Can competition reduce quality?*

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Abstract

We analyse the effect of competition on quality provision in spatial markets such as health care, long-term care, child care and education, where providers compete on both price and quality. By making two key assumptions about the providers in such markets, namely that they are (partly) motivated and have decreasing marginal utility of income, we find, contrary to the existing literature, an unambiguously negative relationship between competition intensity and quality provision. This relationship holds regardless of whether quality and price decisions are made simultaneously or sequentially. However, even if competition reduces quality, it does not necessarily follow that social welfare is reduced.

Keywords: Quality and price competition; Motivated providers; Decreasing marginal utility of income.

JEL classification: D21, D43, L13, L30

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1 Introduction

Quality is a key concern for consumers in many sectors such as health care, long-term care, child care and education. Hospitals, nursing homes, schools and universities compete on quality to attract patients, residents and students. While in some countries prices are typically regulated, in other countries they are not. In this study we focus on institutional settings where providers compete both on quality and price. For example, prices are variable in the hospital sector in the US for patients who are not part of public programmes such as Medicare (for the elderly) or Medicaid (for the poor). In England, the government recently discussed whether public insurers should be able to negotiate prices with public hospitals, so that they would compete not only on quality but also on price. It was ultimately decided not to allow competition on prices due to concerns that quality may suffer (Kmietowicz, 2011). In the UK, France and the US, long-term care institutions (e.g., nursing homes, residential homes) compete on prices in addition to quality to attract residents. Universities in the US, and from 2012 in the UK, compete on prices in addition to quality. In the UK nurseries offer different services in combination with different prices for child care, and therefore also compete on price and quality.

The relationship between competition and quality is hotly debated in several countries. Understanding such relationship is therefore important to design future policies, and to decide whether competition should be encouraged or eliminated. As reviewed below, there are several empirical studies that have found a negative relationship between competition and quality in these sectors. The theoretical literature is however lacking in terms of offering precise mechanisms that can explain these findings. This paper fills this gap in knowledge. We investigate whether competition can lead to a reduction in quality when providers compete on both price and quality. We use a spatial competition framework where consumers trade off travelling distance relative to price and quality offered by the providers in the market. This framework is widely used and well-suited for studying competition in markets such as health care, education, long-term care, etc., where consumers usually have a preference for the closest provider unless more distant providers offer a better quality and/or lower price.

We show that more competition reduces quality (and price) when two plausible assumptions hold: i) the providers are motivated, i.e., have a genuine concern for quality; ii) the providers face decreasing marginal utility from profits. We think both assumptions are highly relevant for the providers in the type of sectors we have in mind. Provider motivation is widely recognised in the health economics and motivated agents literature (see Section 2.1). The assumption of decreasing marginal utility of profits is plausible for small organisations with sole or concentrated ownership (e.g., care and nursing homes, family doctors working in solo practices, and in some countries hospitals, specialists, dentists, and child care providers; see Section 2.2 for full discussion).

Therefore, our model can rationalise the empirical evidence by drawing attention to two assumptions (provider motivation and decreasing marginal utility of profits) which are relevant for the sectors, such as health care, long-term care, child care and education, where the role of competition is currently being discussed. The existing theoretical literature offers limited insight with respect to a potential negative relationship between competition and quality (when prices are flexible). A notable exception is Economides (1993) who applies a Salop model with n firms and shows that a higher number of firms leads to lower equilibrium quality under price-quality competition. However, this results from a pure demand effect (a higher number of firms implies that each firm faces less demand) and the analysis therefore only addresses a limited aspect of competition. Intuitively, a key implication of increased competition is that each firm's demand becomes more responsive to changes in quality and/or price. In a spatial competition framework with inelastic total demand, this effect is perfectly captured by measuring competition as the equivalent of lower transportation costs, which is a standard practice in the literature.

When increased competition makes demand more responsive to price/quality changes, there are two counteracting effects with respect to firms' incentives for quality provision. While more competition increases the incentives to supply high quality for given prices, more competition also reduces the price-cost margin, which, in turn, reduces the incentives to invest in quality. Ma and Burgess (1993) report that the direct effect of more competition on quality is exactly offset by the indirect effect via lower prices so that overall there is no effect of more competition on quality. The same result is reported by Gravelle (1999). However, Brekke, Siciliani and Straume (2010) show that the two above-mentioned effects do not cancel when allowing for income effects in consumer utility. They find that more competition tends to *increase* quality when *consumers* have decreasing marginal utility of income. The reason is a price reduction reduces consumers' marginal utility of income, making *demand* less sensitive to price, which in turn dampens the price reduction due to fiercer competition. In contrast, in this study the reduction in price induced by competition generates a reduction in revenues and profits by the firm, which in turn affects the *supply* incentives to provide quality.

The above-mentioned papers find that competition has either zero or positive effects on quality provision. To our knowledge, the existing literature does not offer any plausible theoretical mechanisms that make the indirect effect outweigh the direct one, thereby establishing a negative relationship between competition and quality. The present paper fills this gap in the literature by showing that if *providers* are motivated and have decreasing marginal utility of profits, a third effect emerges and competition actually reduces quality. The intuition is that more competition leads to lower prices, which in turn reduces profits and increases the marginal utility from profits. Being motivated, the provider works at a negative marginal profits and will therefore respond optimally to fiercer competition by reducing quality in order to recover some of the profit losses generated by the price reduction.

We show that our key result that competition reduces quality is robust to two different modifications of the standard set-up. First, we extend our basic set-up to more than two firms ($n \geq 2$) using a Salop model, and show that both lower transportation costs and more firms leads to lower quality. While the first result relies exclusively on the assumptions that providers are motivated and face decreasing marginal utility of profits, the latter does not but is reinforced by decreasing marginal utility since more firms reduce profits. Second, we allow for sequential quality and price decisions, reflecting that quality often is a more long-term decision than price. We show that the timing of decisions do not qualitatively change our main result. When providers can commit to a given quality level before competing in prices, we also show that this softens quality competition as providers take into account how quality affects own and rival pricing decisions in the subsequent stage. This result is in line with previous findings by Ma and Burgess (1993).[1]

We also investigate the welfare implications of more competition. We define welfare as the sum of consumers' and providers' utility (therefore explicitly taking into account providers' preferences). More competition reduces quality but also reduces prices. If the marginal utility of income is higher for consumers than for providers, then we show that the price effect,

[1] See also Economides (1993) for a similar result in the context of a Salop model.

which increases welfare, dominates the quality effect, which reduces welfare, implying that more competition always increases social welfare.[2]

Our proposed mechanism might rationalise some of the empirical evidence which finds a negative relationship between quality and competition in health care markets. In the health economics literature, quality is often proxied with health outcomes in the form of risk-adjusted mortality rates.[3] The recent literature on competition has favoured the use of mortality rates for *heart attack* patients in particular, which appear to respond and correlate with management quality (see Bloom et al. for a fuller discussion). Mukamel et al. (2001) find that hospital competition increased mortality from 1982 to 1989 in California; Volpp et al. (2003) investigate the effect of price deregulation in New Jersey from 1990 to 1996 and find an increase in mortality; Propper et al. (2004) and Burgess et al. (2008) find a positive relation between competition and mortality rates for patients with heart attack in England when price regulation was not yet introduced and prices were allowed to vary.[4] Grabowski (2004) finds that competition reduces the quality of nursing homes in the US. Forder and Allan (2014) find a similar result for care homes for the elderly in England.

There exists some related theoretical papers that find an adverse effect of competition on quality using quite different approaches. Assuming monopolistic competition, imperfect information and consumer search, Dranove and Satterthwaite (1992) show that improved price information might reduce quality provision, possibly to the extent that welfare is reduced. Using a principal-agent framework, Golan, Parlour and Rajan (2011) find that stronger competition may increase the costs for the principal (shareholders) to incentivise effort by the agent (manager), which reduces the quality of the products offered.[5] However, our paper differ from these

[2] The question of socially optimal quality provision was first analysed by Spence (1975), who showed that a monopolist will provide the socially optimal level of quality only if the willingness to pay for quality is equal for the average and for the marginal consumer. As shown by Ma and Burgess (1993), this equality holds in equilibrium in the Hotelling model with profit-maximising providers and constant marginal utility of profits, but only if the providers make price and quality decisions simultaneously. In our model, with motivated providers and decreasing marginal utility of profits, socially optimal quality provision is generally not obtained in equilibrium and, even if more competition always reduces quality, the welfare effect of more competition is ambiguous.

[3] Although mortality rates are a rather crude way of measuring health, it has the advantage of being routinely measured in administrative databases. Moreover, it can be interpreted unambiguously (in contrast for example to some older measures, such as patient length of stay, which could reflect both quality and efficiency).

[4] See Gaynor (2006) for survey on the effects of competion on quality in hospital markets.

[5] This paper builds on the seminal contributions of Hart (1983) and Schmidt (1997) on the impact of product market competition on managerial incentives. Benabou and Tirole (2014) show that competition may induce firms to adopt excessively high powered incentive schemes (e.g., bonus culture) inducing the most talented agents to reduce unobserved dimensions of quality (which in turn can reduce welfare).

studies in that we allow for motivated providers and explicit strategic interaction between firms.

The rest of the paper is organised as follows. In Section 2 we discuss the rationale for our key assumptions. In Section 3 we present our basic model, and derive our main result that competition reduces quality. In Section 4 we check the robustness of this result by modifying our basic model along two dimensions: (i) more than two firms; (ii) sequential quality and price decisions. In Section 5 we conduct a welfare analysis, while in Section 6 we offer some concluding remarks.

2 Key assumptions

In this section, we discuss the rationale for our two key assumptions, i.e., that providers are motivated and have decreasing marginal utility of income.

2.1 Motivated providers

We assume that providers are motivated and have genuine concern about the quality offered to their consumers. Provider motivation is highly relevant in the health, long-term care and education sectors, as well as other public sector industries. In the theoretical health economics literature, it has long been recognised that providers (doctors, nurses, health care managers) are concerned about the quality of care provided to patients (Ellis and McGuire, 1986; Chalkley and Malcomson, 1998; Eggleston, 2005; Choné and Ma, 2011; Kaarbøe and Siciliani, 2011; Brekke, Siciliani and Straume, 2011, 2012).

This assumption is also made in the recent literature on motivated agents in the broader public sector, where the agent is assumed to share, to some extent, the objective function of the principal (Francois, 2000; Glazer, 2004; Besley and Ghatak, 2005; Dixit, 2005; Lakdawalla and Philipson, 2006; Delfgaauw and Dur, 2008; Makris, 2009; Makris and Siciliani, 2013; Siciliani, Straume and Cellini, 2013). The main idea is that organisations that provide publicly-provided private (or public) goods have a mission, and individuals who work in such organisations are 'mission-oriented' or 'motivated'. Examples given in this literature include doctors and nurses who are committed to improve health, teachers who care about good learning, and researchers who are committed to expanding knowledge.

The assumption that providers are, at least to a certain extent, motivated or altruistic seems plausible and accepted in the theoretical literature. There is also a growing empirical literature which suggests that motivation and pro-social motivation are important components of certain sectors. For example, there is evidence that motivation is key for health care workers' job (Page, 1996; Le Grand, 2003, chapter 2), and Godager and Wiesen (2013) provide evidence of altruistic physician preferences.

2.2 Decreasing marginal utility of income

The assumption of decreasing marginal utility of income is plausible for small organisations with sole or concentrated ownership. This is the case for example of (residential) care homes for the elderly in England. In 2010, there were about 9920 for-profit care homes (and only about 1830 not-for-profit ones) and for 58% the owner had either one or two care homes. Moreover, care homes tend to be small organisations with on average 37 beds. In the US, care homes for the elderly are also numerous (at least 85000) and small, often with ten or fewer beds. About 80% of licensed homes are for-profit facilities (Norton, 2000).

Nurseries providing child care also tend to be small organisations. For example, in England in 1999 there were 9257 providers covering 217239 places. Each nursery had therefore on average 23 children. These tend to be for-profit and are subject to regular inspections from a regulator, known as OFSTED (Bertram and Pascal, 2000). Nurseries tend to be local and highly decentralised. They compete on both quality (type of services provides, green space, play area, quality of food, activities) and price. Across several European countries, the group size is regulated and is around 20-30 children (Austria, Ireland, France, Hungary, Netherlands, Portugal; see European Commission, 2009). Average group size is 16 in day care centres in the US (Blau and Currie, 2006).

Family doctors in some countries are also highly decentralised with doctors working in solo practices. This is the case for example in Germany where more than 50% (out of 132400 providing ambulatory care) have a solo practice and 25% share a practice; practices are generally for-profit (Busse and Riesberg, 2004). In France, more than half of doctors (both generalists and specialists) are self-employed and work in their own practice (about 122500 in 2009). They compete on both the quality of care and the prices charged (Chevreul et al., 2010).

Dentists also tend to work in small practices and on their own in several countries. 90% of dentists in France are self-employed. In England, most dentists work in small private practices. Moreover, dental services tends to be only partially covered by mandated health insurance with significant out-of-pockets payments in most OECD countries, and is not covered at all in some countries such as Australia, Canada and Ireland (Health at a Glance, 2011).

So far, we have focussed on small organisations with sole or highly concentrated ownership. There may be other reasons why large firms or organisations, such as hospitals (in particular private ones, like in the US) might also display decreasing marginal utility of income (Banal-Estañol and Ottaviani, 2006). Large firms may have ownership concentrated in few individuals (e.g., family ownership; LaPorta et al, 1999) and this implies that they may be more sensitive to income effects. Even if ownership is dispersed, the decision making is delegated to professional managers with incentive schemes increasingly linked to profit (Hall and Lirbman, 1998). If management is concentrated, then variations in profit will affect managers individually (Asplund, 2002). As individuals they may exhibit decreasing marginal utility. A firm's payoff function might also be concave in profit due to liquidity constraints and costly financial distress.[6] If external financing is more costly than internal financing, the firm's marginal value of profits will decrease with the profit level. Thus, the assumption of decreasing marginal utility of profits might be particularly relevant for organisations that have small profit margins or that are close to breaking even (Banal-Estañol and Ottaviani, 2006).[7] Furthermore, empirical studies tend to find that liquidity constraints affect the decision of self-employment. For instance, Lindh and Ohlsson (1996) find a quadratic relationship for some regressions between personal inheritance and the probability of becoming self-employed, and Holtz-Eakin et al. (1994) find a quadratic relationship for personal assets and the likelihood of staying self-employed over wage earning. These findings support our assumption of decreasing marginal utility of profits.

[6] In the UK, several hospital managers have been fired or threaten to be fired by the NHS trust boards due to bad performance such as large hospital deficits.

[7] In health economics, the analytically similar assumption of risk-aversion has been used by, e.g., Mougeot and Naegelen (2008) and Felder (2009). In the broader IO literature, see, e.g., Wambach (1999), Asplund (2002), Banal-Estañol and Ottaviani (2006), Janssen and Karamychev (2009), Barreda-Tarrazone et al (2011) for analyses of firms in oligopoly settings.

3 Price and quality competition in a Hotelling model

Our main analysis is conducted using a Hotelling framework. Consider a market with two providers, denoted by $i = 1, 2$, located at each endpoint of the line segment $S = [0, 1]$. Consumers are uniformly located on S with a total mass of one, and each consumer demands one unit from the most preferred provider. The utility of a consumer located at $x \in S$ and buying from provider i is given by

$$u_i(x) = r + \beta q_i - p_i - t|x - z_i|, \tag{1}$$

where q_i and p_i are the quality and price, respectively, of product i, r is the gross consumer surplus, β is the marginal utility of quality, and t is the transport cost per unit of distance to the provider located at z_i, where $z_1 = 0$ and $z_2 = 1$. We assume r is sufficiently high, so that all consumers buy either product 1 or 2 (full market coverage).[8]

Each consumer makes a utility-maximising choice of provider, which gives the demand for provider 1 as

$$D_1(q_1, q_2, p_1, p_2) = \frac{1}{2} + \frac{1}{2t}\left(\beta(q_1 - q_2) - p_1 + p_2\right), \tag{2}$$

while demand for provider 2 is $D_2(q_1, q_2, p_1, p_2) = 1 - D_1(q_1, q_2, p_1, p_2)$. Lower transportation costs make demand for each provider more price- and quality-elastic. Thus, following the standard practice in the literature, we will measure the degree of competition in the market by t^{-1}.

We assume providers derive utility from profits but also from the quality offered to consumers. To keep the analysis simple, the objective function of each provider is assumed to be separable in quality and profits.[9] The objective function of provider i is given by

$$U_i(\pi_i, q_i) = u(\pi_i) + v(q_i), \tag{3}$$

[8] Market coverage requires non-negative utility to the indifferent consumer. A sufficient condition for this to hold in the symmetric equilibrium is that

$$r \geq c + \frac{3t}{2}.$$

[9] This assumption does not qualitatively affect our main result unless $U^i_{\pi_i q_i} < 0$ *and* this effect is sufficiently large in magnitude.

where

$$\pi_i\left(q_i, q_j, p_i, p_j\right) = (p_i - c)D_i\left(q_i, q_j, p_i, p_j\right) - g\left(q_i\right), \tag{4}$$

is the profits of provider i with c denoting the marginal production cost and $g\left(q_i\right)$ the fixed cost of quality. The fixed quality costs are increasing and convex; i.e., $g'\left(q_i\right) > 0$ and $g''\left(q_i\right) > 0$.[10]

We make two critical assumptions on the shape of the objective function of the providers. First, we consider providers that are motivated by assuming that $v'\left(q_i\right) > 0$ and $v''\left(q_i\right) \leq 0$. Second, we allow for decreasing marginal utility of profits by assuming that $u'\left(\pi_i\right) > 0$ and $u''\left(\pi_i\right) < 0$. As discussed in the previous section, both these assumptions are relevant for providers in many markets such as health care, long-term care, child care and education.

3.1 Simultaneous quality and price decisions

Suppose that the two providers choose price and quality simultaneously. The first-order conditions for the optimal quality and price for provider i are, respectively,[11]

$$\frac{\partial U_i\left(q_i, q_j, p_i, p_j\right)}{\partial q_i} = u'\left(\pi_i\left(q_i, q_j, p_i, p_j\right)\right)\left[\frac{\left(p_i - c\right)\beta}{2t} - g'\left(q_i\right)\right] + v'\left(q_i\right) = 0 \tag{5}$$

and

$$\frac{\partial U_i\left(q_i, q_j, p_i, p_j\right)}{\partial p_i} = u'\left(\pi_i\left(q_i, q_j, p_i, p_j\right)\right)\left[D_i\left(q_i, q_j, p_i, p_j\right) - \frac{\left(p_i - c\right)}{2t}\right] = 0. \tag{6}$$

The symmetric Nash equilibrium, denoted by q^* and p^*, has quality and price given by

$$v'(q^*) + u'(\pi(q^*, p^*))\left[\frac{\left(p^* - c\right)\beta}{2t} - g'(q^*)\right] = 0 \tag{7}$$

and

$$u'(\pi(q^*, p^*))\left[\frac{1}{2} - \frac{\left(p^* - c\right)}{2t}\right] = 0. \tag{8}$$

[10] For simplicity, we ignore variable quality costs. However, it can easily be shown that the results are qualitatively the same. The computations can be provided to interested readers upon request.

[11] The second-order conditions are: i) $\partial^2 U_i/\partial q_i^2 = v''(q_i) - u'(\pi_i)g''(q_i) + u''(\pi_i)\left(\frac{(p_i-c)\beta}{2t} - g(q_i)\right)^2 < 0$, ii) $\partial^2 U_i/\partial p_i^2 = u''(\pi_i)\left(D_i(.) - \frac{p_i - c}{2t}\right)^2 - \frac{u'(\pi_i)}{t} = -\frac{u'(\pi_i)}{t} < 0$; iii) $\left(\partial^2 U_i/\partial q_i^2\right)\left(\partial^2 U_i/\partial p_i^2\right) - \left(\partial^2 U_i/\partial q_i \partial p_i\right)^2 > 0$, where $\partial^2 U_i/\partial q_i \partial p_i = \frac{\beta u''(\pi_i)}{2t}$.

From the optimality condition on price we obtain

$$p^* = c + t. \tag{9}$$

Thus, more competition, in the form of lower transportation costs, reduces the price.

Equilibrium profit is given by

$$\pi^* := \pi(q^*, p^*) = (p^* - c)\frac{1}{2} - g\left(q^*\right) = \frac{t}{2} - g\left(q^*\right). \tag{10}$$

Substituting (9) into (7), we get the following equilibrium quality condition:

$$v'(q^*) + u'(\pi^*)\left[\frac{\beta}{2} - g'(q^*)\right] = 0. \tag{11}$$

What is the effect of more competition on quality? Differentiating (11) with respect to q^* and t, we derive

$$\begin{aligned} &\left[u''(\pi^*)\frac{\partial \pi^*}{\partial t}\left(\frac{\beta}{2} - g'(q^*)\right)\right] dt \qquad (12) \\ = \; &-\left[v''(q^*) - u'(\pi^*)g''(q^*) + u''(\pi^*)\frac{\partial \pi^*}{\partial q^*}\left(\frac{\beta}{2} - g'(q^*)\right)\right] dq^* \end{aligned}$$

Substituting for $\frac{\partial \pi^*}{\partial t} = \frac{1}{2}$ and $\frac{\partial \pi^*}{\partial q^*} = -g'\left(q^*\right)$, we obtain

$$\frac{\partial q^*}{\partial t} = -\frac{u''(\pi^*)}{2V''(q^*)}\left(\frac{\beta}{2} - g'(q^*)\right) > 0, \tag{13}$$

where $V''(q^*) := v''(q^*) - u'(\pi^*)g''(q^*) - u''(\pi^*)g'\left(q^*\right)\left(\frac{\beta}{2} - g'(q^*)\right) < 0$. From the equilibrium quality condition (11), notice that

$$\frac{\beta}{2} - g'(q^*) = -\frac{v'(q^*)}{u'(\pi^*)} < 0, \tag{14}$$

which suggests that the profit margin of quality is negative at equilibrium. We therefore obtain the following result:

Proposition 1 *In a Hotelling model where providers set price and quality simultaneously, more* *competition, measured by lower transportation costs, leads to lower quality when providers are motivated ($v'(q) > 0$) and have decreasing marginal utility of profits ($u''(\pi) < 0$). More competition (lower transportation costs) has no effect on quality when (i) providers are motivated ($v'(q) > 0$) and marginal utility of profit is constant ($u''(\pi) = 0$), and (ii) providers are not motivated ($v'(q) = 0$) and marginal utility of profit is decreasing ($u''(\pi) < 0$).*

This proposition describes the main results of the paper. The intuition for these results rely on three different effects generated by more competition. First, competition makes the demand more responsive to a marginal increase in quality. For a given mark-up ($p^* - c = t > 0$), this effect tends to increase quality. However, more competition also reduces the mark-up, which reduces the marginal profit from an increase in quality. These two effects offset each other completely.[12] Under our two critical assumptions, there is however a third effect. More competition reduces the price, which in turn reduces profit and increases the marginal utility from profit. Since providers are motivated, the marginal profit of quality is negative in equilibrium ($\beta/2 - g'(q^*) < 0$). Therefore, each provider responds optimally to more competition by reducing quality in order to recover some of the profit losses generated by the price reduction.

Notice the criticality of our two key assumptions. If the marginal utility does not decrease with higher profits, then $u''(\pi) = 0$ and $\partial q^*/\partial t = 0$. If the marginal utility is constant, variations in profits do not affect the relative willingness to provide quality. If the provider is not motivated, then $v'(q) = 0$, $\frac{1}{2} - g'(q^*) = 0$ and $\partial q^*/\partial t = 0$. In this case, quality is set to maximise profits so that, by the Envelope Theorem, a marginal reduction in quality has no effect on profits.

3.2 Sequential quality and price decisions

The above analysed simultaneous-move game implicitly relies on the assumption that quality and price are more or less equally flexible decision variables. However, in many applications this might be an unrealistic assumption. Many dimensions of quality are such that the choice of quality should be seen more as a long-term decision than price setting, which suggests that quality and price competition is more appropriately modelled as a two-stage game with quality choices being made at the first stage. In some context, though, the opposite is also conceivable,

[12] This is why there is no (net) effect of competition (measured by transportation cost) on quality in many of the spatial competition studies; see e.g., Ma and Burgess (1993) and Gravelle (1999).

where the main dimensions of quality are of a short-term nature and can easily be adjusted. In this subsection we will consider both possibilities.

3.2.1 Quality-then-price competition

Consider a two-stage game in which the providers set quality at stage 1 before they compete in prices at stage 2. The subgame perfect Nash equilibrium of such a game is derived through backward induction.

The price subgame. At stage 2 provider i sets a price that maximises utility given by (3). Using (2) and (4), we obtain the following first-order conditions:

$$\frac{\partial U_i\left(q_i, q_j, p_i, p_j\right)}{\partial p_i} = u'(\pi_i)\left[\frac{1}{2} + \frac{\beta\left(q_i - q_j\right) - 2p_i + p_j + c}{2t}\right] = 0, \tag{15}$$

where $i, j = 1, 2$ and $i \neq j$. For a given pair of quality levels, (q_1, q_2), the equilibrium in the price subgame is characterised by the first-order conditions from which we obtain

$$p_i\left(q_i, q_j\right) = c + t + \frac{\beta\left(q_i - q_j\right)}{3}. \tag{16}$$

From (16) we can easily derive the relationships between quality and prices: $\partial p_i/\partial q_i = \beta/3$ and $\partial p_i/\partial q_j = -\beta/3$.

Quality choices. Inserting the equilibrium values from the price subgame given by (16) into (4), we can express provider i's profits as a function of qualities only.

$$\pi_i\left(q_i, q_j\right) = \left(t + \frac{\beta\left(q_i - q_j\right)}{3}\right)\left(\frac{1}{2} + \frac{\beta\left(q_i - q_j\right)}{6t}\right) - g\left(q_i\right). \tag{17}$$

Assuming each provider sets quality simultaneously to maximise utility given by (3), provider i's optimal quality is given by the following first-order condition:

$$\frac{\partial U_i\left(q_i, q_j\right)}{\partial q_i} = v'(q_i) + u(\pi_i\left(q_i, q_j\right))\left[\beta\left(\frac{1}{3} + \frac{\beta\left(q_i - q_j\right)}{9t}\right) - g'(q_i)\right] = 0. \tag{18}$$

Applying symmetry, equilibrium quality is characterised by

$$v'(q^*) + u'(\pi^*)\left(\frac{\beta}{3} - g'(q^*)\right) = 0, \tag{19}$$

with

$$p^* = c + t \text{ and } \pi^* = \frac{t}{2} - g\left(q^*\right). \tag{20}$$

What is the effect of more competition on quality? Differentiating (19) with respect to q^* and t we obtain

$$\frac{\partial q^*}{\partial t} = \frac{u''(\pi^*)}{-2Z''(q^*)}\left(\frac{\beta}{3} - g'(q^*)\right) > 0, \tag{21}$$

where $Z''(q^*) := v''(q^*) - u'(\pi^*)g''\left(q^*\right) - u''(\pi^*)\left(\frac{\beta}{3} - g'(q^*)\right)g'(q^*) < 0$. From (19), notice that $(\beta/3 - g'(q^*)) < 0$. Thus, we have the following result:

Proposition 2 *In a Hotelling model where providers set quality before price, all results in Proposition 1 still hold.*

Our key result that more competition reduces quality is therefore robust to whether quality decisions are made prior to or simultaneously with the price decisions. The effect of lower transportation costs on quality is qualitatively similar, though the magnitude differs.

Comparing the equilibrium outcomes of the sequential quality-price game in (19)-(20) with the simultaneous quality-price game in (9)-(11), we observe that the equilibrium prices are identical, while equilibrium quality is lower and thus equilibrium profits higher in the sequential game. Thus, quality competition is softer when providers can commit to quality before competing in prices. The reason is that, in the sequential game, provider i takes into account the (negative) effect a higher quality has on provider j's pricing in the following stage. If one provider has lower quality than the other, this provider will be more aggressive in the price game and undercut its rival to compensate for the quality difference. This is exactly the result found by Ma and Burgess (1993). Here, we show that this result is also valid when providers are motivated and have decreasing marginal utility of profit.

3.2.2 Price-then-quality competition

Suppose instead that the firms commit to prices at the first stage of a two-stage game where qualities are set at the second stage. This assumption may hold if the price is paid prior to getting the service and the quality can be controlled during the service period. The first-order condition for the optimal choice of quality for provider i is given by (5), with a similar condition for provider j. These two conditions implicitly define the Nash equilibrium in the second-stage subgame which is given by the functions $q_i(p_i, p_j)$ and $q_j(p_i, p_j)$.

The first-stage problem for provider i is then given by

$$\max_{p_i} U_i(\pi_i, q_i) = u(\pi_i(q_i(p_i, p_j), q_j(p_i, p_j), p_i, p_j)) + v(q_i(p_i, p_j)). \tag{22}$$

By the Envelope Theorem, the effect of p_i on U_i that go through $q_i(p_i, p_j)$ vanishes, implying that the first-order condition for the optimal price at the first stage of the game is

$$u'(\pi_i)\left[D_i - \frac{(p_i - c)}{2t}\left(1 + \beta\frac{\partial q_j}{\partial p_i}\right)\right] = 0. \tag{23}$$

In the symmetric Nash equilibrium, the price is given by

$$p^* = c + \frac{t}{1 + \beta \left.\frac{\partial q_j}{\partial p_i}\right|_{q_j = q^*, p_i = p^*}} \tag{24}$$

If we once more use the simultaneous-move game as a benchmark, a comparison of (23)-(24) with (6) and (9) reveals that sequential decision making, with prices being set first, introduces an extra strategic effect at the price-setting stage, since the price set by provider i will affect quality choices by the competing provider j at the second stage. Suppose that a price increase by provider i reduces (increases) the quality offered by provider j. This would dampen (reinforce) the demand loss of a price increase and would give both providers a stronger (weaker) incentive to increase the price. As a result, the equilibrium price would be higher (lower) than in the simultaneous-move game.[13] Equilibrium quality is then implicitly given by (7), but where p^* is defined by (24) instead of (9).

[13] The expression for $\left.\frac{\partial q_j}{\partial p_i}\right|_{q_j = q^*, p_i = p^*}$, which has an ambiguous sign, is given in Appendix A.1.

Regarding the effect of increased competition (lower transportation costs) on equilibrium quality, the mechanisms are the same as in the simultaneous-move game with added effect of t on $\frac{\partial q_j}{\partial p_i}$, which is generally ambiguous. It is straightforward to verify (see Appendix A.1) that $\left.\frac{\partial q_j}{\partial p_i}\right|_{q_j=q^*,p_i=p^*} = 0$ if the marginal utility of profit is constant or if providers are not motivated. In this case, the degree of competition has no effect on quality provision even if prices are set before quality. With decreasing marginal utility of profits and provider motivation ($u''(\pi) < 0$ and $v'(q) > 0$), the negative relationship between competition and quality reported in Proposition 1 holds also in this version of the game if the second-order effects of t on $\frac{\partial q_j}{\partial p_i}$ are sufficiently small in magnitude.

3.3 Fixed (regulated) prices

Our key result that competition reduces quality depends crucially on the assumption that prices are endogenous and chosen by the firm. To emphasise this point, suppose that prices are fixed at $p_i = p_j = p$. The first-order condition for the optimal quality for provider i is[14]

$$\frac{\partial U_i(q_i, q_j)}{\partial q_i} = u'(\pi_i(q_i, q_j)) \left[\frac{(p-c)\beta}{2t} - g'(q_i) \right] + v'(q_i) = 0 \tag{25}$$

The symmetric Nash equilibrium, denoted by q^*, has quality given by

$$v'(q^*) + u'(\pi(q^*)) \left[\frac{(p-c)\beta}{2t} - g'(q^*) \right] = 0 \tag{26}$$

Equilibrium profit is given by $\pi^* := \pi(q^*) = (p-c)\frac{1}{2} - g(q^*)$. What is the effect of more competition on quality? Differentiating (26) with respect to q^* and t, we derive

$$-u'(\pi^*)\frac{(p-c)\beta}{2t^2}dt = -\left[v''(q^*) - u'(\pi^*)g''(q^*) - u''(\pi^*)g'(q^*)\left(\frac{(p-c)\beta}{2t} - g'(q^*) \right) \right] dq^*, \tag{27}$$

from which we obtain

$$\frac{\partial q^*}{\partial t} = \frac{u'(\pi^*)}{2V''(q^*)} \frac{(p-c)\beta}{t^2} < 0, \tag{28}$$

[14] The second-order condition is $\partial^2 U_i / \partial q_i^2 = v''(q_i) - u'(\pi_i)g''(q_i) + u''(\pi_i)\left(\frac{(p-c)\beta}{2t} - g(q_i)\right)^2 < 0$.

where $V''(q^*) := v''(q^*) - u'(\pi^*)g''(q^*) - u''(\pi^*)g'(q^*)\left(\frac{(p-c)\beta}{2t} - g'(q^*)\right) < 0$. We therefore obtain the following result:

Proposition 3 *In a Hotelling model where providers set quality and prices are fixed, more competition, measured by lower transportation costs, increases quality whenever the fixed price is above the marginal treatment cost.*

This result is in stark contrast with those obtained above. It is only when prices are endogenous that competition reduces quality. If prices are fixed by a regulator, the opposite hold. More competition makes the demand more responsive to quality and increases the marginal benefit from raising quality.

4 Price and quality competition in a Salop model

In this section we consider price and quality competition in the context of a Salop model where $n \geq 2$ providers are symmetrically (equidistantly) located on a circumference equal to 1. On the circle there is a uniform distribution of consumers with density normalised to 1. Consumer utility is given by (1) with the only modification that $i = 1, ..., n$.

This framework gives us one additional measure of competition, namely the number of providers in the market. Additionally, it allows us to consider entry. More specifically, we can use this framework to study how an increase in competition intensity – measured by a reduction in transportation costs – affects quality provision in a free entry equilibrium.

4.1 Simultaneous quality and price decisions

Since the model is symmetric, all providers will set the same price and quality in equilibrium. If provider i's neighbours (competitors) set equal price and quality, i.e., $p_{i-1} = p_{i+1} = p_j$ and $q_{i-1} = q_{i+1} = q_j$, the demand for provider i is given by

$$D_i(q_i, q_j, p_i, p_j) = \frac{1}{n} + \frac{1}{t}\left(\beta(q_i - q_j) - p_i + p_j\right). \tag{29}$$

The profits and utility to provider i are given by (4) and (3). Using (29) and assuming that all providers simultaneously choose prices and qualities to maximise utility in (3), we obtain the following symmetric Nash equilibrium:

$$p^* = c + \frac{t}{n}, \tag{30}$$

$$v'(q^*) + u'(\pi^*) \left[\frac{\beta}{n} - g'(q^*) \right] = 0, \tag{31}$$

with equilibrium profits given by $\pi^* = \pi(q^*, p^*) = t/n^2 - g(q^*)$. As usual, a larger number of providers (higher n) reduces price and profits. Differentiating (31) with respect to q^*, t and n, we obtain

$$\frac{\partial q^*}{\partial t} = -\frac{u''(\pi^*)}{n^2 G''(q^*)} \left[\frac{\beta}{n} - g'(q^*) \right] > 0, \tag{32}$$

$$\frac{\partial q^*}{\partial n} = \frac{1}{n^2 G''(q^*)} \left[\beta u'(\pi^*) + \frac{2t}{n} \left(\frac{\beta}{n} - g'(q^*) \right) u''(\pi^*) \right] < 0, \tag{33}$$

where $G''(q^*) := v''(q^*) - u'(\pi^*) g''(q^*) - u''(\pi^*) g'(q^*) \left(\frac{\beta}{n} - g'(q^*) \right) < 0$. See Appendix A.2 for details. Notice again that $\frac{\beta}{n} - g'(q^*) < 0$. Thus, we have the following result:

Proposition 4 *In a Salop model where providers set price and quality simultaneously, all results in Proposition 1 still hold. Additionally, if competition is measured by the number of providers in the market, more competition leads to lower quality in all cases (for $u''(\pi) \leq 0$ and $v'(q) \geq 0$).*

The effect of lower transportation costs on quality is analogous to the equivalent Hotelling analysis (see Proposition 1). A larger number of providers also leads to lower quality in equilibrium. This relationship relies on two different effects that work in the same direction:

(i) More providers in the market lead to lower demand for each provider, which makes demand more elastic and implies a lower optimal price. This reduces the profit margin of each provider and therefore weakens incentives to invest in quality. Thus, if providers are pure profit maximisers, more competition (due to a larger number of providers) leads to lower quality. This is precisely the effect identified by Economides (1993) and is captured by the first term in the square brackets in (33).

(ii) This effect is reinforced by allowing for provider motivation and decreasing marginal utility of profit. A higher number of providers leads to lower prices and profits. With decreasing marginal utility of profit this implies that the marginal utility of profit increases in the number of providers. Since providers are motivated, the marginal profit of quality is negative in equilibrium.

Therefore, each provider responds optimally to a larger number of providers by reducing quality in order to recover some of the profit losses generated by the price reduction. This effect is captured by the second term in the square brackets in (33).

4.2 Sequential quality and price decisions

Suppose instead that price is a more flexible decision variable such that the providers play a two-stage game where they commit to a quality level prior to price setting.[15] Generalising (29) by allowing the neighbours of provider i to set different prices and qualities, demand for provider i is given by

$$D_i = \frac{1}{n} + \frac{1}{t}\left(\beta q_i - \frac{\beta}{2}\left(q_{i-1} + q_{i+1}\right) - p_i + \frac{1}{2}\left(p_{i-1} + p_{i+1}\right)\right). \tag{34}$$

The first-order condition for the optimal price of provider i in the second-stage subgame is given by

$$u'\left(\pi_i\right)\left[D_i - \frac{\left(p_i - c\right)}{t}\right] = 0, \quad i = 1, ..., n. \tag{35}$$

The set of n first-order conditions define a set of price functions $p_i\left(q_i, \mathbf{q}_j\right)$, where $\frac{\partial p_i}{\partial q_i} > 0$ and $\frac{\partial p_i}{\partial q_j} < 0$, for all $j \neq i$.

At the first stage of the game, the maximisation problem of provider i is given by

$$\max_{q_i} U_i = u\left(\pi_i\left(q_i, \mathbf{q}_j, p_i\left(q_i, \cdot\right), \mathbf{p}_j\left(q_i, \cdot\right)\right)\right) + v\left(q_i\right). \tag{36}$$

By the Envelope Theorem, the effect of q_i on U_i that goes through p_i vanishes and the first-order condition is given by

$$u'\left(\pi_i\right)\left[\frac{\partial \pi_i}{\partial q_i} + \sum_{j \neq i} \frac{\partial \pi_i}{\partial p_j}\frac{\partial p_j}{\partial q_i}\right] + v'\left(q_i\right) = 0, \tag{37}$$

or, more extensively,

$$u'\left(\pi_i\right)\left[\frac{\left(p_i - c\right)}{t}\left(\beta + \frac{1}{2}\sum_{j \neq i}\frac{\partial p_j}{\partial q_i}\right) - g'\left(q_i\right)\right] + v'\left(q_i\right) = 0. \tag{38}$$

[15] The opposite order of moves, defining a price-then-quality competition game, would have an equilibrium in the second-stage subgame characterised by a non-linear system of n equations, which makes it impossible to apply linear algebra methods to characterised the full equilibrium. This particular version of the game is therefore not considered here.

As in the Hotelling model, sequential decision making creates an incentive to reduce quality provision in the first stage in order to dampen price competition in the second stage. This effect is captured by the term $\frac{1}{2}\sum_{j\neq i}\frac{\partial p_j}{\partial q_i}$, which is negative. Evaluated at the symmetric equilibrium, where $p^* = c + \frac{t}{n}$, the equilibrium quality level, q^*, is implicitly given by

$$v'(q^*) + u'(\pi^*)\left[\frac{\beta}{n} + \frac{1}{2n}\sum_{j\neq i}\frac{\partial p_j}{\partial q_i} - g'(q^*)\right] = 0, \tag{39}$$

where $\pi^* = \frac{t}{n^2} - g(q^*)$. It is straightforward to see that the only difference between (39) and (31) is the second term in the square brackets of (39), which captures the effect of quality on rival providers' price setting. However, it can be shown (see Appendix A.3) that this term does not depend on t, which implies that differentiation of (39) with respect to q^* and t yields an expression for $\partial q^*/\partial t$ that is equivalent to (32), with the only difference that $\frac{\beta}{n} - g'(q^*) < 0$ is replaced with $\frac{\beta}{n} + \frac{1}{2n}\sum_{j\neq i}\frac{\partial p_j}{\partial q_i} - g'(q^*) < 0$. Thus, the relationship between transportation costs and equilibrium quality provision is unaffected.

Proposition 5 *In a Salop model where providers set quality before price, all results in Proposition 1 still hold.*

However, when using the number of providers as competition measure, the relationship between competition and quality provision is somewhat more complicated to derive. Based on experimentation with specific values of n, it is possible to show (see Appendix A.3 for details) that the second term in the square brackets of (39) is increasing in n (i.e., it becomes less negative as n increases). This means that more competition, measured by an increase in the number of providers, introduces a third effect that counteracts the two negative effects detailed in the previous subsection. As n increases, the incentive to reduce quality at the first stage in order to dampen price competition at the second stage weakens, which – all else equal – leads to higher quality provision. However, it is also possible to show, again based on specific values of n, that this effect is outweighed by the quality-reducing effect of lower demand when n increases. Thus, although, it is not possible to show this generally, numerical simulations suggest that a higher number of providers lead to lower equilibrium quality provision also in the two-stage game where quality is chosen before price. Details are given in Appendix A.3.

4.3 Free entry

Finally, let us also consider the case where the number of providers is endogenously determined by free entry. For analytical tractability, we consider the case in which quality and price are set simultaneously. For a given value of n, the equilibrium price is given by (30), equilibrium quality is implicitly given by (31), and profits are given by

$$\pi^* = \frac{t}{n^2} - g(q^*). \tag{40}$$

In a free-entry equilibrium, n adjusts until profits are zero and, ignoring integer constraints, the equilibrium number of firms, n^*, is implicitly given by $\pi^*(n^*) = 0$. For this equilibrium to be unique and stable, equilibrium profits must be decreasing in n. In Appendix A.4 we show that this requires the following condition to be satisfied:

$$2t\left[u'(\pi^*)\,g''(q^*) - v''(q^*)\right] - n\beta g'(q^*)\,u'(\pi^*) > 0. \tag{41}$$

In the free-entry equilibrium, q^* and n^* are jointly determined by the following two equations:

$$v'(q^*) + u'(\pi^*)\left(\frac{\beta}{n^*} - g'(q^*)\right) = 0, \tag{42}$$

$$\frac{t}{(n^*)^2} - g(q^*) = 0. \tag{43}$$

By total differentiation of (42)-(43) with respect to q^*, n^* and t, we derive the following relationship between transportation costs and quality provision in the free-entry equilibrium (see Appendix A.4 for details):

$$\frac{\partial q^*}{\partial t} = -\frac{\beta u'(\pi^*)}{n\left[2t\left(u'(\pi^*)\,g''(q^*) - v''(q^*)\right) - n\beta g'(q^*)\,u'(\pi^*)\right]} < 0, \tag{44}$$

where the denominator is positive by equilibrium condition given in (41).

Proposition 6 *In a Salop model with free entry, more competition, measured by lower transportation costs, leads to higher quality provision in the free-entry equilibrium. This result holds regardless of whether the providers are motivated or not, and regardless of whether marginal* *utility of profits is decreasing or constant.*

Thus, Propositions 3 and 5 show that, compared with the case of restricted entry, free entry reverses the relationship between transportation costs and quality provision. For a given number of firms, a transportation cost reduction lowers both price and quality. The overall effect on profits is negative (see Appendix A.4). This leads to exit from the industry, which in turn stimulates quality provision. It appears that the latter effect dominates, leading to an overall reduction in equilibrium quality provision. Notice that this result does not rely on provider motivation or decreasing marginal utility of profits. If $v'(q) = u''(\pi) = 0$, a reduction of transportation costs leads to a lower price and no effect on quality for a given number of firms. However, the price reduction implies lower profits and therefore exit of providers from the market. The resulting reduction in n leads to higher demand for each remaining firm, which stimulates quality provision.

5 Welfare

Even if more competition leads to lower quality, it does not necessarily follow that competition is welfare detrimental. In this section we therefore explore the welfare implications of increased competition in the context of our benchmark Hotelling framework. Welfare is specified as the sum of consumers' and providers' surplus:[16]

$$\begin{aligned} W &= \int_0^{D_1} (r + \beta q_1 - p_1 - tx)\, dx + \int_{D_1}^{1} (r + \beta q_2 - p_2 - t(1-x))\, dx \\ & \quad + u(\pi_1) + u(\pi_2) + v(q_1) + v(q_2), \end{aligned} \tag{45}$$

where D_1 is given by (2) and $D_2 = 1 - D_1$. Imposing the symmetric equilibrium, given by (9)-(11), we can write welfare as

$$W = 2\int_0^{\frac{1}{2}} (r + \beta q^* - p^* - tx)\, dx + 2v(q^*) + 2u(\pi^*). \tag{46}$$

[16] Notice we include provider preferences in our welfare specification. One could argue that this leads to double-counting of quality benefits (particularly if motivation is based on altruism towards consumers). However, our results will not be qualitatively changed by ignoring provider motivation in the welfare specification. Details can be provided upon request to interested readers.

Substituting for the optimal price, from (9), and totally differentiating (46) with respect to t and W, the effect of lower transportation costs on welfare is

$$\frac{\partial W}{\partial t} = \left[\beta + 2\left(v'(q^*) - u'(\pi^*)g'(q^*)\right)\right]\frac{\partial q^*}{\partial t} + (u'(\pi^*) - 1) - \frac{1}{4}. \tag{47}$$

There are three types of effects generated by lower transportation costs: i) lower transportation costs reduce quality; whether this increases or reduces welfare depends on the expression in the square brackets in (47); ii) it reduces prices which increases consumers' utility but it also reduces profits, the net effect being given by the second term in (47); it is only in the special case $u'(\pi^*) = 1$ that the two effects coincide; iii) it directly increases consumers' utility.[17]

Although the effect of lower competition on welfare, as defined by (46), is generally ambiguous, we can derive some further insights by using the equilibrium quality condition in (11) and rewrite (47) as

$$\frac{\partial W}{\partial t} = \left(1 - u'(\pi^*)\right)\left(\beta\frac{\partial q^*}{\partial t} - 1\right) - 2v'(q^*)\frac{\partial q^*}{\partial t} - \frac{1}{4}. \tag{48}$$

If the marginal utility of profits is equal to one ($u'(\pi^*) = 1$), the net effect on welfare of a monetary transfer from consumers to providers is zero. In this case, lower transport costs increase consumers' utility due to cost savings (the third term in (48)), but there is no further effects on welfare because of increased competition. Thus, competition has only a welfare effect when $u'(\pi) \neq 1$, which is generally true when providers have decreasing marginal utility of profit.

Suppose that $u'(\pi^*) < 1$, which implies that the marginal disutility from an increase in price to the consumer is higher than the benefits to the firm from higher profits. Lower transportation costs now have two counteracting effects on welfare. First, it reduces prices, which tends to increase welfare since the gain for the consumer is higher than for the firm (by assumption). Second, it reduces quality, which reduces consumer utility but increases profits, and the net effect is negative (implying lower welfare) given that $u'(\pi^*) < 1$. It is relatively straightforward to show that, in equilibrium, $\beta\frac{\partial q^*}{\partial t} < 1$, implying that the positive effect of lower prices outweighs the negative effect of lower quality, making the first term in (48) negative.[18] Thus, if $u'(\pi^*) < 1$, lower transportation costs will unambiguously increase welfare, not only because of the direct

[17] Notice that this third effect follows directly from the use of t as an (inverse) measure of competition, but has little to do with competition *per se*.

[18] Using (14):

cost savings but also because of increased competition.

Proposition 7 *If the marginal utility of income is higher for consumers than for providers* ($u'(\pi^*) < 1$)*, then increased competition unambiguously increases welfare.*

However, if the marginal utility of income is lower for consumers than for providers, i.e., $u'(\pi^*) > 1$, then the first term in (48) is positive and the overall welfare effect of increased competition is ambiguous. In this case increased competition will have a negative (positive) welfare effect if provider motivation is sufficiently low (high).

6 Conclusions

The relationship between competition and quality in sectors like health care, elderly care, child care and education, is a hotly debated policy issue in several countries. While several empirical studies have found a negative relationship between competition and quality in these sectors, the existing theoretical literature is lacking in terms of offering precise mechanisms that can explain these findings. In this paper we have offered one such possible (and novel) mechanism and shown that this mechanism relies on two key assumptions, namely that the providers are *motivated* and have *decreasing marginal utility of income*. For given quality levels, fiercer competition results in lower profits due to price reductions. We have shown that providers with the two above-mentioned characteristics will respond by lowering their quality in order to recover some of these profit losses.

Our analysis has been conducted within a spatial competition framework, for two main reasons. First, it is a widely used framework for studying competition in health care markets, which is one of our main applications. Second, a spatial competition framework with inelastic total demand allows us to capture the effect of competition on demand responsiveness by using the transportation cost parameter as an inverse measure of competition intensity. However, a potential drawback of this framework is precisely the assumption that total demand is inelastic. Although this might not be an unreasonable approximation in health care markets, for example,

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$$\beta \frac{\partial q^*}{\partial t} - 1 = \frac{v''(q^*) - u'(\pi^*)\, g''(q^*) + u''(\pi^*) \left(\frac{\beta}{2} - g'(q^*)\right)^2}{-V''(q^*)} < 0.$$

it is still a quite strong assumption. One way to relax this assumption is to introduce a monopoly segment of consumers who only decide whether or not to buy from the closest provider (because of lower willingness-to-pay), as in Brekke et al. (2008, 2011). It is relatively straightforward to show that this would not affect our main result as long as the monopoly segment is sufficiently small relative to the competitive segment. However, this approach involves another drawback, namely that the transportation cost parameter ceases to be a precise measure of competition intensity, since lower transportation costs also lead to higher total demand from the monopoly segment.

Finally, as we have shown in our welfare analysis, we would like to stress that a negative relationship between competition and quality does not necessarily imply that competition is welfare detrimental.

Appendix

A.1. Price-then-quality competition in the Hotelling model

The expression for $\partial q_j/\partial p_i$ is derived by totally differentiating the first-order conditions of the second-stage subgame, given by (5), and applying Cramer's Rule. In the symmetric equilibrium, the resulting expression is given by

$$\left.\frac{\partial q_j}{\partial p_i}\right|_{q_j=q^*,p_i=p^*} = \frac{-u''\left(\pi^*\right)\Phi\left[\begin{array}{c}\left(u''\left(\pi^*\right)\Phi^2 - u'\left(\cdot\right)g''\left(\cdot\right) + v''\left(q^*\right)\right)\frac{p^*-c}{2t} \\ +\frac{\beta}{2t}\left(u''\left(\pi^*\right)\left(\frac{1}{2}-\frac{(p^*-c)}{2t}\right)\Phi + u'\left(\pi^*\right)\frac{\beta}{2t}\right)\end{array}\right]}{\left(u''\left(\cdot\right)\Phi^2 - u'\left(\pi^*\right)g''\left(q^*\right) + v''\left(q^*\right)\right)^2 - \left(u''\left(\pi^*\right)\frac{\beta}{2t}\Phi\right)^2}, \tag{A1}$$

where $\Phi := \frac{(p^*-c)\beta}{2t} - g'\left(q^*\right)$. This expression is zero if $u''\left(\pi\right) = 0$ or if $v'\left(q\right) = 0$, which implies $\Phi = 0$. Otherwise, the sign of the expression is *a priori* indeterminate.

A.2. Simultaneous price and quality competition in the Salop model

Recall that equilibrium profits are given by $\pi^* = \pi(q^*, p^*) = t/n^2 - g(q^*)$. Differentiating (31) with respect to q^* and t, we derive

$$\begin{aligned} & \left[u''(\pi^*)\frac{\partial \pi^*}{\partial t}\left(\frac{\beta}{n} - g'(q^*)\right)\right] dt \qquad \text{(A2)} \\ = & -\left[v''(q^*) - u'(\pi^*)g''(q^*)u''(\pi^*)\frac{\partial \pi^*}{\partial q^*}\left(\frac{\beta}{n} - g'(q^*)\right)\right] dq^* \end{aligned}$$

Substituting for $\frac{\partial \pi^*}{\partial t} = \frac{1}{n^2}$ and $\frac{\partial \pi^*}{\partial q^*} = -g'(q^*)$, we obtain:

$$\frac{\partial q^*}{\partial t} = -\frac{u''(\pi^*)\left(\frac{\beta}{n} - g'(q^*)\right)}{n^2\left[v''(q^*) - u'(\pi^*)g''(q^*) - u''(\pi^*)g'(q^*)\left(\frac{\beta}{n} - g'(q^*)\right)\right]}. \qquad \text{(A3)}$$

Defining $G''(q^*) := v''(q^*) - u'(\pi^*)g''(q^*) - u''(\pi^*)g'(q^*)\left(\frac{\beta}{n} - g'(q^*)\right)$, and differentiating (31) with respect to q^* and n, we derive

$$\left[u''(\pi^*)\frac{\partial \pi^*}{\partial n}\left(\frac{\beta}{n} - g'(q^*)\right) - u'(\pi^*)\frac{\beta}{n^2}\right] dn + G''(q^*)dq^* = 0. \qquad \text{(A4)}$$

Substituting for $\frac{\partial \pi^*}{\partial n} = -\frac{2t}{n^3}$, we obtain

$$\frac{dq^*}{dn} = \frac{\beta u'(\pi^*) + u''(\pi^*)\frac{2t}{n}\left(\frac{\beta}{n} - g'(q^*)\right)}{n^2 G''(q^*)}. \qquad \text{(A5)}$$

A.3. Quality-then-price competition in the Salop model

By a slight redefinition of (39) in Section 4, equilibrium quality in the two-stage game where n firms choose first quality and then price is implicitly given by

$$v'(q^*) + u'(\pi^*)\left[f(n) - g'(q^*)\right] = 0, \qquad \text{(A6)}$$

where

$$f(n) := \frac{\beta}{n} - \frac{1}{2n}\sum_{j \neq i}\frac{\partial p_j}{\partial q_i} > 0. \qquad \text{(A7)}$$

The system of n first-order conditions in the second-stage price competition subgame can be expressed on matrix form as

$$\mathbf{A}\mathbf{p}+\mathbf{B}\mathbf{q}=\mathbf{y}, \tag{A8}$$

where $\mathbf{p}$ and $\mathbf{q}$ are two (column) vectors of n prices and qualities, respectively, $\mathbf{y}$ is a vector of n identical constants, $\frac{t}{n}+c$, whereas $\mathbf{A}$ and $\mathbf{B}$ are two $n\times n$ matrices given by, respectively,

$$\mathbf{A}=\begin{bmatrix} 2 & -\frac{1}{2} & 0 & \cdot & \cdot & 0 & -\frac{1}{2} \\ -\frac{1}{2} & 2 & -\frac{1}{2} & 0 & \cdot & \cdot & 0 \\ 0 & -\frac{1}{2} & 2 & -\frac{1}{2} & 0 & \cdot & \cdot \\ \cdot & 0 & -\frac{1}{2} & 2 & -\frac{1}{2} & \cdot & \cdot \\ \cdot & \cdot & 0 & -\frac{1}{2} & 2 & \cdot & 0 \\ 0 & \cdot & \cdot & \cdot & \cdot & \cdot & -\frac{1}{2} \\ -\frac{1}{2} & 0 & \cdot & \cdot & 0 & -\frac{1}{2} & 2 \end{bmatrix} \tag{A9}$$

and

$$\mathbf{B}=\begin{bmatrix} -\beta & \frac{\beta}{2} & 0 & \cdot & \cdot & 0 & \frac{\beta}{2} \\ \frac{\beta}{2} & -\beta & \frac{\beta}{2} & 0 & \cdot & \cdot & 0 \\ 0 & \frac{\beta}{2} & -\beta & \frac{\beta}{2} & 0 & \cdot & \cdot \\ \cdot & 0 & \frac{\beta}{2} & -\beta & \frac{\beta}{2} & \cdot & \cdot \\ \cdot & \cdot & 0 & \frac{\beta}{2} & -\beta & \cdot & 0 \\ 0 & \cdot & \cdot & \cdot & \cdot & \cdot & \frac{\beta}{2} \\ \frac{\beta}{2} & 0 & \cdot & \cdot & 0 & \frac{\beta}{2} & -\beta \end{bmatrix}. \tag{A10}$$

Equilibrium prices in the second-stage subgame are then given by

$$\mathbf{p}=\mathbf{y}\mathbf{A}^{-1}-\mathbf{B}\mathbf{A}^{-1}\mathbf{q}. \tag{A11}$$

Notice that, since t only appears in $\mathbf{y}$, it follows straightforwardly that $\partial p_j/\partial q_i$ does not depend on t.

Comparing (A6) and (31) in Section 4, we see that the only difference is that $\frac{\beta}{n}$ in (31) is replaced by $f(n)$ in (A6). This implies that, if a change in n affects $\frac{\beta}{n}$ and $f(n)$ in a qualitatively similar way, i.e., if $f(n)$ is decreasing in n, then the negative relationship between q^* and n in the simultaneous-move game, given by (33), also carries over to the case of sequential decision-making. Since we are able to invert $\mathbf{A}$ only for specific values of n, our strategy is to calculate $f(n)$ for $n = 2, ..., 10$ and make inferences based on this. These calculations are reported in Table A1.

Table A1: Quality-then-price competition in the Salop model

Number of providers	$f(n) := \frac{\beta}{n} - \frac{1}{2n}\sum_{j\neq i}\frac{\partial p_j}{\partial q_i}$
$n = 2$	$f(n) = \frac{5}{12}\beta = 0.416\,67\beta$
$n = 3$	$f(n) = \frac{4}{15}\beta = 0.266\,67\beta$
$n = 4$	$f(n) = \frac{19}{96}\beta = 0.197\,92\beta$
$n = 5$	$f(n) = \frac{3}{19}\beta = 0.157\,89\beta$
$n = 6$	$f(n) = \frac{71}{540}\beta = 0.131\,48\beta$
$n = 7$	$f(n) = \frac{8}{71}\beta = 0.112\,68\beta$
$n = 8$	$f(n) = \frac{265}{2688}\beta = 0.09859\beta$
$n = 9$	$f(n) = \frac{209}{2385}\beta = 0.08763\beta$
$n = 10$	$f(n) = \frac{989}{12\,540}\beta = 0.07887\beta$

These calculations confirm that, at least for the range of n considered, $f(n)$ is decreasing in n, implying $\partial q^*/\partial n < 0$.

A.4. Free-entry equilibrium in the Salop model

A unique and stable free-entry equilibrium requires

$$\frac{d\pi^*}{dn} = \frac{\partial \pi^*}{\partial n} + \frac{\partial \pi^*}{\partial q}\frac{\partial q^*}{\partial n} < 0. \tag{A12}$$

Using (33) and (40) from Section 4, we have

$$\frac{d\pi^*}{dn} = -\frac{2t}{n^3} - \frac{g'(q^*)\left(\beta u'(\pi^*) + \frac{t}{n}\left(\frac{\beta}{n} - g'(q^*)\right)u''(\pi^*)\right)}{n^2\left(v''(q^*) - u''(\pi^*)\,g'(q^*)\left(\frac{\beta}{n} - g'(q^*)\right) - u'(\pi^*)\,g''(q^*)\right)}, \tag{A13}$$

which can be re-arranged as

$$\frac{d\pi^*}{dn} = \frac{-n\left[2t\left(u'\left(\pi^*\right)g''\left(q^*\right) - v''\left(q^*\right)\right) - n\beta g'\left(q^*\right)u'\left(\pi^*\right)\right] - tg'\left(q^*\right)u''\left(\pi^*\right)\left(\beta - ng'\left(q^*\right)\right)}{n^3\left[g'\left(q^*\right)u''\left(\pi^*\right)\left(\beta - ng'\left(q^*\right)\right) + n\left(g''\left(q^*\right)u'\left(\pi^*\right) - v''\left(q^*\right)\right)\right]}. \tag{A14}$$

The denominator is positive and $d\pi^*/dn < 0$ requires that the numerator is negative. When noticing that $\beta - ng'\left(q^*\right) < 0$ (from the first-order condition in (31)), a negative numerator requires that the condition $2t\left(u'\left(\pi^*\right)g''\left(q^*\right) - v''\left(q^*\right)\right) - n\beta g'\left(q^*\right)u'\left(\pi^*\right) > 0$ is satisfied (this condition is necessary if $u''\left(\pi\right) = 0$ and sufficient if $u''\left(\pi\right) < 0$).

The free-entry equilibrium is defined by (42)-(43) in Section 4. Total differentiation of this system with respect to q^*, n^* and t yields

$$\begin{bmatrix} G''\left(q^*\right) & -\Theta \\ -g'\left(q^*\right) & -\frac{2t}{n^3} \end{bmatrix} \begin{bmatrix} dq^* \\ dn^* \end{bmatrix} + \begin{bmatrix} u''\left(\pi^*\right)\frac{1}{n^2}\left(\frac{\beta}{n} - g'\left(q^*\right)\right) \\ \frac{1}{n^2} \end{bmatrix} dt = 0, \tag{A15}$$

where

$$G''(q^*) := v''(q^*) - u'(\pi^*)g''(q^*) - u''(\pi^*)g'(q^*)\left(\frac{\beta}{n} - g'(q^*)\right) < 0$$

and

$$\Theta := \frac{2t}{n^3}\left(\frac{\beta}{n} - g'\left(q^*\right)\right)u''\left(\pi^*\right) + \frac{\beta}{n^2}u'\left(\pi^*\right) > 0.$$

Using Cramer's Rule, the effect of a marginal change in t on equilibrium quality in a free-entry equilibrium is given by

$$\frac{\partial q^*}{\partial t} = \frac{\begin{vmatrix} -u''\left(\pi^*\right)\frac{1}{n^2}\left(\frac{\beta}{n} - g'\left(q^*\right)\right) & -u''\left(\pi^*\right)\frac{2t}{n^3}\left(\frac{\beta}{n} - g'\left(q^*\right)\right) - u'\left(\pi^*\right)\frac{\beta}{n^2} \\ -\frac{1}{n^2} & -\frac{2t}{n^3} \end{vmatrix}}{\begin{vmatrix} G''\left(q^*\right) & -u''\left(\pi^*\right)\frac{2t}{n^3}\left(\frac{\beta}{n} - g'\left(q^*\right)\right) - u'\left(\pi^*\right)\frac{\beta}{n^2} \\ -g'\left(q^*\right) & -\frac{2t}{n^3} \end{vmatrix}}, \tag{A16}$$

which reduces to (44) in Section 4.

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