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Hospital Quality Competition Under Fixed Prices

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Hospital quality competition under fixed prices

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Executive Summary

1. The relationship between the quality of health care and the extent of competition amongst providers has been the subject of intense policy interest and debate. As part of the ESHCRU programme we are undertaking a set of related investigations into this relationship in the hospital sector, in primary care (general practices) and in social care. In this initial report on competition amongst hospitals we

- review the theoretical economics literature on competition and quality,
- briefly describe the relevant empirical literature on
  - whether choice of hospital is influenced by quality
  - whether greater competition is associated with higher quality
- report on preliminary empirical analyses of
  - the correlations amongst 16 hospital quality measures
  - the association between distance based measures of competition and these quality measures.

We conclude by describing our future research suggested by the theoretical and empirical literature reviews and our initial empirical analyses.

2. The review of the theoretical literature suggests that the plausible argument that greater competition amongst providers facing fixed prices will lead to higher quality rests on strong assumptions which may not hold. The literature shows that more competition increases quality when providers are profit maximisers and marginal cost of treatment is constant. Competition has an ambiguous or negative effect on quality when providers are altruistic, the marginal cost of treatment is increasing and quality is only imperfectly observable. The literature has been largely silent on the relationship between market size, as measured by total population or population density, and quality.

3. If the choice of hospital by patients and their advisors does not respond to hospital quality then hospitals will not gain extra revenue from improving their quality relative to their rivals. Our review of the small number of studies of the influence of quality on the choice of hospital suggests that most studies find that demand does respond to quality after controlling for other factors including distance and waiting times. The quality measures ranged from standardised mortality for specific conditions to general hospital reputation as evaluated by health care professionals.

4. We reviewed the only empirical evidence to date on competition and quality in the NHS. These five papers focussed primarily on mortality rates for patients admitted with acute myocardial infarction (AMI). The use of AMI mortality for emergency admissions as a quality measure is justified by its correlation with other measures of quality expected to influence demand for elective care. The papers report that competition raises quality when prices are fixed but reduces it when prices are market determined by providers or by negotiation between providers and purchasers.

5. We found, using Dr Foster data for 2008/9, that in general different quality measures are not highly correlated and often not correlated at all. This suggests that focusing on any single quality measure may lead to a partial picture of the association of quality and competition.

6. Our initial cross-section investigation of the association between competition and quality suggests that the direction and strength of the association depends on the quality measure: there is a negative association between competition and some mortality indicators but not others, a positive

association between competition and some readmission rates but not others, and a negative association between competition and patients' satisfaction. The association is also sensitive to how market size and London factors are entered into the analysis.

7. Our initial investigations suggest that further theoretical and empirical modelling is required. Theory models need extending, in particular to investigate the implications of market size, and to use this analysis to inform further empirical analysis. Although the simple cross section associations in our initial empirical work do not test for causality, the sensitivity of our results to alternative measures of quality and the specification of the models raises the possibility that the results in previous studies employing other methods may also not be robust. We plan to use data from Hospital Episode Statistics linked with other socio-economic and administrative data sets to construct additional quality and competition measures and to use panel data methods to investigate the relationship between competition and quality.

1. Introduction

The relationship between quality of health care and competition amongst providers has been the subject of intense policy debate. As part of the ESCHRU programme we are investigating the relationship in three sectors: hospital care, primary care (general practice) and social care (nursing and residential homes).

In this interim report on hospital competition and quality we start by reviewing the predictions and key assumptions of the theoretical economics literature (Section 2). We discuss the conditions under which greater competition will lead to higher quality. We note that the literature has been largely silent on the relationship between market size, as measured by total population or population density, and quality. We set out a simple model in the Appendix which suggests that neglect of market size can bias estimates of the effect of competition, as conventionally measured, on quality.

We review the empirical literature in section 3, restricting attention to studies in the NHS hospital sector. This literature primarily uses mortality rates for patients admitted with acute myocardial infarction (AMI) as the quality indicator and reports that that competition raises quality when prices are fixed but reduces it when prices are market determined by providers or by negotiation between providers and purchasers. We discuss the strengths of the evidence in the literature, focussing here on the argument that, although competition is expected to operate via the demand for elective care, use of AMI mortality for emergency admissions as a quality measure can be justified if it is correlated with other measures of quality expected to influence demand for elective care.

A large number of hospital quality indicators are available. In section 4 we report on our investigation of the extent to which different quality indicators are correlated within hospitals. Using Dr Foster data for 2008/9 we find that in general different quality measures are not highly correlated and often not correlated at all. This suggests that focusing on any single quality measure may lead to a partial picture of the association between quality and competition.

In section 5 we report on an initial investigation of the robustness of estimates of the cross–section association between competition and quality. After controlling for whether a hospital is a Foundation Trust or a teaching hospital, we find that the direction and strength of the association depends on the quality measure: there is a negative association between competition and some mortality indicators but not others, a positive association between competition and some readmission rates but not others, and a negative association between competition and patients' satisfaction. The association is also sensitive to whether we allow for whether a hospital is in or outside London and allow the association to differ for London and non-London hospitals. Finally, as suggested by our simple theoretical model, the association between competition and quality is sensitive to whether and how measures of competition incorporate the population density or total population around providers.

Section 6 outlines our plans for further work. Simple cross section associations do not establish causality and the empirical literature discussed in section 3 has been careful to use other statistical methods (difference in differences and instrumental variables) which are more likely to identify causal relationships. However, the sensitivity of simple cross-section associations to the choice of quality measure, to allowing for whether a hospital is in London, or to the way that population size is allowed for, raises the possibility that the results in previous studies may also not be robust. We therefore propose to use in future work a panel of data on the competiveness of hospitals' markets to investigate whether results are sensitive to these factors.

2. Review of theory literature

The effect of competition on hospital behaviour has been the subject of an extensive theoretical literature and several recent literature reviews (Gaynor, 2006; Gaynor and Town, 2011). Here, we focus on literature analysing competition in a healthcare system where hospitals' prices are fixed. This includes the Payment by Results (PbR) system in England which is based on Healthcare Resource Groups (HRGs). The payment system is similar to the DRG (Diagnosis Related Groups) system introduced by Medicare in the US in the early eighties, though US hospitals have a larger proportion of privately insured patients and a higher proportion of them are for-profit or private not-for-profit organisations rather than public hospitals.

We therefore do not discuss the literature on hospital competition under variable prices, where each hospital can set prices constrained only by the demand function it faces or where prices are the result of a bargaining procedure between the purchaser of health services (a private or a public insurer) and the hospital (Barros and Martinez-Giralt, 2012).

It is often claimed that under a fixed-price regime, more competition leads to higher quality. The intuition underlying the claim is that with fixed prices hospitals can attract more patients only by raising their quality. With more competition amongst hospitals, demand will be more responsive to quality, thereby increasing the additional revenue from raising quality. Formal economic models show that this intuition is correct provided that more competition does increase the responsiveness of demand to quality, that providers are profit maximisers, that the marginal cost of additional patients is constant, and that providers always meet whatever demand is generated by their quality demand (Ma and Burgess, 1993; Gaynor, 2006; Gaynor and Vogt, 2003).

The incentive to increase quality is stronger, the larger the profit margin, ie the difference between price and the marginal cost of additional patients. Increasing the fixed price will increase the marginal net profit from higher quality and so will increase quality: the quality supply function is increasing in the fixed price.

Since under the English PbR prospective payment system, the price is related to the average cost, the profit margin will be larger for procedures characterised by large fixed costs and low marginal costs. The profit margin will be positive for hospitals operating at volumes where their marginal cost is constant or decreasing. The profit margin will also be greater if the prospective price computation includes investment/capital costs (whether this is the case varies across countries). In some countries, like Norway, the fixed price is a proportion of the average cost (around 40-60% of the average cost). In this case it is not obvious that the profit margin is positive. If the profit margin is negative, then the financial incentive to increase quality will be negative: providers will wish to reduce quality but will be constrained by sanctions from quality regulators and the threat of malpractice suits from patients. Increases in competition in this case can reduce quality.

2.1 Hospital objectives

The extent to which providers respond to competition depends on who is taking decisions which affect quality, their preferences, and who is the "residual claimant" ie has control over any financial surplus. Almost all hospitals providing care to NHS patients are public: they have no shareholders. However, they are subject to financial targets which require them to break even or earn a financial surplus to be reinvested in providing services. Thus they will take the financial consequence of decisions about quality into account.

Some decisions affecting quality in a hospital are made at hospital level: hospitals invest in better trained staff or in better record keeping. Others are made by doctors and nurses who, in the NHS, are typically paid a paid a fixed salary, as opposed to fee for service, or a share of profits. We may expect the financial incentive to respond to increased competition by raising quality will be diluted if those who take decisions affecting quality do not receive any financial benefit from higher quality.

In the health economics literature, it is recognised that doctors may not be entirely selfish (McGuire, 2000) so that they do not act like income or profit maximisers (net of their effort costs) but are motivated by an altruistic concern for patients' health. Alternatively, the hospital's objectives can be viewed as the result of bargaining between managers (who are more concerned with financial constraints and targets) and doctors who are more directly concerned with patient wellbeing. It is therefore common in the health economics literature to assume that providers act as if they were maximising a weighted sum of profits and benefits for the patients. This assumption implies that providers may be willing to treat patients on whom they make a financial loss and for whom the marginal profit from an increase in quality is negative. In these circumstances more competition may lead to lower quality.

There is however another effect of altruism which works in the opposite direction. If providers are altruistic they also have a higher marginal benefit from increasing quality: attracting an additional patient increases total patient benefit which increases the utility of the provider through the altruistic component. This effect tends to reinforce the positive effect of competition on quality. Depending on the size of the two effects more competition may increase or reduce quality (Brekke, Siciliani and Straume, 2011). A similar type of reasoning applies when hospitals compete on waiting times as opposed to quality, where waiting times can be thought of a negative form of quality (Brekke, Siciliani and Straume, 2008).

2.2 Specialisation

As well as competing on quality hospitals may specialise by attracting particular types of patient. By specialising, providers can reduce the competition they face in their specialist treatment. The extent to which hospitals have an incentive to specialise depends on the convexity of the cost function with respect to quality (ie the degree to which a marginal increase in quality increases the marginal cost of quality). The less convex is the cost function, the more there is scope to relax quality competition. In some cases the incentive may be so strong that specialisation is maximal. The degree of specialisation also depends on price-cost margin. An increase in the price (and in the margin) gives stronger incentive to compete in quality, which in turn increases the incentive to further specialise to relax quality competition (Brekke, Nuscheler and Straume, 2006).

Nuscheler (2003) also investigates quality and location (specialisation) in a spatial framework. Moreover, he assumes free entry. He shows that generally higher regulated prices discourage entry, which is surprising. The reason for this result is that a higher price encourages a quality increase which reduces profit margins and this effect may be stronger than the price increase.

2.3 Information on quality

The incentive to compete on quality may be enhanced by giving more accurate information about quality to patients, for example by publishing data on quality measures. Such information reduces the cost of quality comparisons amongst hospitals for GPs or patients. It seems intuitive that this would increase the responsiveness of demand to quality and hence increase the marginal profit from increasing quality. However, Gravelle and Sivey (2010) show that this argument is correct only when hospitals do not differ significantly in the quality they provide. If the difference between providers' marginal cost of providing quality is large, then their quality differences will tend to be large. In such cases better information about quality may lead to lower quality. Demand at a hospital depends on the difference in quality between that hospital and a competing hospital, and on the distribution of the differences in the errors each patient makes when observing qualities at the two hospitals. Unless an individual patient's errors in observing quality are perfectly correlated across hospitals, the distribution of the difference in errors for each patient is unimodal and centred on zero. For most patients the difference in their errors is small and few patients have large differences in errors. Thus the marginal revenue from improving quality is smaller, for both hospitals, when the true quality difference is large. Improving the accuracy of patient information makes it even less likely that they will have large differences in errors and thus reduces the marginal revenue from quality increases when the true quality difference is large. Thus if the initial quality difference is large better information will reduce marginal revenue from quality at both hospitals and thus reduce quality levels at both hospitals.

In Gravelle and Masiero (2000) GPs are paid by capitation (a fee for each patient registered in the practice). GPs compete on quality but quality is only imperfectly observed. The study shows that for a given capitation fee, the presence of imperfect information reduces the effect of a higher capitation fee on quality.

2.4 Dynamic analysis and cost structure

All the above analyses have been derived within a static framework where providers play a one-shot game, and decisions on quality are made and are implemented in one period. But some types of quality are akin to a stock which increases only if the investment in quality is higher than its depreciation rate. It has been shown that when providers are allowed to revise their investment decisions more frequently (which can be thought of as a more competitive environment compared to one where quality can be revised only after a long time gap), long-run quality may be lower if the marginal cost of treating a patient is increasing. This result arises because in a dynamic setting lower quality investment by one provider will induce a future reduction in quality investment by the other provider (quality levels are strategic complements over time (Brekke et al, 2010).

2.5 Gatekeeping

Brekke, Nuscheler and Straume (2007) investigate how hospital quality competition is affected by the introduction of compulsory gatekeeping where every patient needs to have a referral to access a hospital specialist. They find that gatekeeping may amplify or dampen competition depending on the relative size of two effects. On one hand competition is amplified by higher GP attendances, ie more patients get better recommendations on which provider to use. On the other hand it can be dampened by improved accuracy in diagnosis.

2.6 Cream-skimming

If providers can differentiate the level of quality among different patients with different severity levels, then they might have an incentive to cream-skim, ie to increase the quality for profitable patients (where the profit margin is positive) and to 'skimp', ie to reduce the quality for non-profitable ones (where the profit margin is negative). These incentives may be strengthened in the presence of more intense competition (Ellis, 1998).

2.7 Cost-containment effort

In the absence of any cost reimbursement arrangement, any type of payment which does not vary £1 for £1 with costs (for example a fixed budget or a prospective payment system like PbR) will give the appropriate incentive to keep costs down. If the provider is the residual claimant who has control over any surplus, the incentives to exert effort to keep costs down are such that the benefits from lower cost reductions are equal to the marginal disutility from such effort. Any effect of competition on cost-containment effort arises through the interaction with quality.

If more competition increases quality and cost-containment effort and quality are substitutes, then more competition may lead to lower cost-containment effort. On the contrary if they are complements higher quality will induce an increase in cost-containment effort. One reason for such complementarity may arise if higher quality leads to higher volume of patients treated, which in turn may increase the marginal benefit from investing in cost-containment effort since the higher profit margin will apply to a larger volume of patients treated (these results can be obtained by adapting the analysis of Ma, 1994).

Table 1 Theoretical papers on quality and competition under fixed prices

Paper	Competition measure	Effect on quality	Key assumptions
Ma and Burgess (1993)	Lower transportation costs	Positive	Profit maximiser provider, constant marginal cost
Gaynor (2006)	Number of providers	Positive	Higher n. of providers increases elasticity of demand wrt quality
Brekke, Siciliani and Straume (2011)	Lower transportation costs, number of hospitals	Ambiguous	Altruism, increasing marginal cost of treatment
Brekke, Nuscheler and Straume (2006)	Lower transportation costs	Ambiguous	Convexity of the cost function of quality
Gravelle and Sivey (2010)	Information accuracy	Ambiguous	Quality is observable with a noise
Gravelle and Masiero (2000)	Information accuracy	Positive	Switching costs
Brekke et al (2010)	Provider revises quality choice more frequently	Negative	Increasing marginal cost of treatment; dynamic analysis
Ellis, 1998	Lower transportation costs	Positive for low-cost patients. Negative for high-cost patients	Profit maximiser provider, patients differ in costs

2.8 Gaps in the literature

The theoretical literature on hospital competition under fixed prices does not take account of a number of features of hospital markets which may affect predictions about competition and quality.

2.8.1 Rationing by waiting

Much of the literature relies on the implicit assumption that the only way hospitals can compete, given that the prices paid by patients are fixed (at zero), is via their quality and that they meet the demand generated by their choice of quality. But in the market for elective care demand depends on waiting time as well as quality (Beckert, Christensen and Collyer, 2012; Gaynor, Propper and Seiler, 2010). Given the quality and supply chosen by a provider, the waiting time adjusts to ensure that demand equals supply.

Brekke, Siciliani and Straume (2008) consider the effect of competition in a model with a fixed number of providers facing a regulated price where providers compete via their waiting times but not via quality. Greater competition (lower transportation costs) reduces the equilibrium waiting time. But none of the literature has yet considered the effect of greater competition in markets where quality and waiting time affect demand.[1]

[1] Chalkley and Malcomson (1998) show that the incentive effect of the regulated price on quality is weakened when demand at the chosen quality is less than the capacity of the provider but they assume that demand depends only on quality and so cannot consider the role of waiting times.

2.8.2 Linked markets

Since most types of hospital care require that the patient visit the hospital and greater distances impose greater access costs on patients, the market for a hospital is geographically defined: patients beyond a certain distance (or travel time) will not use the hospital.[2] The set of competitors for a hospital A is the set of hospitals whose catchment area includes patients who are in hospital A's catchment area. In general, hospitals do not have the same sets of competitors: the fact that hospital A and B are competitors and that B and C are competitors does not imply that A and C are competitors. Catchment areas may overlap but they are not identical. The empirical literature generally takes account of this fact when constructing measures of competition facing a hospital but there are no formal theoretical models of hospital competition and quality which do so.[3]

2.8.3 Market size

Hospital markets (catchment areas) defined in terms of travel time or travel cost vary in both population size and density. But the theoretical literature on hospital competition is silent on the role of the size of the market as measured by the total population or density of potential patients. The population is assumed to be fixed and is often normalised to 1 in order to reduce notation. This has the unfortunate consequence that the question of whether population in a market affects quality or the response of quality to competition is then not considered.

The literature on standard markets with profit maximising firms with free entry and exit suggests that market size has important consequences for quality and specialisation. Thus Shaked and Sutton (1987) have shown that as the number of consumers in a market increases both the maximal level of quality offered by firms and the extent of specialisation will increase.

We have sketched in Appendix B a simple model of quality competition under fixed prices and show that as the population size and density vary so does the level of quality. The reason is that if population density increases the number of patients gained by increasing quality is higher so that more densely populated areas will have higher quality. Holding population density constant, a higher population means that any hospital will treat more patients and, if marginal costs of treatment and quality are increasing with the number of patients, this will reduce the marginal incentive to increase quality. Population size and density also affect the extent to which an increase in competition (the number of firms) increases quality. However, the model makes quite specific assumptions about the distribution of patients, the location of providers and the cost function so that it is not clear how general these result are or whether the methods in Shaked and Sutton (1987) ,which make quite weak assumptions about the strategic interactions of firms, can be applied to healthcare markets with regulated prices.

2.8.4 Determinants of market structure

The literature on hospital competition under fixed prices typically assumes a one stage game in which hospitals simultaneously choose quality. The number of hospitals is taken as exogenous and the effect of competition is modelled by investigating the effect on quality of an increase in the number of firms.

In markets where providers are private and profit maximising rather than public and there is no control over entry a two stage game is more appropriate: firms first decide whether to enter or remain in a market and then decide on their actions given the number of firms who are in the market. With no entry controls the number of firms is determined by a zero profit condition.

[2] Strictly this depends on quality or patients' valuation of it relative to access costs being finite.
[3] Beckert (2010) has set out a model of interlinked retail markets in which consumers care about distance, price and other characteristics of stores and used it to estimate demand functions.

In interpreting data on the relationship between competition and quality it matters how the number of firms (and thus the amount of competition) was determined. If the process determining the number of firms leads to the number of firms being correlated with other factors affecting quality then cross section estimates of the effect of competition, based on the association of quality and competition across markets, are biased. For example, in the simple model sketched in Appendix B, we find that population size in a market affects both the quality in the market and the number of firms. This suggests that unless population size is included as a covariate in the regression of quality on the number of firms the estimated effect of the number of firms on quality will be biased.

3. Empirical literature: selective review

In this section we briefly review two relevant literatures. The first examines whether choice of hospital is affected by quality and the second tests directly for an effect of competition on quality in the English NHS.

3.1 Literature on choice of hospital and quality

One of the key steps in the argument that greater competition, with fixed prices, can lead to higher quality is that the choice of a hospital by patients (or their GP advisors) is influenced by its quality relative to that of other available hospitals. Thus by improving quality, relative to other hospitals, a hospital can attract more patients and thereby increase its revenue. The papers are summarised in Table 2. We do not limit the papers to those for markets where price is regulated since we are interested in whether quality affects demand, holding other factors constant, rather than whether competition affects quality.

Most of the studies suggest that, after controlling for other factors such as patient characteristics and distance, the probability of a hospital being chosen increases with measures of quality.

Three of the 12 are studies set in the English NHS (Beckert et al, 2012; Gaynor et al, 2011; Sivey, 2008) and are in line with the other, mainly US, studies. The papers on the English NHS allow for waiting times, distance, and patient characteristics. Beckert et al (2012) and Gaynor et (2011) find that higher quality leads to increased demand and Sivey (2008) finds demand increases with quality (mortality) in one of his specifications but not the other.

Most of the papers model the choice of individuals amongst hospitals using either conditional logit or mixed logit. Conditional logit models make the strong assumption that the probability of choosing hospital A rather than hospital B is not affected by the characteristics of other hospitals. Thus the relative probabilities of choosing A over B when the choice set includes hospital C which has the same characteristics as B are assumed to be the same as when the choice set does not include C. But it seems more plausible that patients who would have chosen C will switch to B in its absence so that the proportion choosing A will fall. Mixed logit models do not impose this restriction and also allow for the possibility that the effects of hospital characteristics on choice vary with unobservable characteristics of patients. The conditional logit model allows the effects of hospital characteristics on choice to vary only with observable characteristics of patients.

One of the problems in estimating the effects of hospital quality on choice is that measured hospital quality may depend on the mix of patients at the hospital and the mix of patients may depend in part on quality. Thus, for instance, measured quality is lower if the hospital attracts sicker patients and sicker patients care more about true quality, then the effect of quality on demand will be underestimated. Thus it is important to use measures of quality which allow for the effects of patient characteristics on quality. The papers do this in three ways. First, they may use a standardised quality measure for a hospital calculated as the ratio of actual quality to the quality which would be expected at the hospital given its patients mix. Second, individual patient quality is regressed on patient characteristics and a hospital dummy and the estimated hospital effect is used as the measure of quality. Both methods are improved by using richer data on individual patients to estimate hospital quality. Third, as in Sivey (2008), demand is first estimated as a function of waiting time, distance and a hospital dummy variable capturing all unobserved hospital factors, and then the hospital effect regressed on hospital characteristics including quality. It is argued (Murdoch, 2006) that this procedure prevents the under-estimation of standard errors which arises if quality measures are entered directly in the demand model.

A second problem arises in systems, like the NHS, where hospital waiting times adjust to equate demand and supply. Higher treatment quality will lead to longer waiting times if the hospital does not increase the number of patients treated. Thus waiting times should be included in the demand model because they affect demand and may be correlated with quality. Gaynor et al (2011) also allow for the possibility that waiting time for CABG is correlated with unobserved aspect of CABG quality by using waiting times for other procedures in the same hospital as an instrumental variable for CAGB waiting time. Sivey (2008) estimates a model of waiting time for individual patients including patient characteristics and a hospital dummy and then calculates the waiting time for a hospital as the median of the estimated waiting times. This procedure removes any bias arising from the individual patient quality and waiting times being correlated with unobserved patient characteristics. Beckert et al (2011) use a hospital level average waiting time which assumes that there are no unobserved hospital level quality measures affecting demand which are also correlated with waiting times.

3.2 Literature on NHS hospital competition and quality

There are five studies on NHS hospital competition and quality. They are summarised in Table 3. Two studies (Propper et al, 2004; Propper et al, 2008) cover the internal markets period of the 1990ies when prices were not fixed. Three studies are for the later fixed PbR price regime. Bevan and Skellern (2011) and OHE (2012) have also reviewed these studies and the three most recent ones have been subject of an exchange in The Lancet (Pollock et al, 2011a; 2011b; Bloom et al, 2011b; 2012).

These five papers focussed primarily on mortality rates for patients admitted with acute myocardial infarction (AMI). The use of AMI mortality for emergency admissions as a quality measure is justified by its correlation with other measures of quality expected to influence demand for elective care. The papers report that competition raises quality when prices are fixed but reduces it when prices are market determined by providers or by negotiation between providers and purchasers.

An observed association between competition and hospital quality does not prove that competition affects quality. For example,

(i) if higher quality hospitals disproportionately attract patients who are sicker and if the quality measure fails to allow appropriately for differences in casemix, and the competition measure is based on market shares, then we may observe a positive association between measured quality and measured competition;

(ii) if hospital competition is measured using hospitals' shares of patients treated in an area and patient choice of hospital is influenced by quality, then higher quality hospitals will have greater market shares and will appear to be in less competitive markets.

(iii) when competition is measured in terms of the numbers of alternative providers, there may be factors (such as population density or size in the model we sketch in Appendix B) which influence both the entry/exit decisions of providers and the quality decisions of providers in the market.

Table 2 Quality and choice of hospital: empirical papers

Paper	Sample	Quality measure	Methods	Covariates	Results	Comments
Beckert et al (2012)	England. 2008/9. 39,060 elective hip replacement patients, 216 NHS hospitals	Standardised overall mortality rate; MRSA; CQC; good communication	Conditional logit. Similar results from mixed logit with random coefficients	Age, gender, rurality, income, health deprivation. LSOA to site distance; teaching hospital, Foundation Trust, staff per bed, MRSA, CQC quality, CQC financial rating, waiting time; GP relative referral frequency to hospital 2006-8. PCT effects.	Demand decreases with mortality, waiting time, MRSA; increases with CQC rating;	
Burns & Wholey (1992)	Phoenix. 1989. 4 medical, 2 surgical DRGs.	Standardised in-hospital mortality for each DRG	Conditional logit.	Distance. Supply of physicians near hospital.	Demand lower if higher mortality for AMI, atrial fibrillation, gastro-intestinal bleeding, large bowel resection.	
Cutler et al (2004)	New York. 1991-1999. CABG patients	Reports of standardised mortality	Linear model with time, hospital FEs.		Fewer low severity CABG patients at hospital if previous high mortality report.	
Gaynor et al, 2011.	England. 29 hospitals, 13,000 elective CABG pa, 2003/4-2007/8	CABG hospital mortality rate	Conditional logit; waiting time for other procedures as IV; distance as IV for quality.	Age, gender, income deprivation, comorbidity; waiting times;	Demand decreases with mortality (0.3 elasticity post 2005); and waiting time (0.3 elasticity post 2005). Sicker patients more sensitive to mortality, less to quality.	
Ho (2006)	USA. 1997/8; 217 hospitals, 11 hospital markets, 28,666 indemnity/PPO patients	Hospital characteristics (teaching status, set of services offered).	Conditional logit; hospital fixed effects; regression of hospital FEs on hospital characteristic	Age, gender, working status, Zip code median income, distance; diagnosis. Hospital dummy characteristics in second stage.	Patients prefer hospitals with better services for their diagnosis.	No copayment data; 5% emergency patients
Hodgkin (1996)	27 hospitals. New Hampshire. 1985-91. Diagnostic cardiac catheterisation.	Availability of catheterisation. Standardised mortality. Staff per bed.	Conditional logit. Hospital FE	Age, gender, travel time, comorbidity, primary diagnoses. Patient mortality risk, probability of needing catheterisation. Insurance type.	Demand increased by catheterisation availability for patients most likely to need one. Demand higher if hospital mortality higher.	Number of hospitals offering procedure increased from 2 to 9.
Howard (2005)	US. Kidney transplant patients 2000-2002.	Graft failure rate adjusted for patient characteristics.	Mixed logit, random coefficients	Age, gender, ethnicity, diabetes, education, employment, current treatment, insurance type.	Demand increases with quality, decreases with distance.	
Luft et al (1990)	California. 1983. 7 surgical, 5 medical	Standardised mortality;	Conditional logit.	Distance, charges, medical school, ownership.	If mortality higher, demand smaller for 4/7 surgical, 2/5	Demand reduced by higher mortality for

	diagnoses. 99465 patients. 115 hospitals.	complication rates			medical procedures; higher for 1/7 surgical, 1/5 medical.	CABG, AMI
Pope (2009)	USA. 1994-2004. Non emergency Medicare patients	Reported quality rankings	Hospital level demand with year, hospital- ,speciality FEs; individual level mixed logit (random coefficients).	Distance.	Volume increases following improved ranking; probability of choice increases with ranking.	
Sivey (2008)	England. 2001/2-2003/4. 41019 CABG patients. 33 hospitals.	Standardised mortality.	One stage model: conditional & mixed logit with standardised mortality. Two stage model: conditional & mixed logit with hospital FEs plus regression of FEs on hospital characteristics including quality.	Patient characteristics, diagnoses. Waiting time. Travel time. London hospital.	One stage model: demand lower if mortality higher. Two stage model: no significant effect of mortality.	
Tay (2003)	AMI. Non HMO Medicare. 14,374 patients. 339 hospitals. California, Oregon, Washington. 1994	10 year average mortality & complication rates; nurses per bed, teaching status, high tech services (catheterisation, revascularisation).	Conditional logit; mixed logit with random coefficients. Quadratic in mortality, complication rates.	Age, gender, ethnicity; beds, distance.	Demand falls with distance and increases with quality. But for complication rate demand is higher at low and high rates.	50% patients arrive in ambulance. 46% patients admitted to hospital nearest to home.
Varkevisser et al (2010)	Netherlands. 2003. 5389 non-emergency first outpatient appointments for neurosurgery. 66 hospitals	Overall reputation; reputation for neurosurgery; university medical centre.	Conditional logit.	Gender, non-adult; self employed. travel time, waiting time below average.	Demand increases with overall reputation, waiting time below average. No effect of neurosurgery reputation.	Average of 26 hospitals within 60 minutes.
Varkevisser et al (2012)	Netherlands. 2006. 2670 non emergency Angioplasty (PCI). 19 hospitals. Single health insurer.	2005 heart failure readmission rate; pressure sores; overall reputation; cardiology reputation (newspaper ranking).	Conditional logit; mixed logit random coefficients	Age, gender, employment status, travel time. University medical centre.	Demand increases with overall reputation, cardiology reputation, university medical centre; pressure sores; decreases with readmission rate. 1 point increase in overall reputation (0.4 SD) increases demand by 65%.	Pressure ulcers negatively correlated with other quality measures. No waiting time control.

A number of strategies are available to increase the likelihood that an observed association is evidence of causality.

(i) *rich set of covariates*. Including covariates which plausibly affect quality reduce the risk of omitted variable bias. In the studies of competition and quality this suggests in particular the need to allow for patient characteristics affecting measured quality ie for thorough casemix adjustment. The studies examined here correct for casemix adjustment by including age, gender etc as explanatory variables which is more flexible than first directly or indirectly standardising quality with respect to age, gender etc as in many of the demand studies in Table 2, for example Beckert et al (2011).

(ii) *predicted market shares*. Some competition measures are based on patterns of use of providers, as in the Herfindahl-Hirschman index (HHI) which is the sum of the providers' squared market shares. Markets with higher HHIs are interpreted as less competitive. But observed patterns of use reflect the quality of providers since quality affects patient choice. Thus a provider with higher quality will have larger market share and higher HHI and the estimated effect of competition (smaller HHI) on quality will be under-estimated. Kessler and McClellan (2000) therefore suggest that the HHI is calculated from estimates based on a demand model which includes distance as the key explanatory and which does not contain hospital quality or other hospital variables correlated with quality.

(iii) *instrumental variables* for competition: variables which are correlated with competition but which are not correlated with unobservable factors affecting quality. For example, Gaynor et al (2011) use the political marginality of an area as an instrument for the competing number of hospitals, arguing that decisions on closing or merging hospitals will be affected by political considerations which are independent of the quality a hospital.

(iv) *difference in differences*: compare changes in quality over time for providers which had different changes in competition. The obvious way to implement this strategy is compare hospitals where rivals entered or left with those where the set of rivals was unchanged. Because there has been little entry or exit by hospitals providing NHS care in the periods studied by papers adopting this strategy, competition is argued to depend on market structure (numbers of rivals or market shares) and national competition policy. Changes in national policy lead to different changes in effective competitive pressures for providers depending on their market structure. The methodology of difference-in-difference relies on the assumption of common trends: AMI mortality rates should fall at the same rate in the treatment and the control group ie for providers with different number of competitors. If the trends instead differ, then the empirical evaluation of pro-competition policy interventions will be biased upwards if mortality rates fall more rapidly in more competitive areas. It is possible, as in Cooper et al (2011), to allow differential trends in the high and low competition groups of hospital and to test if the change in policy affected the trend one group compared to the other.

Table 3 Quality and NHS hospital competition: empirical papers

		Competition		Quality	Method	Covariates	Results
Paper	**Data**	**Market structure measure**	**Competition policy**				
Propper et al (2004)	202 Trusts; Pooled 1995/6-1997/8	(i) number of Trusts within 30min drive time per head of population (ii) share of catchment population within 30 min drive of 20+ Trusts	Provider competition encouraged. Some flexibility on prices especially for patients of fundholding practices.	AMI mortality; 30 day in hospital; Trust level. 3 year weighted average	Trust level. Cross section. OLS	AMI patient age/gender distribution; beds, total admissions, AMI admissions; teaching hospital; heart specialism; London; Region; mortality, morbidity, unemployment.	Trusts in more competitive areas have higher mortality rates. Elasticities: (i) 0.19; (ii) 0.07
Propper et al (2008)	Panel 145 Trusts; 1991/2-1999/2000	Dummy variables based on (i) number of Trusts within 30min drive time (ii) number of Trusts within 30min drive time per head of population; (iii) 100% of catchment area within 30 min of at least 6 Trusts. Measured for 1993.	Competition encouraged 1992/3 to 1996/7; restricted 1991/2 & 1997/8 to 1999/2000.	AMI mortality; 30 day in hospital; Trust level. Shrunk to year national mean	Trust level. Hospital FE. DID. Treatment group: Trusts with competitive market; Treatment: competition encouraged	Total admissions; length of stay of AMI emergency patients; total income; regional budget.	Trusts in competitive areas had smaller reduction in AMI mortality during periods when competition was permitted compared to those in non-competitive areas.
Cooper et al (2011)	433,325 AMI patients; 2002Q1 to 2008Q4	Negative log of HHI. (i) GP market HHI: hospitals within radius of 95th percentile of distance travelled by practice patients; weighted average of HHIs for 5 elective procedures. (ii) HHIs calculated using estimated demands; (iii) standard deviation of distance to nearest four hospital used as IV for competition measure.	Fixed prospective prices rolled out from 2005/6. Greater choice of provider from 2006Q2	AMI 30 day mortality in hospital.	Linear individual mortality probability. DID linear trends between hospitals in more competitive areas before and after choice made easier.	Age, gender, Charlson comorbidity index, income deprivation. Hospital FEs. GP FEs.	Mortality declined faster in more competitive areas when choice was made easier.
Gaynor et al (2011)	130 Trusts in 2003/4; 121 in 2007/8.	HHIs for 2003/4 for MSOAs using elective predicted patient flows. HHI for hospital is weighted average of MSOA HHIs.	Fixed prospective prices rolled out from 2005/6. Greater choice of provider from January 2006.	(i) AMI deaths within 30 days (any location), ages 35-74. (ii) All cause 28 day within hospital mortality	Trust level, OLS DID with hospital FEs.	Age/gender patient mix.	Greater reduction in mortality (AMI, all cause) in areas with smaller predicted HHI. No difference in reduction using actual HHI.
Bloom et al (2011)	100 Acute Trusts. 2006.	(i) Number of competing hospitals within 30km. Political marginality used as IV. (ii) Weighted average of HHIs of areas using predicted choices.		In hospital mortality from AMI and surgery. MRSA rates. Health Care Commission ratings.	2SLS using political marginality as IV for number of competing hospitals.	Number of private hospitals. Age/gender mix. Total & AMI admissions. Number of sites. Population density. FT status. Interviewer FEs. London dummy. Teaching hospital dummy.	Lower AMI mortality in hospitals with better management. Better management in hospitals facing more competition.

AMI: acute myocardial infarction. DID: difference in differences. FE: fixed effect. FT: Foundation Trust hospital. HHI Herfindahl-Hirschman Index (sum of squared shares of providers). IV: instrumental variable. MSOA: medium super output area (average population 7200). MRSA: methicillan resistant staphylococcus areaus. OLS: ordinary least squares. 2SLS: two stage least squares.

Propper, Burgess and Green (2004) examine the effect of competition on death rates from AMI using a sample of 202 Trusts for a cross-section of three pooled financial years 1995/6-1997-8. The cross-section design is vulnerable to potential confounding from omitted variables though the authors include covariates such as local morbidity and whether the Trust was a teaching hospital. The key quality measure is AMI in-hospital deaths within 30 days of emergency admission with a myocardial infarction for patients aged 50 and over. Competition is measured as the number of trusts in a catchment area of 30 minutes travel time. As part of sensitivity analysis the study also uses the number of trusts standardised by the population of the catchment area. They find that more competition increases death rates. The result arises within an institutional framework where prices are not fixed. They argue that mechanism through which the result arises is that competition reduces prices, which in turn drives down quality because the marginal profit on additional patients attracted by higher quality is lower.

Propper, Burgess and Gossage (2008) extend the above analysis to cover the period 1991/2–1999/2000. They argue that competition was encouraged by the government in year 1991/2 and during 1997/8-1999/2000. Using a difference-in-difference methodology they compare the differences between AMI rates between years when competition was encouraged and years when it was not for a “treatment” group of hospitals facing many rivals against the difference for a “control” group (with no or few rivals). They find that when competition was encouraged hospitals in the treatment group with more rivals reduced their AMI rates more than hospitals in the control group.

Cooper et al. (2011) estimates the effect of competition on AMI mortality rates during a period (2002-2008) when they argue that prices were fixed. The analysis uses data from 227 hospital sites as opposed to data aggregated at Trust level (therefore allowing for Trusts with multiple sites). A difference-in-difference methodology was adopted. They assume that the introduction of Patient Choice from 2005 onward led to an increase in competition and that this increase in competition was greater in more competitive areas with more providers. Competition was measured using market shares based on predicted rather than actual demand. They find that the introduction of Patient Choice was associated with a bigger reduction in AMI mortality in more competitive areas. AMI mortality fell by 0.31 percentage points per year faster in areas where competition was more intense by one standard deviation of their market structure indicator.

Gaynor, Moreno-Serra and Propper (2011) use a similar methodology, also arguing that the introduction of Patient Choice increased competition more for hospitals in markets with a more competitive structure and using predicted demand to calculate market shares. They use two years of data: 2003 and 2007. The sample includes 130 hospitals (trusts) in 2003 and 121 in 2007. They find that hospitals which had a 10% higher Herfindahl index (ie faced less competition) in 2003 had a smaller (by 2.9%) decrease in AMI mortality rates between 2003 and 2007. There is a similar association for overall mortality rates, though the effect is quantitatively smaller. Hospitals facing less competition in 2003 also had an increase in overall length of stay between 2003 and 2007 relative to providers facing more competition in 2003.

Bloom et al. (2011a) investigate the effect of competition on management quality. Management quality is measured by an index which includes incentives management, monitoring, target-setting and lean operations. The data are obtained through interviews from 100 trusts (about 61% of all trusts) and a mix of 161 clinicians and managers working in cardiology and orthopaedics specialities. The data is a cross section for 2005-6. The key measure of competition is the number of hospitals within a 30 km radius (their preferred measure of competition; Herfindahl indices based on market shares are also used as part of sensitivity analysis). To address the potential endogeneity between quality and competition an instrument based on the degree of political competition (public hospitals are less likely to be closed in marginal constituencies) is used. They find that increasing the number of rival providers by three increases the index of management quality by more than a standard deviation, which implies a 6% reduction in AMI mortality rates.

The above studies focus on mortality rates (in particular AMI mortality rates and overall mortality rates). AMI mortality is argued to be less susceptible to manipulation in response to changes in the PbR tariff which rewarded upcoding which would produce a spurious increase in quality with less serious patients classified as more serious but having better outcomes.

The fact that AMI admissions are emergencies is also argued to be a merit because this removes potential problems arising if the market competition is calculated using data from elective patient choices which reflect quality. However, because competition is for elective patients, not emergencies, it must also be argued that Trust decisions which affect quality for elective patients must also change AMI quality in the same direction. This requires that mortality rates, in particularly for AMI, are correlated with the quality measures which affect demand from elective patients: they should act as a ‘canary in the mine shaft’.

Some correlations of AMI mortality with other quality indicators are reported in Cooper et al (2011), for example AMI and overall mortality have a correlation of 0.33. This seems quite low and, since elective treatments have much lower mortality than AMI and other emergencies, it is unclear that the correlation supports the canary in the mineshaft argument. Some studies are quite sceptical of the use of mortality as a measure of quality. For example, Pitches, Mohammed and Lilford (2007) undertook a systematic literature review of 36 studies of the relationship between risk adjusted mortality and quality of care found that, of the 51 cases examined, there was a positive association in 26/51, a negative association in 9/51 and no association in 16/51.

In the next section we use data from Dr Foster to undertake a preliminary examination of the extent to which a range of clinical and patient reported quality measures are correlated.

4. Correlations amongst quality measures

In this section we examine the correlations between different quality measures at hospital level using data by Dr Foster (released in November 2010). The sample includes 147 trusts and refers to financial year 2009-2010. We use data on mortality rates, readmission and redo rates, and patients' experience. We use data on standardised mortality rates split in different categories: overall, from high risk conditions, from low risk conditions, deaths after surgery, in-hospital stroke mortality and deaths resulting from hip fracture.

Table 4 has summary statistics for the 16 quality measures which are described in more detail in Appendix A. Most variables have been normalised to 100. Mortality rates have been computed by dividing the actual number of deaths by the expected number and multiplying the figure by 100. As an example consider overall mortality rates. The maximum value within the hospital sample is 118: this implies that that the hospital with highest mortality rates has 18% more than expected mortality rates. The standard deviation is 9%. Readmission rates have a similar scaling.

Hip and knee revisions and manipulations have a different scaling. The descriptive statistics suggest that on average 1.1% of patients are in need of a hip revision and manipulation. The rate for knee revisions is 0.5%. Redo rates for prostate section is 4.4%. The proportion of patients with hip fracture who received an operation within 2 days is on average 67.4%. On average 86.2% of patients found the hospital clean, 70.2% thought that they were involved in decisions, and 88% thought that they had confidence and trust in the doctors treating them.

Table 4. Descriptive statistics: quality measures

	mean	sd	min	Max	count
Overall mortality rate	99.264	9.303	71.855	117.930	147
Mortality from high risk conditions	99.645	9.946	73.018	121.109	147
Mortality from low risk conditions	92.513	26.743	31.299	182.502	147
Deaths after surgery	100.182	25.438	26.330	179.417	147
Deaths resulting from hip fracture	99.565	23.160	43.544	167.870	147
In-hospital stroke mortality	101.726	14.159	66.102	166.067	147
Hip replacement readmissions	104.796	25.491	33.395	175.313	147
Knee replacement readmissions	102.346	35.256	0.000	219.409	147
Stroke readmission	101.442	20.336	56.279	158.079	147
Hip revisions and manipulations within 1 year	1.070	0.602	0.000	3.509	147
Knee revisions and manipulations within 1 year	0.506	0.667	0.000	7.143	147
Redo rates for prostate resection	4.401	2.031	0.000	12.311	145
Hip fracture - Operation given within 2 days	67.403	11.966	33.586	94.309	147
Clean Hospital room/ward	86.2	2.715	79	93.7	147
Involved in decisions	70.244	3.244	60	78	147
Trust in doctors	88.31	2.202	81.5	93	147

4.1 Mortality rates

Table 5 (top-left quadrant) provides a correlation matrix between six different mortality indicators (overall, from high and low risk conditions, deaths after surgery, in-hospital stroke mortality, deaths resulting from hip fracture).

Overall mortality rates are highly correlated with high-risk condition ones (with a correlation of 0.8). This is probably due to high-risk conditions being a large determinant of overall mortality rates. They have otherwise a correlation in the range 0.29-0.35 with other mortality indicators.

Mortality rates from high-risk conditions have correlations in the range 0.25-0.49 with mortality rates other than overall mortality. Mortality rates from low-risk conditions have a low correlation with any other measure (in the range 0.14-0.35). The correlation between death after surgery and any other measure is in the range 0.02-0.29.

Deaths resulting from hip fracture have a correlation of 0.37 with mortality rates of high risk conditions (again due to some extent to the first being included in the second), of 0.33 with overall mortality and between 0.16-0.2 with any other mortality indicator.

In-hospital stroke mortality rates have a correlation of 0.49 with mortality rates of high risk conditions (again due to some extent to the first being included in the second), of 0.32 with overall mortality rates and between 0.02-0.16 with any other mortality indicator.

4.2 Readmissions, revisions and redo

Table 5 (bottom-right quadrant) gives the correlations hip and knee readmissions, stoke readmissions , hip and knee revisions and manipulations within 1 year, redo rates for prostate resection, and hip fracture operation within 2 days. Note that, the last indicator (hip fracture operations within 2 days) is a positive quality measure while the others are negative.

Readmissions. Hip readmissions have a correlation of 0.32 with knee readmissions and of only 0.07 with stroke readmissions. There is very low correlation with the other measures (in the range -0.05 to 0.02). Note that, perhaps surprisingly, there is no correlation between hip readmissions and hip revisions (0.01), and between hip readmissions and the proportion of operations within 2 days following a hip fracture (0.02).

Knee readmissions have, as already mentioned, a correlation of 0.32 with hip readmissions and only 0.09 with stroke readmission. There is very low correlation with other measures (in the range -0.06 to 0.11). As for hip, there is no correlation between knee readmissions and knee revisions (-0.06). Stroke readmissions have a low correlation with all other measure (0.01 to 0.09).

Revisions and redos. Hip and knee revisions have a correlation of 0.38 but there is low correlation with any other measure (in the range -0.06 to 0.11). Redo rates for prostate resection have low correlation with any other measure (in the range -0.06 to 0.11).

Operation within 2 days. The proportion of hip fracture patients with an operation within two days has a low correlation with all other measure (in the range -0.02 to 0.11).

4.3 Readmissions and mortality rates

Table 5 (top-right quadrant) also provides the correlation between the different readmission and mortality rates. This is generally low and varies between -0.18 (knee revisions and mortality from low risk conditions) and 0.16 (death from hip fracture and stroke readmissions). Note that there is no correlation between stroke readmission rates and stroke in-hospital mortality rates (0.04).

Table 5. Correlations amongst mortality and readmission variables

	Overall mortality rate	Mortality from high risk conditions	Mortality from low risk conditions	Deaths after surgery	Deaths resulting from hip fracture	In-hospital stroke mortality	Hip replacement readmissions	Knee replacement readmissions	Stroke re-admission	Hip revisions and manipulations within 1 year	Knee revisions and manipula-tions within 1 year	Hip fracture - Operation given within 2 days	Redo rates for prostate resection
Overall mortality rate	1.00	0.80	0.35	0.29	0.33	0.32	0.02	-0.02	-0.03	0.01	-0.09	-0.05	-0.13
Mortality from high risk conditions	0.80	1.00	0.25	0.25	0.37	0.49	0.04	0.02	-0.03	-0.09	-0.16	-0.09	-0.07
Mortality from low risk conditions	0.35	0.25	1.00	0.22	0.19	0.14	-0.07	0.11	-0.12	-0.05	-0.18	0.03	-0.04
Deaths after surgery	0.29	0.25	0.22	1.00	0.20	0.02	-0.08	-0.12	-0.02	-0.09	-0.11	-0.07	-0.16
Deaths resulting from hip fracture	0.33	0.37	0.19	0.20	1.00	0.16	-0.04	-0.06	0.16	-0.02	-0.05	-0.05	-0.08
In-hospital stroke mortality	0.32	0.49	0.14	0.02	0.16	1.00	0.03	-0.04	0.04	-0.05	0.06	-0.03	0.02
Hip replacement readmissions	0.02	0.04	-0.07	-0.08	-0.04	0.03	1.00	0.32	0.07	0.01	0.02	0.02	-0.05
Knee replacement readmissions	-0.02	0.02	0.11	-0.12	-0.06	-0.04	0.32	1.00	0.09	0.11	-0.06	-0.02	-0.01
Stroke readmission	-0.03	-0.03	-0.12	-0.02	0.16	0.04	0.07	0.09	1.00	0.04	0.06	0.01	0.08
Hip revisions and manipulations within 1 year	0.01	-0.09	-0.05	-0.09	-0.02	-0.05	0.01	0.11	0.04	1.00	0.38	0.09	-0.06
Knee revisions and manipulations within 1 year	-0.09	-0.16	-0.18	-0.11	-0.05	0.06	0.02	-0.06	0.06	0.38	1.00	0.02	0.01
Hip fracture - Operation given within 2 days	-0.05	-0.09	0.03	-0.07	-0.05	-0.03	0.02	-0.02	0.01	0.09	0.02	1.00	0.11
Redo rates for prostate resection	-0.13	-0.07	-0.04	-0.16	-0.08	0.02	-0.05	-0.01	0.08	-0.06	0.01	0.11	1.00

Note: absolute value of correlation of at least 0.21 required for significance at 1%.

4.4 Patients' experience

Table 6 focuses on patients' experience. The three indicators on patients' experience have a correlation which varies between 0.46 and 0.76 (bottom-right quadrant). There is a nearly zero or a negative correlation between patients' experience and the selected mortality (from high risk conditions and from hip fracture) rates and readmission (hip and stroke) rates. The correlation ranges between 0.02 and -0.24. A negative correlation, despite being low, is to be expected since higher mortality or readmission rates measure 'negative' outcomes and the patients' experience variables measure 'positive' ones. Therefore, a negative correlation suggests that providers with better mortality rates also have higher patients' satisfaction.

Table 6. Correlations: satisfaction, mortality, and readmissions

	Mortality from high risk conditions	Deaths resulting from hip fracture	Hip replacement readmissions	Stroke readmission	Clean Hospital room/ward	Involved in decisions	Trust in the doctors
Mortality from high risk conditions	1.00	0.37	0.04	-0.03	0.02	-0.14	-0.15
Deaths resulting from hip fracture	0.37	1.00	-0.04	0.17	0.03	-0.04	-0.06
Hip replacement readmissions	0.04	-0.04	1.00	0.07	-0.10	-0.18	-0.04
Stroke readmission	-0.03	0.17	0.07	1.00	-0.17	-0.24	-0.22
Clean Hospital room/ward	0.02	0.03	-0.10	-0.17	1.00	0.50	0.46
Involved in decisions	-0.14	-0.04	-0.18	-0.24	0.50	1.00	0.76
Trust in the doctors	-0.15	-0.06	-0.04	-0.22	0.46	0.76	1.00

Note: absolute value of correlation of at least 0.21 required for significance at 1%

4.5 Conclusions

The correlation between different types of quality measures is generally low, especially for correlations between mortality for high risk conditions and measures of quality for hip and knee surgery which are elective procedures, and between mortality for high risk conditions and patient experience measures.

5. Association of quality and competition

5.1 Competition measures

We develop several competition measures based on the number of hospitals within a catchment area of 10, 15, 20, 30, 40 and 50 kilometres radius (line distance and car distance) and with a catchment area based on 30 minutes car drive. These are described in Table 7.

The average number of providers within 15 km and 30 minutes car drive is respectively equal to 3.6 and 3.7 providers (these two measures have a correlation of 0.92). About one third of all hospitals are 'monopolists', ie they do not have any other provider within a 30 minutes car drive. Another third is characterised by two or three providers. 16% have four to six providers, 12% have seven to ten providers, and only 7% have more than eleven providers (up to a maximum of 15).

The number of providers within 15 km is highly correlated with the number of providers within 10, 20, 30, 40 and 50 km (the correlation varying between 0.73 and 0.96; see Table 8 for details).

The average population within a catchment radius 15 km is on average 1.1 millions. There are about 4 providers per million population within a 15 km radius, with a minimum of 0.9 and a maximum of 15.5 (and a standard deviation of 2.4). The correlation between the number of providers within 15 km and the number of providers within 15 km standardised by the catchment population is -0.16.

About 16% of the hospitals (24 hospitals) are in London. 50% of the hospitals have Foundation Trust status, and 18% of the hospitals are teaching hospitals.

Table 7. Competition measures: descriptive statistics

	Mean	SD	Min	Max	Count
N. providers within 10 km	2.116	2.366	1	12	147
N. providers within 15 km	3.558	4.359	1	19	147
N. providers within 20 km	5.136	6.142	1	23	147
N. providers within 30 km	8.102	8.238	1	27	147
N. providers within 40 km	11.340	9.998	1	32	147
N. providers within 50 km	15.422	11.797	1	38	147
N. providers within car distance: 10km	1.626	1.589	1	9	147
N. providers within car distance: 15km	2.469	2.980	1	15	147
N. providers within car distance: 20km	3.585	4.501	1	19	147
N. providers within car distance: 30km	5.782	6.834	1	24	147
N. providers within car distance: 40km	7.986	8.241	1	28	147
N. providers within car distance: 50km	10.422	9.536	1	32	147
N. providers within 30min	3.687	3.430	1	15	147
Population within 15km (in millions)	1.104	1.335	0.064	5.103	147
N. providers / Population within 15km	4.002	2.358	0.909	15.567	147
Trust is in London	0.177	0.383	0	1	147
Foundation Trust	0.497	0.502	0	1	147
Teaching Trust	0.163	0.371	0	1	147

Table 8. Correlations amongst competition measures

	N. providers within 10 km	N. providers within 15 km	N. providers within 20 km	N. providers within 30 km	N. providers within 40 km	N. providers within 50 km	N. Provider within 30min	N. providers / Pop within 15km
N. providers within 10 km	1	0.93	0.88	0.77	0.69	0.63	0.90	-0.14
N. providers within 15 km	0.93	1	0.96	0.88	0.80	0.73	0.92	-0.16
N. providers within 20 km	0.88	0.96	1	0.95	0.89	0.82	0.91	-0.24
N. providers within 30 km	0.77	0.88	0.95	1	0.97	0.91	0.85	-0.31
N. providers within 40 km	0.69	0.80	0.89	0.97	1	0.97	0.80	-0.36
N. providers within 50 km	0.63	0.73	0.82	0.91	0.97	1	0.76	-0.40
N. providers within 30min	0.90	0.92	0.91	0.85	0.80	0.76	1	-0.26
N. providers/Pop within 15km	-0.14	-0.16	-0.24	-0.31	-0.36	-0.40	-0.26	1

Note: absolute value of correlation of at least 0.21 required for significance at 1%

5.2 Competition measures and mortality

Table 9 provides cross-sectional regression results on the association of competition (measured by the number of providers within 30 minutes drive time) with the different mortality measures. We begin with the simplest model and then add control variables.

The upper section of Table 9 shows that there is a negative and statistically significant association between competition and overall mortality, mortality from high-risk conditions, and deaths after surgery, but there is not a statistically significant association for low-risk conditions, deaths from hip fracture (though the coefficient is negative) and in-hospital stroke mortality (the coefficient is positive). The association is such that, if it were causal, increasing the number of hospitals in the catchment area by one reduces the probability of overall mortality (or relative risk) by approximately 1% (0.9%). The possible effect is similar when mortality rates for high-risk conditions are used as the dependent variable and larger when death after surgery is used (2% reduction).

The middle part of Table 9 replicates the analysis but controls for whether the hospital has teaching status and Foundation Trust status. Adding such controls does not qualitatively alter the results. The coefficient on competition in the overall and high-risk mortality regressions is however reduced. Teaching hospitals have lower overall mortality rates and Foundation trusts have lower mortality following a hip fracture.

The bottom part of Table 9 shows the association of competition and mortality rates when we allow for a London effect. London enters both as a dummy variable and as an interaction with the competition variable. Competition ceases to have a significant association either on overall mortality rates, high-risk conditions mortality rates and death after surgery. Hospitals in London have generally lower mortality rates (except for deaths resulting from hip fracture), though this is statistically significant at 10% level only for 'deaths after surgery' and not significant for the other measures. Competition now has a negative statistically significant association (at 10% level) with mortality from low-risk conditions for hospitals not based in London and a positive statistically significant association (at 5% level) for hospitals based in London.

Table 10 replicates the analysis provided in Table 9 but uses the number of providers within 15 km standardised by population as the competition measure. Competition is not significant when we do not control for a London effect. The association between competition and overall mortality rates,

Table 9. Competition and Mortality rates

	Overall mortality rate	Mortality from high risk	Mortality from low risk	Deaths after surgery	Deaths resulting from hip fracture	In-hospital stroke mortality
N. Provider within 30min	-0.907***	-0.849***	-0.840	-1.955***	-0.610	0.260
	(0.000)	(0.000)	(0.194)	(0.001)	(0.277)	(0.448)
Constant	102.6***	102.8***	95.61***	107.4***	101.8***	100.8***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N. Provider within 30min	-0.661***	-0.709***	-0.954	-2.002***	-0.334	0.322
	(0.003)	(0.005)	(0.171)	(0.002)	(0.569)	(0.384)
Controls:						
Teaching Trust	-6.250***	-3.504	2.903	1.027	-7.510	-1.546
	(0.002)	(0.114)	(0.641)	(0.858)	(0.154)	(0.640)
Foundation Trust	-0.735	0.376	0.482	-2.896	-9.177**	0.169
	(0.604)	(0.811)	(0.914)	(0.480)	(0.015)	(0.943)
Constant	103.2***	102.7***	95.28***	108.8***	106.7***	100.7***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N. Provider within 30min	0.0816	0.0901	-2.438*	-0.121	1.345	0.259
	(0.841)	(0.843)	(0.060)	(0.918)	(0.218)	(0.708)
Trust is in London	-5.583	-3.217	-28.25	-26.21	3.752	-10.03
	(0.313)	(0.603)	(0.107)	(0.101)	(0.799)	(0.285)
London x N. Provider	-0.292	-0.565	4.125**	0.345	-2.133	0.970
	(0.654)	(0.438)	(0.047)	(0.854)	(0.222)	(0.381)
Controls:	Yes	Yes	Yes	Yes	Yes	Yes
Constant	102.5***	101.8***	99.76***	108.1***	103.9***	101.6***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	147	147	147	147	147	147

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

Table 10. Competition (N. providers/population within 15km) and mortality rates

	Overall mortality	Mortality from high risk conditions	Mortality from low risk conditions	Deaths after surgery	Deaths resulting from hip fracture	In-hospital stroke mortality
N prov / Population by 15km	0.388	0.442	1.148	0.518	0.484	-0.403
	(0.237)	(0.207)	(0.223)	(0.563)	(0.554)	(0.420)
Constant	97.71***	97.88***	87.92***	98.11***	97.63***	103.3***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N prov / Population by 15km	0.148	0.299	1.196	0.339	0.0977	-0.431
	(0.639)	(0.394)	(0.215)	(0.711)	(0.904)	(0.400)
Controls:						
Teaching Trust	-8.205***	-5.456**	1.109	-5.014	-8.475*	-0.970
	(0.000)	(0.012)	(0.851)	(0.373)	(0.091)	(0.757)
Foundation Trust	-0.549	0.622	1.073	-2.369	-9.076**	-0.0391
	(0.707)	(0.701)	(0.810)	(0.577)	(0.017)	(0.987)
Constant	100.4***	99.11***	87.00***	100.9***	105.2***	103.6***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N prov / Population by 15km	0.0578	0.212	1.154	-0.210	0.0584	-0.301
	(0.847)	(0.530)	(0.243)	(0.813)	(0.944)	(0.563)
Trust is in London	27.18**	28.07**	23.23	1.488	37.36	36.37*
	(0.021)	(0.034)	(0.547)	(0.966)	(0.247)	(0.075)
London x N prov / Population by 15km	-11.40***	-11.68***	-9.243	-8.342	-14.46	-11.70*
	(0.003)	(0.006)	(0.455)	(0.454)	(0.163)	(0.074)
Controls:	Yes	Yes	Yes	Yes	Yes	Yes
Constant	102.2***	100.9***	88.09***	108.5***	106.5***	102.6***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	147	147	147	147	147	147

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

Table 11. Competition (N providers within 15km) and mortality rates, allowing for population

	Overall mortality	Mortality from high risk conditions	Mortality from low risk conditions	Deaths after surgery	Deaths resulting from hip fracture	In-hospital stroke mortality
N. providers within 15 km	-0.370	-0.368	2.034	-2.237	0.600	-2.493*
	(0.633)	(0.672)	(0.412)	(0.322)	(0.774)	(0.057)
Controls:						
Teaching Trust	-5.611***	-2.985	2.449	2.394	-7.144	-1.057
	(0.005)	(0.176)	(0.696)	(0.675)	(0.178)	(0.748)
Foundation Trust	-1.458	-0.349	-0.642	-4.654	-9.726**	0.820
	(0.305)	(0.826)	(0.887)	(0.260)	(0.012)	(0.730)
Population within 15km	-0.978	-1.012	-8.890	1.226	-3.159	8.767**
	(0.699)	(0.721)	(0.272)	(0.868)	(0.643)	(0.040)
Constant	103.4***	102.8***	94.97***	108.7***	107.0***	100.7***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N. providers within 15 km	0.691	0.993	1.040	-3.183	3.100	-2.408
	(0.446)	(0.326)	(0.725)	(0.232)	(0.207)	(0.121)
Population within 15km	-0.290	-0.487	-10.47	10.90	-0.663	11.98**
	(0.920)	(0.880)	(0.270)	(0.201)	(0.933)	(0.017)
Trust is in London	4.672	6.974	-1.805	-32.40*	8.610	-8.308
	(0.446)	(0.308)	(0.928)	(0.073)	(0.603)	(0.428)
London x N providers within 15km	-1.550**	-1.958***	1.534	0.483	-3.730**	-0.399
	(0.017)	(0.007)	(0.464)	(0.797)	(0.033)	(0.715)
Controls:	Yes	Yes	Yes	Yes	Yes	Yes
Constant	101.3***	100.2***	97.17***	107.6***	101.9***	99.64***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	147	147	147	147	147	147

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

mortality from high-risk conditions and deaths after surgery is not statistically significant. The analysis suggests that hospitals in London have higher (overall, high-risk and stroke) mortality and that conditional on being in London higher competition reduces mortality for the same indicators.

Table 11 replicates the analysis provided in Table 10 but population and number of providers enter as separate variables in the regression. As in Table 10 competition as measured by the number of providers has no association with mortality rates. Population also has no association, with the exception of stroke mortality where higher population is positively associated with mortality rates. When London is included as a control and interacted with the measure of competition, we again find that the number of providers has no association with mortality for hospitals not in London. Conditional on being in London, a higher number of providers is negatively associated with overall and high-risk mortality rates, and deaths following a hip fracture.

5.3 Competition measures and readmission, redo rates

The upper part of Table 12 replicates the analysis when other quality measures are used as the dependent variable. There is a positive and statistically significant association between competition and stroke readmission rates, and competition and knee revisions. Increasing the number of providers by one increases stroke readmissions by 1.8% and knee revisions by 0.04% (given a sample mean of 0.5, this implies an increase in knee revisions by 8%). The coefficient is positive but not significant for hip and knee readmission rates, for hip revisions, redo rates for prostate resection and hip fracture operation within 2 days.

When controls for teaching and foundation status are added into the analysis (middle part of Table 12), the results remain qualitatively similar, with the exception of knee replacement readmissions: the coefficient is now positive and significant. Increasing the number of providers by one increases knee replacement readmissions by 1.5%. Teaching hospitals have lower readmissions rates for knee and stroke readmissions. The coefficient is large, respectively 20% and 11% lower readmissions.

In the bottom part of Table 12 we allow for a London effect. For hospitals not located in London, competition increases stroke readmission rates but this is not the case for hospitals located in London. For hospitals not in London, the association of competition with knee revisions ceases to be significant. This is due to hospitals in London having higher knee revisions rates. Conditional on being in London, more competition reduces knee revisions rates, though the coefficient is significant only at 10% level.

For hospitals not located in London, competition increases hip replacement readmission rates. For hospitals located in London the opposite holds: competition reduces hip replacement readmission rates. Moreover, hospitals in London have higher hip replacement readmission rates. When we look at redo rates for prostate resection a rather different picture emerges. For hospitals not located in London, competition reduces redo rates. For hospitals located in London, competition increases redo rates.

Table 13 replicates the analysis but uses as competition measure the number of providers within 15 km standardised by population. We see that now there is a *negative* statistically-significant association between competition and (hip, stroke) readmission and knee revision rates, and positive for the proportion of hip fracture within two days. This is in contrast with the results obtained in Table 12. Once we control for the hospital being located in London, we only find some significant associations between competition and the quality indicators for the sample of hospitals that are not located in London (for three out of four indicators, competition increases quality).

Table 12. Competition and Readmissions/Revisions

	Hip replacement readmissions	Knee replacement readmissions	Stroke readmission	Hip revisions and manipulations within 1 year	Knee revisions and manipulations within 1 year	Hip fracture - Operation given within 2 days	Redo rates for prostate resection
N. Provider within 30min	0.567	0.757	1.783***	0.0202	0.0401**	0.276	0.0645
	(0.358)	(0.375)	(0.000)	(0.166)	(0.012)	(0.340)	(0.191)
Constant	102.7***	99.55***	94.87***	0.996***	0.358***	66.38***	4.163***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N. Provider within 30min	0.769	1.544*	2.200***	0.0250	0.0481***	0.405	0.0575
	(0.246)	(0.088)	(0.000)	(0.110)	(0.005)	(0.190)	(0.279)
Controls:							
Teaching Trust	-4.851	-19.73**	-10.75**	-0.125	-0.205	-3.030	0.174
	(0.414)	(0.016)	(0.016)	(0.371)	(0.179)	(0.273)	(0.713)
Foundation Trust	3.799	1.669	-3.851	-0.0424	-0.0688	3.362*	0.00289
	(0.370)	(0.772)	(0.224)	(0.671)	(0.526)	(0.089)	(0.993)
Constant	100.9***	99.31***	97.14***	1.021***	0.399***	64.78***	4.157***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N. Provider within 30min	3.108**	0.623	2.199**	0.0221	0.0195	-0.470	-0.252***
	(0.011)	(0.713)	(0.019)	(0.450)	(0.524)	(0.410)	(0.010)
Trust is in London	37.08**	-5.503	-1.690	0.377	1.226***	-9.880	-2.048
	(0.024)	(0.810)	(0.893)	(0.342)	(0.004)	(0.202)	(0.110)
London x N. Provider within	-5.833***	1.479	0.153	-0.0307	-0.0797	1.823**	0.510***
	(0.003)	(0.584)	(0.918)	(0.510)	(0.106)	(0.047)	(0.001)
Controls:	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	94.47***	101.1***	97.28***	0.995***	0.342***	66.87***	4.785***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)
Observations	147	147	147	147	147	147	145

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

Table 13. Competition (N. providers/population within 15km) and readmissions/revisions

	Hip replacement readmissions	Knee replacement readmissions	Stroke readmission	Hip revisions and manipulations within 1 year	Knee revisions and manipulations within 1 year	Hip fracture - Operation given within 2 days	Redo rates for prostate resection
N prov / Population by 15km	-1.814**	-0.731	-2.660***	-0.0303	-0.0387*	0.805*	0.102
	(0.042)	(0.557)	(0.000)	(0.152)	(0.099)	(0.055)	(0.155)
Constant	112.1***	105.3***	112.1***	1.192***	0.660***	64.18***	3.994***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N prov / Population by 15km	-1.888**	-1.165	-2.937***	-0.0336	-0.0429*	0.838**	0.116
	(0.038)	(0.354)	(0.000)	(0.121)	(0.073)	(0.049)	(0.113)
Controls:							
Teaching Trust	-4.375	-16.02**	-6.797	-0.0804	-0.0960	-0.858	0.481
	(0.432)	(0.039)	(0.109)	(0.544)	(0.512)	(0.741)	(0.283)
Foundation Trust	3.019	0.965	-5.274*	-0.0586	-0.0929	3.554*	0.0258
	(0.472)	(0.868)	(0.099)	(0.558)	(0.400)	(0.071)	(0.939)
Constant	111.6***	109.4***	117.0***	1.248***	0.740***	62.43***	3.839***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N prov / Population by 15km	-1.700*	-1.063	-2.694***	-0.0277	-0.0249	0.972**	0.135*
	(0.069)	(0.406)	(0.000)	(0.211)	(0.287)	(0.025)	(0.066)
Trust is in London	45.66	-51.61	-10.92	0.324	1.437	4.746	-2.380
	(0.208)	(0.301)	(0.684)	(0.706)	(0.115)	(0.777)	(0.403)
London x N prov / Population by 15km	-14.32	20.65	7.507	-0.0375	-0.279	0.129	1.157
	(0.219)	(0.198)	(0.384)	(0.892)	(0.339)	(0.981)	(0.206)
Controls:	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	110.0***	106.8***	113.4***	1.174***	0.523***	60.69***	3.522***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	147	147	147	147	147	147	145

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

Table 14. Competition (N providers within 15km) and readmissions/revisions, allowing for population

	Hip replacement readmissions	Knee replacement readmissions	Stroke readmission	Hip revisions and manipulations within 1 year	Knee revisions and manipulations within 1 year	Hip fracture - Operation given within 2 days	Redo rates for prostate resection
N. providers within 15 km	-3.666	-0.603	-2.256	-0.00389	-0.145**	2.111*	0.0237
	(0.120)	(0.851)	(0.200)	(0.944)	(0.013)	(0.053)	(0.899)
Controls:							
Teaching Trust	-3.344	-19.54**	-10.33**	-0.124	-0.235	-3.377	0.0208
	(0.574)	(0.017)	(0.021)	(0.381)	(0.108)	(0.220)	(0.965)
Foundation Trust	4.748	3.099	-1.567	-0.0199	0.0153	3.387*	0.101
	(0.270)	(0.598)	(0.625)	(0.845)	(0.885)	(0.089)	(0.770)
Population within 15km	13.02*	5.841	12.87**	0.0762	0.633***	-5.735	0.193
	(0.091)	(0.578)	(0.026)	(0.675)	(0.001)	(0.107)	(0.752)
Constant	101.7***	99.96***	97.87***	1.032***	0.356***	65.14***	4.050***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N. providers within 15 km	1.181	-2.738	-2.327	0.0134	-0.128*	1.551	-0.296
	(0.662)	(0.476)	(0.265)	(0.841)	(0.065)	(0.231)	(0.173)
Population within 15km	10.33	7.176	17.95***	-0.00225	0.539**	-7.205*	0.193
	(0.233)	(0.560)	(0.008)	(0.992)	(0.016)	(0.083)	(0.782)
Trust is in London	37.34**	-16.86	-14.39	0.322	0.361	0.576	-2.014
	(0.042)	(0.516)	(0.308)	(0.474)	(0.439)	(0.947)	(0.170)
London x N prov 15km	-6.574***	2.882	-0.345	-0.0174	-0.0156	0.914	0.451***
	(0.001)	(0.289)	(0.815)	(0.711)	(0.748)	(0.318)	(0.004)
Controls:	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	93.93***	103.3***	96.56***	1.024***	0.353***	66.54***	4.615***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Observations	147	147	147	147	147	147	145

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

Table 14 replicates the analysis provided in Table 13 but allows population and number of providers to enter independently in the regression equation. It is still the case that the number of providers is negatively associated with knee revisions and positively with the proportion of hip fracture operations within two days. The association with hip replacement and stroke readmissions is not significant anymore. However, for these two variables (as well as knee revisions) population is positively associated with readmission rates. Once we control for hospitals being located in London, the number of providers is still negatively associated with stroke readmissions if hospitals are not located in London and with hip replacement readmissions for hospitals located in London. However, the number of providers is positively associated with redo rates for prostate resections for hospitals located in London. Finally, hospitals in London have higher hip-replacement readmission rates.

5.4 Competition measures and patient experience

Table 15 (upper part) shows that competition is associated with worse patients' experience, in terms of cleanliness and decision involvement but not for trust in nurses. The coefficients appear to be small. Adding one provider reduces the proportion of satisfied patients by less than 0.2%. When control variables are added to the regression (mid part of the table), we see that teaching hospitals and Foundation Trust are characterised by better patient's experience in the three dimensions of patient experience. The association with competition becomes larger and more statistically significant for all three dimensions of patients' experience.

Table 15. Competition and patient experience

	Clean Hospital room/ward	Involved in decisions	Trust in the doctors
N. Provider within 30min	-0.194***	-0.171**	-0.0153
	(0.003)	(0.028)	(0.775)
Constant	86.92***	70.88***	88.37***
	(0.000)	(0.000)	(0.000)
N. Provider within 30min	-0.250***	-0.272***	-0.0925*
	(0.000)	(0.001)	(0.077)
Controls:			
Teaching Trust	1.482**	2.617***	2.016***
	(0.011)	(0.000)	(0.000)
Foundation Trust	1.464***	1.347***	1.119***
	(0.001)	(0.007)	(0.001)
Constant	86.13***	70.12***	87.74***
	(0.000)	(0.000)	(0.000)
N. Provider within 30min	-0.103	-0.384***	-0.0735
	(0.380)	(0.006)	(0.438)
Trust is in London	-4.093**	-6.918***	-4.038***
	(0.011)	(0.000)	(0.002)
	0.211	0.741***	0.343**
London x N. Provider within 30min	(0.260)	(0.001)	(0.025)
Controls	Yes	Yes	Yes
Constant	86.24***	70.84***	88.03***
	(0.000)	(0.000)	(0.000)
Observations	147	147	147

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

Once we allow for a London effect a different picture emerges. Hospitals in London are characterised by worse patients' experience. The effect is large: patients' satisfaction is lower by 4-7%. Conditional on hospitals not being located in London, it is still the case that competition reduces satisfaction with patients' involvement. There is no statistically significant effect on the other two dimensions. Interestingly, conditional on being located in London more competition increases both satisfaction with patients' involvement and trust in nurses.

Table 16 replicates the analysis but uses as a competition measure the number of providers within 15 km standardised by population. We see that now there is a *positive* statistically-significant association between competition and satisfaction in patient's involvement (which is in contrast to the results provided in Table 15). Once we control for the hospital being located in London, this result is confirmed for the hospitals that are not located in London. We do not find a statistically significant association between competition and any other patient satisfaction measure, and nor do we find that hospitals in London differ in patients' satisfaction.

Table 16. Competition (N. providers / population within 15km) and patient experience

	Clean Hospital room/ward	**Involved in decisions**	**Trust in the doctors**
N prov / Population by	0.0675	0.401***	0.0443
	(0.481)	(0.000)	(0.569)
Constant	85.93***	68.64***	88.13***
	(0.000)	(0.000)	(0.000)
N prov / Population by	0.115	0.490***	0.115
	(0.216)	(0.000)	(0.112)
Controls:			
Teaching Trust	0.806	2.262***	1.841***
	(0.160)	(0.001)	(0.000)
Foundation Trust	1.554***	1.564***	1.176***
	(0.000)	(0.001)	(0.001)
Constant	84.82***	67.11***	86.94***
	(0.000)	(0.000)	(0.000)
N prov / Population by	0.0538	0.440***	0.0833
	(0.545)	(0.000)	(0.253)
Trust is in London	0.564	-0.589	-1.143
	(0.871)	(0.884)	(0.687)
	-1.086	-0.495	-0.0267
London x N prov / Population by 15km	(0.330)	(0.702)	(0.977)
Controls	Yes	Yes	Yes
Constant	85.69***	67.79***	87.35***
	(0.000)	(0.000)	(0.000)
Observations	147	147	147

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

Table 17 allows for population to enter independently from the number of providers. Similarly to Table 16, the number of providers is positively correlated with satisfaction in patient's involvement. Population is negatively associated with both patients' involvement and trust in doctors. When we control for hospitals being located in London, it is still the case that for hospitals not located in London the number of providers is positively associated with patients' involvement and population is negatively associated with it.

Table 17. Competition (N providers within 15km) and patient experience, allowing for population

	Clean Hospital	Involved in decisions	Trust in the doctors
N. providers within 15 km	0.0594	0.762***	0.232
	(0.793)	(0.005)	(0.206)
Controls:			
Teaching Trust	1.590***	2.567***	2.075***
	(0.006)	(0.000)	(0.000)
Foundation Trust	1.194***	0.961*	0.967***
	(0.004)	(0.050)	(0.004)
Population (millions) within 15km	-0.927	-3.207***	-1.063*
	(0.211)	(0.000)	(0.077)
Constant	86.14***	70.14***	87.81***
	(0.000)	(0.000)	(0.000)
N. providers within 15 km	-0.132	0.541*	0.149
	(0.621)	(0.090)	(0.495)
Population within 15km (millions)	0.0163	-2.954***	-0.560
	(0.985)	(0.004)	(0.424)
Dummy=1 if Trust is in London	-3.772**	-2.067	-1.896
	(0.038)	(0.336)	(0.200)
London x N prov 15km	0.186	0.289	0.0730
	(0.324)	(0.199)	(0.636)
Controls:	Yes	Yes	Yes
Constant	86.21***	70.46***	87.81***
	(0.000)	(0.000)	(0.000)
Observations	147	147	147

t statistics in parentheses, * p <0.1, ** p<0.05, *** p<0.01.

5.5 Preliminary conclusions

Our main empirical findings suggest that a range of quality indicators tend to be poorly correlated within a hospital. The analysis therefore cautions against extrapolating the findings for a specific quality indicator to others. Moreover, we find that the association between competition and quality varies across quality measures, with the covariates included, and whether hospital is in London.

6. Future research

6.1 Theoretical analysis

Empirical work requires a solid theoretical framework to produce hypotheses, to guide the specification of equations to be estimated, to aid in interpreting results, and to warn when and how empirical results may be misleading. Our survey of the literature identified a number of gaps (the linking of provider markets, waiting times, population size in markets, and the determinants of the number of providers). We plan to extend existing models of hospital competition under fixed prices to incorporate these features to inform our empirical analysis.

6.2 Empirical analysis

Our survey of the relevant empirical literature and our preliminary empirical investigations suggest that the question of the existence and size of the effect of competition on hospital quality in the NHS is not yet settled. Future research should further explore the effect of competition on quality in a number of directions.

We plan to use Hospital Episode Statistics data to construct AMI mortality rates (not part of the Dr Foster quality indicator set we used in this preliminary analysis) and additional quality measures (such as measures of preventable mortality, patient reported outcomes, and some measures included in the NHS Performance Framework). Some of the measures will be specific to elective care. We will examine the correlations amongst these measures to further test how well AMI mortality is correlated with other measures of quality, the extent to which specific quality measures vary over time within hospitals, and the extent to which correlations amongst quality measures are persistent over time.

Simple cross section associations do not establish causality and the empirical literature discussed in section 3 has generally been careful to use other statistical methods (difference in difference analysis with panel data and instrumental variables) which are more likely to be tests for causality. However, the sensitivity of our simple cross-section associations to the choice of quality measure, to allowing for whether a hospital is in London,[4] or to the way that population size is allowed for, raises the possibility that the results in previous studies may also not be robust. We will therefore use a panel of data on the competiveness of hospitals' markets to investigate whether results using more sophisticated statistical tests are also sensitive to these and other factors. We will also investigate the robustness of results to alternative definitions of competitive market structures. Given the importance of distance in defining markets and the interdependence of hospitals' decisions on quality we will investigate the use of methods which allow for spatial clustering of providers and patients (Barrios et al, 2010; Mobley, 2003; Mobley, Frech and Anselin, 2009).

[4] Propper, Burgess and Green (2004) and Bloom et al (2011) include London dummies in their models as intercept shifters but do not interact them with competition to test whether the effects of competition differ in London.

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Appendix A Quality measures

The quality measures are from the Dr Foster websites www.drfosterhealth.co.uk/quality-reports/, www.drfosterhealth.co.uk/patient-experience/.

Mortality rates

The mortality data, like those for the other non-patient experience measures, are derived from Hospital Episode Statistics for April 2009 to March 2010. The mortality data reported by Dr Foster are risk adjusted. A logistic regression is used to estimate the expected in-hospital mortality. Each measure is adjusted for differences in case-mix: sex, age on admission, admission method, socio-economic deprivation, primary diagnosis, co-morbidities, number of previous emergency admissions, financial year of discharge, palliative care, month of admission, ethnicity and source of admission.

The overall standardised mortality rates account for all in-hospital deaths, i.e. all spells whose method of discharge was death. Stroke and hip fracture mortality rates is restricted to in-hospital mortality whose spells' primary diagnostic was respectively acute cerebrovascular disease (ICD10: G46, I60-I64, I66) or fracture neck of femur (ICD10: S720-S722). Standardised deaths after surgery refer to surgical patients who had a secondary diagnosis such as internal bleeding, pneumonia or a blood clot and subsequently died.

High risk conditions include mortality from spells whose primary diagnosis is one of the these five groups: Acute myocardial infarction (ICD10: I21, I22), Acute cerebrovascular disease (ICD10: G46, I60-I64, I66), Pneumonia (ICD10: A202, A212, A310, A420, A430, A481, A78, B012, B052, B250, B583, B59, B671, J12-J16, J170-J173, J178, J18, J850, J851), Congestive heart failure - nonhypertensive (ICD10: I50) and Fracture of neck of femur - hip (ICD10: S720-S722). Low risk conditions include all in-hospital mortalities from all conditions with a death rate lower than 0.5%. This includes more than 100 diagnosis groups.

Readmission rates

Dr Foster also provides data on hospital readmissions within 28 days from discharge for patients admitted for stroke, knee and hip replacement. Stroke, knee and hip replacement standardised readmission ratios are the ratio of observed number of spells with emergency readmissions within 28 days of discharge with a knee replacement procedure (procedure/OPCS code O18, W40-W42,W5[234][1389](+Z844-6), W580-2(+Z846)), a hip replacement procedure (W37-W39, W93-W95) or a acute cerebrovascular disease diagnostic (ICD10: G46, I60-I64, I66), respectively, to the expected number of readmissions for each procedure estimated using a logistic regression that adjusts for factors to indirectly standardise for differences in case-mix (which is the same used for in-hospital mortality standardised ratios). The readmission rate attributed to a given hospital includes all patients who were treated in that hospital and readmitted within 28 days in that same hospital or any other hospital.

Revisions

We also use knee revisions and manipulations within a year and similarly data for patients in need of hip replacement. The knee or hip revisions and manipulations within 1 year are the proportion of joint replacements with a revision procedure within 365 days of the initial (index) procedure, over the total number of joint replacements carried out at the trust over a three year period. The measure refers to a three year period since revisions occur infrequently and therefore sample size may be small in a given year.

Redo rates

Redo rates for prostate resection are the rates of endoscopy resection of outlet of male bladder procedure (OPCS code: M65) spells where a second operation was performed within three years (April 2004 and March 2007). More precisely, all spells where another TURP (Transurethral resection of the prostate) procedure was performed within 3 years of the last TURP procedure are included in the numerator. The denominator includes all TURP procedures discharged between April 2004 and March 2007.

Hip fracture operations within two days

The proportion of hip fracture operations within 2 days is the percentage of patients with a fracture neck of femur primary diagnoses (ICD10: S720-S722) that have received a related procedure (W code) within two days.

Patients' experience

The patient experience measures are based on the 2009 NHS Inpatient Survey for the Care Quality Commission which is administered to a random sample of patients in all acute trusts. The variables are derived from three questions to patients: 1) "In your opinion how clean was the hospital room or ward?" (Clean hospital room/ward). The patient could give one of five possible answers: very clean, fairly clean, not very clean, not at all clean. Dr Foster measures the proportion of patients who found the hospital or room very clean or clean. 2) "Were you involved as much as you wanted to be in decisions about your care and treatment?" (Involved in decisions). The patient could answer: yes, definitely; yes, to some extent; no. Dr Foster measures the proportion of patients who answered yes. 3) "Did you have confidence and trust in the doctors treating you? (Trust in the doctors). The patient could answer: yes, always; yes, sometimes; no. Dr Foster measures the percentage of patients who answered yes.

Appendix B
Model of competition, market size, and quality under fixed prices

This appendix sketches a simple model of a market for hospital care in which hospitals face regulated prices and compete for patients via their choice of quality. The model develops the standard circular road specification of Vickrey (1964) and Salop (1979) which is also the basis for the papers on competition and quality by Gravelle (1999) and Brekke et al (2011).

1 Model

Consider a market for hospital treatment where n hospitals are equidistantly located on a circle with circumference of length L. H identical patients are distributed uniformly around the circle with density $h = H/L$ Locations of hospitals and patients are defined by their clockwise distance from an arbitrary origin on the circle. Each patient demands at most one unit of treatment. The utility of a patient who is located at w and is treated at hospital i, located at z_i, is

$$U(w, z_i) = v - t\left|w - z_i\right| + q_i, \tag{1}$$

where q_i is the quality at hospital i, t is the transportation cost per unit of distance travelled, and V is the gross valuation of treatment. We assume v is large enough that all patients choose to be treated.

The distance between hospitals is equal to L/n. The patient who is indifferent between seeking treatment at hospital i located at z_i and the neighbouring hospital $i-1$ located at $z_i - \frac{L}{n}$, is located at w_i^-, defined by $v - t\left|w_i^- - z_i\right| + q_i = v - t\left|w_i^- - (z_i - \frac{L}{n})\right| + q_{1-1}$, so that

$$w_i^- = z_i - \left(\frac{tL}{n} + q_i - q_{i-1}\right)\frac{1}{2t} = z_i - \left(\frac{L}{2n} + \frac{q_i - q_{i-1}}{2t}\right)$$

Similarly patients at

$$w_i^+ = \left(q_i - q_{i+1} + \frac{t}{n}\right)\frac{L}{2t} - z_i = \frac{L}{2n} + \frac{q_i - q_{i+1}}{2t} - z_i$$

are indifferent between hospital i and hospital $i+1$ located at $z_i + \frac{L}{n}$.

Total demand facing hospital i from both segments is[1]

$$D_i = D\left(q_i, q_{-1}, q_{i+1}\right) = h\left(w_i^+ - w_i^-\right) = \frac{H}{n} + \frac{h}{t}\left(q_i - \frac{q_{i-1} + q_{i+1}}{2}\right), \tag{2}$$

so that

$$\frac{\partial D_i}{\partial q_i} = \frac{h}{t} \tag{3}$$

A higher *total* population H implies a higher demand and an increase in quality increases demand more when population *density* $h = H/L$ is higher.

Hospitals are prospectively financed by a third-party payer offering a per-treatment price p and a lump-sum transfer T. The cost function is $C(x_i, q_i)$ where x_i is the number of patients treated, with $C_x > 0$, $C_q > 0$, $C_{xx} \geq 0$, $C_{qq} > 0$ and $C_{xq} \lesseqgtr 0$. The last assumption means that we allow for both cost substitutability ($C_{xq} > 0$) and cost complementarity ($C_{xq} < 0$) between quality and output. We assume that hospitals meet their demand D_i generated by their quality and the quality of their neighbouring hospitals. We assume that $p > C_x$ to ensure that treating more patients at given quality will increase profit.

The objective function of hospital i is

$$\pi = T + pD\left(q_i, q_{-1}, q_{i+1}q_i, q_{-1}, q_{i+1}\right) - C\left(D\left(q_i, q_{-1}, q_{i+1}\right), q_i\right) = \pi(q_i, q_{-1}, q_{i+1}; \cdot) \tag{4}$$

Altruistic concerns for patients could be incorporated into the model by assuming that the hospital gets utility $A(x_i, q_i)$ from treating x_i patients with quality q_i and writing the utility function as $u_i = \pi_i + A_i = T + pD_i - C^*(D_i, q_i)$ where $C^* = C - A$.

Hospitals simultaneously and independently choose their qualities to maximise (4) so that the first order condition is

$$\begin{aligned}
\pi_{q_i} &= \left[p - C_x(D_i(q_i, q_{i-1}, q_{i+1}), q_i)\right]\frac{\partial D_i}{\partial q_i} - C_q(D_i(q_i, q_{i-1}, q_{i+1}), q_i) \\
&= \left[p - C_x(D_i(q_i, q_{i-1}, q_{i+1}), q_i)\right]\frac{h}{t} - C_q(D_i(q_i, q_{i-1}, q_{i+1}), q_i) = 0 \qquad (5)
\end{aligned}$$

The second-order condition is

$$\begin{aligned}
\pi_{q_i q_i} &= -\frac{\partial D_i}{\partial q_i}\left[C_{xx}\frac{\partial D_i}{\partial q_i} + 2C_{xq}\right] - C_{qq} \\
&= -\frac{h}{t}\left[C_{xx}\frac{h}{t} + 2C_{xq}\right] - C_{qq} < 0 \qquad (6)
\end{aligned}$$

With firms identical except for location there is a symmetric equilibrium with all firms choosing the same quality q^e provided that either $C_{xq} \neq 0$ or $C_{qq} \neq 0$.[2]. The symmetric

[1] We restrict attention to configurations of quality across hospitals where it is never the case that a patient will wish to choose a hospital other than one of the two nearest.

[2] We must assume that either $C_{qq} \neq 0$ or $C_{qx} \neq 0$ otherwise an equilibrium will not exist. With both $C_{qq} = 0$ and $C_{qx} = 0$, so that the cost function is $C = g(x) + \delta q$, the marginal profit from quality when all firms choose the same quality so that $x_i = H/n$ for all i, is $(p - g'(H/n))(h/t) - \delta$ which is constant with respect to q_i. Apart from the knife edge case in which $(p - g'(H/n))(h/t) = \delta$, every firm will want to increase or decrease quality so that all firms having the same quality cannot be an equilibrium.

equilibrium satisfies

$$\pi_{q_i} = [p - C_x(D_i(q^e, q^e, q^e), q_e)] \frac{\partial D_i}{\partial q_i} - C_q(D_i(q^e, q^e, q^e), q_e) = 0 \tag{7}$$

where $\partial D_i / \partial q_i = h/t > 0$. Equilibrium quality q^e is found by substituting (2)-(3) into (7) and setting $q_i = q_{i-1} = q_{i+1} = q^e$.

1.1 Constant marginal cost

With cost function $C = cx + \frac{1}{2}\delta q^2$ the equilibrium quality is:

$$q^e = \frac{h}{\delta t}(p - c) = \frac{H}{\delta t L}(p - c) \tag{8}$$

so that equilibrium quality under monopolistic competition is not affected by the number of firms but increases with the population density and decreases with transport cost , provided that price exceeds marginal treatment cost: $\partial q^e / \partial n = 0$, $\partial q^e / \partial h > 0$, $\partial q^e / \partial t < 0$.

An increase in the number of providers has no effect on quality: a increase in the number of providers reduces demand for each provider but does not alter the marginal benefit of quality.A lower transportation costs increases quality because it increases the responsiveness of demand to quality.

A higher population increases quality. The intuition is analogous to that for a lower transportation cost: a higher population increases the demand increase from an increase in quality.

The econometric implication of the dependence of quality on population density is that if density is not controlled for in the regression model, the estimated effect of variables with which it is correlated will be biased. In particular, if the number of providers is positively correlated with the population density, then the effect of competition, measured by the number of providers in a market, will biased upward.

1.2 Increasing marginal cost

With cost function is $C = \frac{1}{2}cx^2 + \frac{1}{2}\delta q_i^2$, equilibrium quality is

$$q^e = \frac{h}{\delta t}\left(p - c\frac{H}{n}\right) = \frac{H}{\delta t L}\left(p - c\frac{H}{n}\right) \tag{9}$$

Now an increase in the number of providers increases quality, again providing that price exceeds marginal treatment cost. With more providers, each provider treats fewer patients and, because marginal cost of treatment is increasing in the number of patients, the marginal cost of treatment is reduced, so that the marginal profit from higher quality, after allowing for the resulting increase in numbers treated, is higher with more providers. A higher number of providers now increases quality: an increase in the number of providers reduces the marginal treatment cost and makes a marginal benefit of quality more profitable.

The effect of an inrease in the total population H is ambigous:

$$\frac{\partial q^e}{\partial H} = \frac{1}{\delta t L}\left(p - 2c\frac{H}{n}\right) \gtrless 0 \tag{10}$$

On one hand, higher population implies a larger number of patients who are willing to shift when quality increases. On the other hand, it implies a higher marginal treatment cost which reduces the marginal profit from higher quality. margin. Depending on which of the two effects is larger, quality may increase or decrease.

The effect of an increase in the geographical size of the market as captured by the circumference L, keeping the population H constant, is unambiguously negative

$$\frac{\partial q^e}{\partial L} = -\frac{H}{\delta t L^2}\left(p - 2c\frac{H}{n}\right) < 0 \tag{11}$$

Thus less densely populated markets have lower quality than markets with the same population but higher population density. The reason is that when the geographical size of the market L increases, hospitals are further apart and patients have on average to incur higher travel costs to access a hospital. An increase in quality by a hospital will therefore attract fewer additional patients so that the marginal revenue from quality is reduced.

1.3 Non separable cost function

The first two examples assume that the cost of additional quality is independent of the number of patients treated. For example, quality is improved by investments in better software for record keeping or in greater investment in better trained staff. Now suppose that the cost of quality depends on the number of patients treated. For example, quality is improved by employing more staff per patient. With the cost function $C = \gamma x^{\alpha} q$ $(\alpha \geq 1)$ we have $C_x >$, $C_{xx} \geq 0$, $C_q > 0$, $C_{xq} > 0$. Equilibrium quality is

$$q^e = \frac{p}{\delta}\left(\frac{n}{H}\right)^{\alpha-1} - \frac{tL}{n\alpha} = \frac{p}{\delta}\left(\frac{n}{H}\right)^{\alpha-1} - \frac{tH}{hn\alpha} \tag{12}$$

which is decreasing in t and total population but increasing in the number of firms and the density of population.

1.4 General cost function

With a general cost function the symmetric equilibrium q^e is defined implicitly by the first order condition on quality (5) evaluated at $q_i^e = q^e$, $i = 1, ..., n)$

$$f(q^e, H, t, L, p, n) = \frac{H}{tL}\left[p - C_x\left(\frac{H}{n}, q^e\right)\right] - C_q\left(\frac{H}{n}, q^e\right) = 0 \tag{13}$$

Thus for some parameter k,[3]

$$\frac{\partial q^e}{\partial k} = -\frac{f_k(q^e, H, t, L, p, n)}{f_{q^e}(q^e, H, t, L, p, n)} \tag{14}$$

Now

$$f_{q^e}(q^e, H, t, L, p, n) = -\left[\frac{H}{tL} C_{xq}\left(\frac{H}{n}, q^e\right) + C_{qq}\left(\frac{H}{n}, q^e\right)\right] \tag{15}$$

and the existence of a symmetric equilibrium (see footnote 1) requires either $C_{xq} \neq 0$ or $C_{qq} \neq 0$. To avoid perverse comparative statics we assume that $f_{q^e} < 0$, which requires either $C_{xq} > 0$ or $C_{qq} > 0$.

Increases in t reduce quality, provided the requlated price exceeds marginal cost,

$$\frac{\partial q^e}{\partial t} = -\frac{1}{f_{q^e}} \frac{H}{t^2 L} (p - C_x) \tag{16}$$

The effect of increase in the number of firms is

$$\frac{\partial q^e}{\partial n} = -\frac{1}{f_{q^e}} \left[\frac{H}{tL} C_{xx} \frac{H}{n^2} + C_{qx} \frac{H}{n^2}\right] \tag{17}$$

which is positive if marginal treatment cost is increasing and the marginal cost of treatment greater with higher quality. The effect of an increase in population is

$$\frac{\partial q^e}{\partial H} = \frac{-1}{f_{q^e}} \left[\frac{1}{tL} (p - C_x) - \frac{H}{tL} C_{xx} \frac{1}{n} - C_{qx} \frac{1}{n}\right] \tag{18}$$

which is ambiguous without further assumptions about the cost function. However, an increase in the geographical market size (L) reduces quality if price exceeds marginal treatment cost

$$\frac{\partial q^e}{\partial L} = \frac{-1}{f_{q^e}} \left[-\frac{H}{tL^2} (p - C_x)\right] < 0 \tag{19}$$

2 Free entry

Profit for every firm in the symmetric equilibrium ($q_i^e = q^e$, $i = 1, ..., n$) is

$$\pi(q_i^e, q_{i-1}^e, q_{i+1}^e; \cdot) = \pi^e(n, H) = T + p\frac{H}{n} - C\left(\frac{H}{n}, q^e(n, H)\right) \tag{20}$$

where $q^e(n, H)$ is given by (13) which is the first order condtion (5) evaluated at $q_i^e = q^e$, $i = 1, ..., n$).

[3] Note that at the equilibrium a parameter change will change all firms' qualities equally and leave demand unchanged. Thus the effect of a parameter change in equilibrium (with the number of firms fixed) is not given by total differentiaton of the first order condition (5) holding the qualities of other firms constant.

The effect of the number of the providers n on the equilibrium profit is

$$\begin{aligned}\frac{\partial \pi^e}{\partial n} &= -(p-C_x)\frac{H}{n^2} - C_q\frac{\partial q^e}{\partial n}\frac{H}{n^2} \\ &= -(p-C_x)\frac{H}{n^2} - C_q\frac{(C_{xx}+C_{qx})}{C_{qq}+C_{qx}\frac{H}{tL}}\frac{H}{n^2} \qquad (21)\end{aligned}$$

which is negative as long as the price is above the marginal cost and the cost function is sufficiently convex in quantity. Note that the marginal effect of n on equilibrium profit is the sum of the direct effect of n plus the indirect effect through the induced change in quality. If the quality of all other providers was being held constant this latter term would be zero because the firm chooses its quality to maximise quality, given the qualtiy level of its rivals which it takes as given in the Nash equilibrium. But the change in n induces changes in the qualities of all firms so that the envelope theorem does not apply and the indirect effect is not zero.[4]

Intuitively, a higher numbers of providers reduces demand which reduces profits (first term) and moreover it increases quality thanks to the lower marginal cost (second term). Therefore, overall more entry reduces profitability. With free entry and exit, the equilibrium number of providers n^e is the number of providers such that equilibrium profit is zero:

$$\pi^e(n^e, H) = T + p\frac{H}{n^e} - C\left(\frac{H}{n^e}, q^e(n^e, H)\right) = 0 \qquad (22)$$

Totally differentiating the above condition, we investigate the effect of H on n^e :

$$\frac{\partial \pi^e}{\partial n^e}dn^e + \frac{\partial \pi^e}{\partial H}dH = 0$$

or, more extensively,

$$\begin{aligned}\frac{dn^e}{dH} &= \frac{-\pi^e_H}{\pi^e_n} = \frac{\frac{1}{n^e}(p-C_x) - C_q\frac{\partial q^e}{\partial H}}{\left[(p-C_x) + C_q\frac{\partial q^e}{\partial n^e}\right]\frac{H}{(n^e)^2}} \\ &= \frac{\frac{1}{n^e}(p-C_x) - C_q\frac{(p-C_x)-\frac{1}{n}\left[C_{xx}\frac{H}{tL}+C_{qx}\right]}{C_{qq}+C_{qx}\frac{H}{tL}}}{\left[(p-C_x) + C_{q^e}\frac{(C_{xx}+C_{qx})}{C_{qq}+C_{qx}}\right]\frac{H}{(n^e)^2}} \qquad (23)\end{aligned}$$

A higher population density increases the profitability of the market and encourages entry (first term in the numerator). However, population density also affects quality (second term in the numerator). If quality is higher then it reduces profit; if it is lower it increases profit. Whether quality increases or decreases depends on two opposite effects: on one hand, higher demand generates an incentive to compete more fiercely on quality; on the other hand, higher demand increases the marginal cost which tends to reduce quality.

Depending on the assumptions about the cost function it is possible that markets with larger populations will have more or less competition (more or fewer providers). We have also seen in section 1.4 that markets with more providers can have higher or lower quality.

[4] The effect of n on equilibrium quality is given by the implicit differentiation of the first order condition on quality evaluated at equilibrium qualities for all providers (13).

Thus empirical analyses need to take account of population size in markets. Failing to include a measure of population in the regression of quality on competition could lead to a biased estimate of the effect of competition on quality. If larger population leads to both an increase in the number of providers and quality then omitting population from the regression model will bias the estimated effect of the number of firms on quality upwards. Similar potential omitted variable bias arises from the effect of other aspects of market size, such as population density or market area (captured in these models by L).

3 Extensions

The current model assumes that providers always meet the demand. In further work we plan to investigate the relationship between competition and quality when, as is the case in the NHS and many other public health care systems, there is rationing by waiting. If we retain the Vickrey (1964) circular market model, this requires specifying preferences over quality and waiting times to derive demand functions $D(q_i, q_{i-1}, q_{i+1}, \omega_i, \omega_{i-1}, \omega_{i+1})$ where the waiting time ω_i for provider i is defined by $D(q_i, q_{i-1}, q_{i+1}, \omega_i, \omega_{i-1}, \omega_{i+1}) = x_i$ and providers choose quality and supply (x_i) thus determining waiting times (or quality and waiting times thus determining supply).

It seems likely that the market will exhibit two types of equilibrium: one with positive waiting times and zero quality (if p is small enough) and another (if p is high enough) with zero waiting times and positive quality which is equivalent to the model above. It seems unlikely that there can be both positive waiting times and positive (above minimum) quality in equiliberium with providers who are motivated solely by profit. If a provider with positive quality and waiting time reduces its quality, keeping its supply constant, so that its waiting time falls to equate demand to its supply, then it will have an unchanged revenue and its costs will be lower. Thus equilibria with postive quality and waiting times require, in the deterministic waiting time framework, that providers are partially altruistic. In these types of specification it is likely that the role of the budget constraint on hospitals will become important.