planner prefers greater horizontal differentiation to soften costly quality competition.

[27]Parameters: $\tau = c = 1$, $b = 2$, $\theta_1 = \theta_2 = 0.005$ for the blue graphs, $\theta_1 = \theta_2 = 0.35$ for the red graphs.

[28]Parameters: $\tau = c = 1$, $b = 2$, $\theta_2 = 0.005$, $\theta_1 = 0.005$ for the blue graphs, $\theta_1 = 0.35$ for the red graphs.

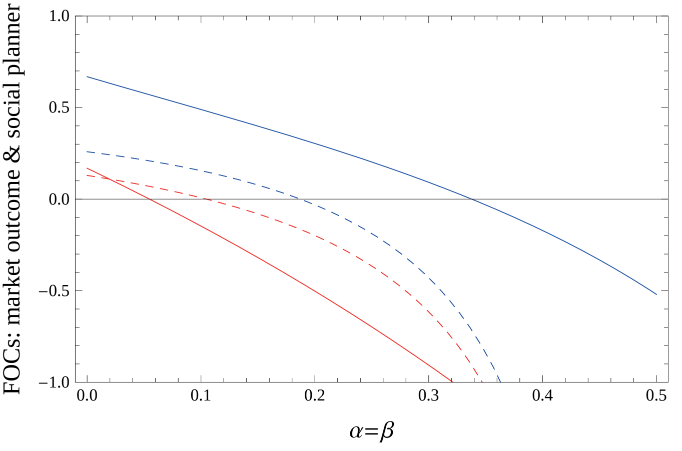

Figure 6: Solid (dashed) lines indicate the social planner's (market outcome) FOCs. Blue (red) graphs indicate lower (higher) altruism levels.

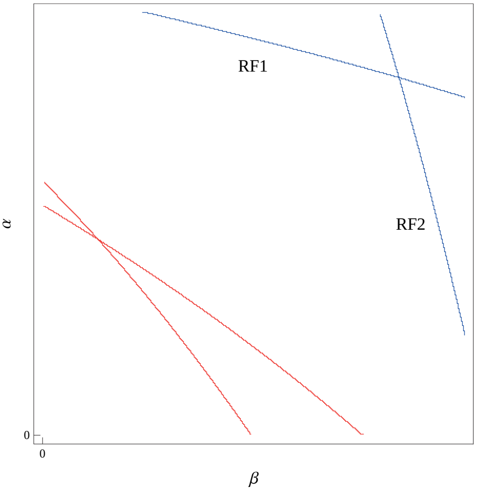

Figure 7: Welfare maximizing α^W and β^W: $\theta_1 = \theta_2$ (blue) and $\theta_1 > \theta_2$ (red)

3 Conclusion

One of the most distinctive characteristics of the healthcare market vis-a-vis other markets is the altruism of healthcare providers. Recent empirical evidence deduced from laboratory experiments by Godager and Wiesen (2013) as well as Brosig-Koch et al. (2013) shows not only the existence of altruism in healthcare providers, but also substantial heterogeneity in these altruism levels. Building on this evidence, our key contribution to the body of research is to introduce altruism heterogeneity into a spatial quality competiton framework.

We have demonstrated that the assumption of altruism heterogeneity yields both, new insights from a theoretical point of view and relevant implications for policy makers. From a theoretical perspective, we find that more altruistic physicians provide higher quality of care which in turn induces other physicians to increase quality. Greater horizontal differentation decreases quality levels, that is vertical and horizontal differentiaton are strategic complements. In a scenario with endogeneous location choice, more proximate physicians trade off the positive direct stealing effect of capturing market share against the negative increased quality competition effect. In contrast to a standard price competiton framework, our model highlights that physicians tend to choose medium levels of horizontal differentiation while the more altruistic physician locates closer to the center and provides higher quality levels. In turn, the less altruistic physician locates closer to the boundaries and provides relatively lower quality levels.

Compared to the market outcome, the social planner prefers more or less horizontal differentiation depending on the levels of altruism. The more altruistic physicians are, the higher the likelihood that the social planner prefers greater horizontal differentiation to offset costly quality overprovision. When altruism heterogeneity is considered, the social planner positions the more altruistic physician closer to the center. Again, whether the social planner prefers more or less horizontal differentiation as compared to the market outcome depends on the level and the degree of altruism heterogeneity.

Based on these results, there are potential lessons to be learned for policy makers. One such conclusion is that to avoid undesirable quality over- or underprovision, or in geographic terms agglomeration or dispersion of physicians, healthcare policy reforms must consider the level and heterogeneity in physicians' altruism. Thus, estimating the distribution of altruism levels represents a fruitful area for future research. Based on our results, such research would enable policy makers to design better healthcare reforms.

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Appendix

Proof 1: General remarks

In the following we show that q_D^* maximizes both Π_1 as well as Π_2. As sufficient condition for a maximum is that the Hessian matrix F is negative definite at q_D^*. This can be shown by

$$\Pi_{i,q_iq_i}\left(q_i = q_D^*, q_j = q_D^*\right) = c - \frac{\Gamma}{\tau(1-2\ell)} < 0 \tag{14}$$

with

$$\Gamma \equiv \sqrt{4c^2\tau^2\left(1-2\ell\right)^2 + b^2\left(p+b\theta\right)^2} \tag{15}$$

as well as

$$|F| = \begin{vmatrix} \Pi_{1,q_1q_1} & \Pi_{1,q_1q_2} \\ \Pi_{2,q_2q_2} & \Pi_{2,q_2q_2} \end{vmatrix} = \frac{3b^2\left(p+b\theta\right)^2 - 4c\tau\left(1-2\beta\right)\left(\Gamma - 3c\tau\left(1-\beta\right)\right)}{4\tau\left(1-2\ell\right)^2} > 0 \tag{16}$$

Proof 2: Strategic complement or substitutes?

First, we consider RF_1:

$$\frac{\partial \Pi_{1,q_1}}{\partial q_2}\left(q_D^* = q_i = q_j\right) = -\frac{b}{2\tau\left(1-\alpha-\beta\right)}\,\pi_{1,q_1} = -\left(1 + \frac{\Gamma}{2\tau\left(1-2\ell\right)}\right) < 0 \tag{17}$$

and due to $\Pi_{1,q_1q_1}\left(q_1 = q_D^*, q_2 = q_D^*\right) < 0$ it directly follows $\partial q_1\left(q_2\right)/\partial q_2 > 0$ from the RF_1 and due to symmetry also $\partial q_2\left(q_1\right)/\partial q_1 > 0$ from the RF_2.

Proof 3: Change of α and β

In principle, the comparative static results of the RFs are given by

$$\frac{\partial q_1^*\left(\alpha,\beta,\theta_1,\theta_2\right)}{\partial \alpha} = \frac{\begin{vmatrix} -\Pi_{1,q_1\alpha} & \Pi_{1,q_1q_2} \\ -\Pi_{2,q_2\alpha} & \Pi_{2,q_2q_2} \end{vmatrix}}{|F|} = \frac{-\Pi_{1,q_1\alpha}\Pi_{2,q_2q_2} + \Pi_{1,q_1q_1}\Pi_{2,q_2\alpha}}{|F|} > 0 \tag{18}$$

as well as

$$\frac{\partial q_2^*\left(\alpha,\beta,\theta_1,\theta_2\right)}{\partial \alpha} = \frac{\begin{vmatrix} \Pi_{1,q_1q_1} & -\Pi_{1,q_1\alpha} \\ \Pi_{2,q_2q_1} & -\Pi_{2,q_2\alpha} \end{vmatrix}}{|F|} = \frac{-\Pi_{1,q_1q_1}\Pi_{2,q_2\alpha} + \Pi_{1,q_1\alpha}\Pi_{2,q_2q_1}}{|F|} > 0 \tag{19}$$

where

$$|F| = \begin{vmatrix} \Pi_{1,q_1q_1} & \Pi_{1,q_1q_2} \\ \Pi_{2,q_2q_1} & \Pi_{2,q_2q_2} \end{vmatrix} = \Pi_{1,q_1q_1}\Pi_{2,q_2q_2} - \Pi_{1,q_1q_2}\Pi_{2,q_2q_1} > 0. \tag{20}$$

First, for $q_D^* = q_1^* = q_2^*$ the term $|F_{q_1,\alpha}|$ simplifies to

$$\begin{aligned} |F_{q_1,\alpha}| &= \begin{vmatrix} -\Pi_{1,q_1\alpha} & \Pi_{1,q_1q_2} \\ -\Pi_{2,q_2\alpha} & \Pi_{2,q_2q_2} \end{vmatrix} \\ &= \frac{b^2p^2(1+\ell) + 2b^3p(1+\ell)\theta + b^4(1+\ell)\theta^2 - 2c\tau(2+\ell)(1-2\beta)(\Gamma - 2c\tau(1-2\ell))}{2b\tau(1-2\ell)^2} > 0 \end{aligned}$$

Second, for $q_D^* = q_1^* = q_2^*$ the term $|F_{q_2,\alpha}|$ simplifies to

$$\begin{aligned} |F_{q_2,\alpha}| &= \begin{vmatrix} -\Pi_{1,q_1q_1} & -\Pi_{1,q_1\alpha} \\ -\Pi_{2,q_2q_1} & -\Pi_{2,q_2\alpha} \end{vmatrix} \\ &= \frac{b^2p^2(2-\ell) + 2b^3p(2-\ell)\theta + b^4(2-\ell)\theta^2 - 2c\tau(3-\ell)(1-2\beta)(\Gamma - 2c\tau(1-2\ell))}{2b\tau(1-2\ell)^2} > 0 \end{aligned}$$

Proof 4: Change of θ_1 ***and*** θ_2

In principle, the comparative static results of the RFs are given by

$$\frac{\partial q_1^*(\alpha,\beta,\theta_1,\theta_2)}{\partial\theta_1} = \frac{\begin{vmatrix} -\Pi_{1,q_1\theta_1} & \Pi_{1,q_1q_2} \\ -\Pi_{2,q_2\theta_1} & \Pi_{2,q_2q_2} \end{vmatrix}}{|F|} = \frac{-\Pi_{1,q_1\theta_1}\Pi_{2,q_2q_2} + \Pi_{1,q_1q_2}\Pi_{2,q_2\theta_1}}{|F|} > 0 \tag{21}$$

and

$$\frac{\partial q_2^*(\alpha,\beta,\theta_1,\theta_2)}{\partial\theta_1} = \frac{\begin{vmatrix} \Pi_{1,q_1q_1} & -\Pi_{1,q_1\theta_1} \\ \Pi_{2,q_2q_1} & -\Pi_{2,q_2\theta_1} \end{vmatrix}}{|F|} = \frac{-\Pi_{1,q_1q_1}\Pi_{2,q_2\theta_1} + \Pi_{1,q_1\theta_1}\Pi_{2,q_2q_1}}{|F|} > 0 \tag{22}$$

First, for $q_D^* = q_1^* = q_2^*$ the term $|F_{q_1,\theta_1}|$ simplifies to

$$|F_{q_1,\theta_1}| = \frac{b(\Gamma - c\tau(1-2\ell))(b(p+b\theta)\Gamma)}{4c\tau(1-2\ell)^2} > 0 \tag{23}$$

Second, for $q_D^* = q_1^* = q_2^*$ the term $|F_{q_1,\theta_2}|$ simplifies to

$$|F_{q_1,\theta_2}| \quad = \quad \frac{b\left(\Gamma - c\tau\left(1-2\ell\right)\right)\left(b\left(p+b\theta\right)\Gamma\right)}{8c\tau\left(1-2\ell\right)^2} > 0 \tag{24}$$

And it directly follows

$$|F_{q_1,\theta_1}| > |F_{q_1,\theta_2}| \tag{25}$$

Proof 5: Change of τ

In principle, the comparative static results of the RFs are given by

$$\frac{\partial q_1^*\left(\tau\right)}{\partial\tau} = \frac{\begin{vmatrix} -\Pi_{1,q_1\tau} & \Pi_{1,q_1q_2} \\ -\Pi_{2,q_2\tau} & \Pi_{2,q_2q_2} \end{vmatrix}}{|F|} = \frac{-\Pi_{1,q_1\tau}\Pi_{2,q_2q_2} + \Pi_{1,q_1q_2}\Pi_{2,q_2\tau}}{|F|} < 0 \tag{26}$$

and

$$\frac{\partial q_2^*\left(\tau\right)}{\partial\tau} = \frac{\begin{vmatrix} \Pi_{1,q_1q_1} & -\Pi_{1,q_1\tau} \\ \Pi_{2,q_2q_1} & -\Pi_{2,q_2\tau} \end{vmatrix}}{|F|} = \frac{-\Pi_{1,q_1q_1}\Pi_{2,q_2\tau} + \Pi_{1,q_1\tau}\Pi_{2,q_2q_1}}{|F|} < 0. \tag{27}$$

For $q_D^* = q_1^* = q_2^*$ the term $|F_{q_1,\theta_2}|$ simplifies to

$$|F_{q_1,\tau}| \quad = \quad \frac{10c\tau\left(1-2\ell\right)\left(\Gamma - 2c\tau\left(1-2\ell\right) - 3b^2\left(p+b\theta\right)\right)}{4b\tau^2\left(1-2\ell\right)} < 0 \tag{28}$$

Due to symmtry it follows $|F_{q_1,\tau}| = |F_{q_2,\tau}|$.

Proof 6: Change of ℓ_B^W

The ℓ which maximizes W_B is given by

$$\ell_B^W = \frac{1}{2} + \frac{b^2\left(2p - b\left(1-2\theta\right)\right)}{8c\tau\left(p - b\left(1-\theta\right)\right)} \tag{29}$$

and monotonically increasing in θ. It is noted that $0 < \ell_B^W < 1/2$ holds, if the effect of quality on the patient benefit is limited. More formally, we assume $p < b < 2p$ and $\theta < \left(b-p\right)/b$ such that $0 < \ell_B^W < 1/2$ maximizes W_B. For less restrictive assumptions, we must study boundary solutions which are not our primary interest. Related to this, it is noted that $\ell_B^W = 0$ for $\theta > 1 - p/b - b^2/\left(2\left(b^2 + 2c\tau\right)\right)$.