Hospital competition and quality for non-emergency patients in the English NHS

Giuseppe Moscelli*,**, Hugh Gravelle* and Luigi Siciliani*,**

Abstract

We investigate the effect on the quality of three high-volume non-emergency treatments of a reform that relaxed restrictions on patient choice of hospital. We employ a quasi difference-in-difference strategy and use control functions allowing for patient selection into providers correlated with unobserved morbidity. Public hospitals facing more rivals reduced quality, increased waiting times, and reduced length of stay for hip and knee replacements. This is likely due to regulated prices implying larger losses on these treatments compared to coronary artery bypass grafts, where no effects were found. Our findings are robust to estimation methods and competition measures, allowing for private providers’ entry.

1. Introduction

In OECD economies health spending accounts for around 9% of GDP (OECD, 2019). Reforms in several countries have attempted to increase competition among healthcare providers to...
reduce costs and improve quality (EXPH, 2015; OECD, 2012; Siciliani et al., 2017). In systems with low or zero patient co-payments, hospitals facing regulated prices can attract patients only by improving quality. It is argued that increasing competition among hospitals will lead to higher quality. One way to increase competitive pressures is to enhance the ability of patients to choose their hospital (Blöchliger, 2008; Le Grand, 2003).

Theory models predict that greater competition increases quality when hospitals maximize profit, face regulated prices, have constant marginal costs, and the price exceeds the cost of the marginal patient (Gaynor, 2006), but predictions are ambiguous when additional features of the hospital sector and the institutional context are taken into account (Katz, 2013). Hospitals in publicly funded systems may face constraints on capacity resulting in an increasing marginal cost of treatment. Demand for elective (non-emergency) care is rationed by waiting time (Lindsay and Feigenbaum, 1984) and patients can wait a long time for treatment (Siciliani et al., 2013). This will affect the response of quality and supply to greater competition and imply that evaluation of competition policy should also take account of its effect on waiting time. Public and non-profit hospitals may have altruistic motives and a limited ability to appropriate profits. These may lead them to treat patients whose marginal cost exceeds the regulated price and thus to respond to competition policies, which make demand more responsive to quality, by reducing quality (Brekke et al., 2011, 2014).

We use a natural experiment to investigate the effect of greater patient choice on the quality of three high volume non-emergency treatments: hip replacement, knee replacement, and coronary artery bypass. Prior to 2006, patients in the English National Health Service (NHS) had their choice of hospital limited to those with which their local health authority had a contract. In 2006 patients were given the right to be offered a choice of at least four hospitals and this was later extended to any qualified provider. We use a quasi difference in differences strategy to investigate whether the relaxation of constraints on patient choice led to larger changes in quality for hospitals with more rivals. We measure hospital quality by whether patients have an emergency hospital readmission within 28 days of discharge after their index elective treatment, or whether they die anywhere within 30 days of admission for coronary bypass surgery.

We make five main contributions. First, we examine whether the 2006 patient choice reform had greater effects on quality of elective (non-emergency) surgical treatments for hospitals with more rivals (and also consider the effects on waiting times and patient length of stay.) The bulk of previous literature, reviewed in third subsection of Section 2, is concerned with the effect of competition on the quality of emergency treatment, mainly for acute myocardial infarction (AMI). We examine elective treatments because hospitals compete for elective, rather than emergency, patients. Moreover, the correlation between emergency and elective quality patients across hospitals is low (as we show in Section 5) and we find that the reform had different effects on emergency and elective quality.

Second, we consider three high-volume elective treatments: hip replacement, knee replacement, and coronary artery bypass grafts (CABG). These are procedures whose patients’ health outcomes have been used by the English NHS as indicators of the performance of NHS-funded secondary healthcare providers.1 Hip and knee procedures are in a different specialty (musculoskeletal) from CABG (circulatory), which has fewer providers, all in the public sector. There are also low correlations in quality across the procedures, even for hip and knee replacements. Using these three procedures allows us to examine the heterogeneity of the effects of the choice reform across specialties, within specialties, and across market structures.

Patients’ choice of hospital is affected, inter alia, by their beliefs about its quality and patients with different levels of morbidity may vary in the relative importance they attach to quality compared to other attributes, such as distance. The choice reform widened patient choice sets and its effect on choice of hospital could have varied with patient morbidity. Concerns about choice

1 See https://digital.nhs.uk/data-and-information/publications/clinical-indicators/compendium-of-population-health-indicators/compendium-hospital-care/.
of providers of different quality being differently affected by unobserved patient morbidity led the earlier literature to concentrate on the effect of competition on the quality of emergency rather than elective conditions. Our third contribution is to test for and control for this selection bias using control functions (Terza et al., 2008; Wooldridge, 2015).

Fourth, we develop a new theory model to guide our analysis and interpretation of results. Previous theory models have examined how hospitals in fixed price regimes compete in quality (Gaynor, 2006; Brekke et al., 2014) or in waiting times (Brekke et al., 2008; Sa et al., 2019) but not in both. We provide a theory model where the hospital simultaneously chooses quality and waiting times.

Finally, we examine some possible mechanisms underlying the effects of the choice reform on quality. First, longer waiting times could affect emergency readmissions because patient health could deteriorate while waiting for treatment. Second, changes in length of stay could have affected our elective quality measure (emergency readmissions after elective treatment) if patients were discharged “quicker but sicker.” Third, hospitals with better emergency quality could have worse elective quality within the same specialty because physicians must choose how to allocate their efforts between them. We therefore test whether the choice reform also affected waiting times and length of stay for our three elective procedures and the mortality rates for emergency acute myocardial infarction (AMI) and emergency hip replacement.

We find that for the two musculoskeletal treatments—hip and knee replacements—the choice reform led to reduced quality for providers facing more rivals pre-reform relative to those facing fewer rivals. We estimate that, relative to a provider with no rivals, the choice reform increased emergency readmissions after hip replacement by 0.57% for a provider facing the average number of rivals, compared to the mean pre-reform risk of 5.72%. For knee replacement, the reduction was 0.30%, compared to the baseline risk of 1.9%. There was no effect of the choice reform on quality (whether measured by emergency readmission or mortality) for CABG patients. We find evidence of endogenous time-varying patient selection into hospitals. Allowing for unobserved patient selection increases the magnitude of the estimated effect of the choice reforms by a fifth for hip replacement, but doubles it for knee replacement.

Our results are robust to the use of alternative competition measures based on different definitions of the relevant market. They are also robust to different control function methods, to the inclusion of indicators of rurality and population density, to allowing the effects of covariates to differ pre- and post-choice reform, to allowing for potential sample selection bias from focusing on NHS patients treated in NHS hospitals, to allowing for cream-skimming by new private entrants, and to survivorship bias arising because only patients who do not die are counted in our emergency readmission measure.

We find that providers facing more rivals pre-reform had greater increases in waiting times and reductions in length of stay for hip and knee replacements, thereby possibly increasing readmission rates. Effort diversion is suggested by our finding that the choice reform reduced mortality for emergency hip fracture patients (in the same specialty as elective hip and knee replacements) and for emergency AMI patients (in the same specialty as elective CABG patients).

Theory models suggest that a key factor influencing the effect of competition on quality is whether the hospital makes a profit on the patients who would be attracted by an increase in quality. Thus, the apparently counter-intuitive negative effect of the choice reforms on hip and knee replacement quality may be explained by our back of the envelope calculations, which suggest that hospitals were making a larger loss on hip and knee replacements, where we find a reduction in quality, than on CABG treatments, where we find no effect on quality.

In the next section, we describe the institutional settings of the English NHS and summarize previous literature. In Section 3, we sketch a theoretical model to guide the interpretation of our results. In Sections 4 and 5, we explain the methods used in the empirical analysis and describe the data. Section 6 presents the results. Section 7 concludes with a discussion of the results and their relationship with those from other studies of hospital competition and quality.
2. **Background**

**English National Health Service.** NHS hospital treatment is tax funded and there are no charges to patients. Patients can only access elective hospital care by a referral from their family doctor (general practitioner; henceforth, GP). Most hospital care for NHS patients is provided by public hospitals (NHS Trusts), which are public bodies subject to financial and regulatory control and expected to break even.

A series of changes in the market for NHS-funded hospital care were introduced during our study period (2002/3-2011/12) with the intention of stimulating competition to improve quality (Department of Health, 2000, 2002) and reduce waiting times. During the study period, local health authorities (Primary Care Trusts, PCTs) held budgets from the Department of Health to purchase hospital care for their populations. Before 2003/4, PCTs mainly placed block contracts with local healthcare providers to treat all patients referred to the hospital. GPs could in principle refer to any NHS provider, with an out-of-area tariff being charged if the provider was not in contract with the PCT in which the patient was resident.

Between 2003/4 and 2008/9, prospective payment per patient treated was progressively rolled out. The payment system was based on Healthcare Resource Groups (HRGs): groupings of hospital services of similar costs and type, akin to Diagnosis Related Groups. The tariff for a procedure was the average of relevant HRG costs over all hospitals in the two previous years, with an allowance for geographic variation in input prices (Monitor, 2013; Grašič et al., 2015).

Until 2003/4, very few NHS-funded patients were treated in private sector hospitals. From 2003/4, privately owned Independent Sector Treatment Centres (ISTCs) specializing in the provision of a limited set of elective treatments, including hip and knee replacement but not CABG, were encouraged to locate in areas where NHS patients were experiencing long waiting times (Department of Health, 2004; Department of Health, 2006). They received favorable 5-year contracts with revenue that did not vary with the number of patients treated (Naylor and Gregory, 2009). From 2008/9 onward, other private providers were allowed to provide most types of non-emergency treatment to NHS-funded patients. These non-ISTC private providers were paid the same HRG based tariff per patient as NHS providers. As initial ISTC contracts expired, ISTCs were also paid the HRG tariff from 2009/10 onward.

Before 2006, the amount of choice for elective care varied across PCTs and general practices, depending on the set of hospitals with which the PCT had placed block contracts and GPs’ willingness to refer outside this set. From 2006/7, elective patients had to be offered a choice of at least four hospitals by their GPs and from 2008/9, they could choose any qualified provider, whether NHS or private.

The numbers of NHS patients treated in the private sector increased rapidly from 2008/9 (Arora et al., 2013). By 2010/11, the private sector treated around 4% of all NHS elective patients (Hawkes, 2012).

To complement the choice reform, an electronic booking service for outpatient appointments was rolled out from 2005 (Dusheiko and Gravelle, 2018). This made it easier for patients and their GPs to book outpatient appointments during a consultation and provided information on waiting times for appointments. In 2007, the NHS Choices website was established to provide public information on all providers of NHS services. The website enabled users to search for providers within specified distances and is likely to have improved patient information about what was available locally.

Patient choices of hospital are guided by their GPs (Beckert, 2018) who are repeat players (on average a general practice will have around six patients per year who have a hip replacement) and GPs from different practices can exchange information at local medical committees.

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2 Our data are for financial years (e.g., 1st April 2010 to 31st March 2011).

3 Financial penalties for emergency readmissions following elective procedures were introduced in 2011 (Kristensen, 2017) but will not have affected provider incentives in our study period (2002/3 to 2010/11).

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and other meetings of local GPs. There is considerable evidence that choice of hospital is affected by quality (Brekke et al., 2014). Moscelli et al. (2016) found that elective hip replacement patients were less likely to choose hospitals with higher emergency readmission rates after hip replacement, and Gaynor et al. (2016) that elective CABG patients less likely to choose hospital with higher CABG mortality rates. Both studies found that responsiveness of demand to these quality measures increased after the choice reform.

**Elective hip and knee replacement and coronary artery bypass markets.** Elective hip and knee replacement are musculoskeletal treatments, usually for osteoarthritis health problems, while CABG is a cardiovascular procedure used for some circulatory system diseases (e.g., clogged arteries). In the English NHS, all three are publicly-funded high-volume elective procedures (**Figure 1**), with a yearly average of about 10,000 first time CABG treatments and over 45,000 each for primary hip and knee replacement.

The supply sides of the markets for these treatments differ. In the period covered by our sample, NHS-funded hip (knee) replacement surgery was offered in 232 (238) NHS sites and 47 (52) private hospital sites. Between 2005/6 and 2010/11, the percentage of NHS-funded patients treated in private providers increased from 1.3% to 13.6% for hip replacements and 1.2% to 13.7% for knee replacements (web Appendix Table A1). NHS-funded elective CABG surgery was performed almost exclusively in 47 NHS hospital sites.

Privately funded elective CABG patients treated in private hospitals accounted for 4.87% of all CABG patients in England (NICOR, 2012). In 2010/11, 11% of elective hip and knee replacements were privately funded (Arora et al., 2013).

**Previous literature.** The empirical literature on hospital competition and quality has mainly focused on quality for emergency conditions, in particular acute myocardial infarction (AMI). This approach reduces possible bias from selection of hospitals by patients with different unobserved morbidity as emergency patients are unlikely to be choosing their hospital, but it relies on the assumption that quality for emergency patients is strongly correlated with quality, and therefore demand, from elective patients (Bloom et al., 2015). Results are mixed, with some studies finding that increased competition increases quality (Kessler and McClellan, 2000; Kessler and Geppert, 2005; Cooper et al., 2011; Gaynor et al., 2013; Colla et al., 2016; Bloom
et al., 2015) and others that it has no effect (Mukamel et al., 2001) or reduces quality (Shen, 2003; Propper et al., 2004; Propper et al., 2008), or has effects which vary across the type of emergency condition (Moscelli et al., 2018a).

There are fewer studies of competition for elective care. Colla et al. (2016), using cross-sectional data and relying on observables to allow for case-mix differences across hospitals, find that competition had no effect on 30-day emergency readmission rates for Medicare hip and knee replacement patients and reduced quality for dementia patients. Wilson (2016) uses a control function with distance as an instrumental variable to control for unobserved selection among hemodialysis patients in Atlanta. Quality at a provider was lower the greater the proportion of local providers who were affiliated with said provider. In a 1 year cross-section study of English hip replacement patients, Feng et al. (2015) measure quality using very detailed data on patient reported outcomes and find that competition had a positive but statistically insignificant association with quality. Cooper et al. (2018) find that the opening of a private hospital near an NHS hospital led to a reduction in its pre-operative length of stay for hip and knee replacement patients, and left the NHS providers to treat sicker patients who had longer post-operative length of stay. Using data from 2009 to 2012, Skellern (2018) finds that competition had a negative effect on patient reported outcomes for NHS hip and knee replacement, groin hernia, and varicose veins, though the effect is statistically insignificant once hospital fixed effects are allowed for.

Our analysis combines features from these studies: patient level outcomes; focus on elective treatments; longitudinal variation in a country-wide setting (all admissions in England); using a control function to allow for patient unobservable self-selection; inclusion of hospital site fixed effects to allow for unobservable time-invariant supply-side differences; and analysis of the effects of the competition on quality, waiting times, and length of stay.

3. Theoretical framework: competition, waiting time, and quality

The hospital faces a demand function \( D(q, w, \theta) \) which is increasing in quality \( (D_q > 0) \) and decreasing in waiting time \( (D_w < 0) \). \( \theta \) is a parameter which increases the responsiveness of demand to quality and waiting time \( (D_{\theta q} > 0, D_{w\theta} < 0) \) and can be interpreted as an exogenous measure promoting competition, such as a policy increasing patient choice, or improving information about quality. The policy may increase or reduce demand.\(^4\)

The hospital chooses \( w \) and \( q \) and meets the resulting demand. Its cost function \( C(D(q,w;\theta),q) \) is increasing and convex in output and quality. Its objective function is

\[
v(w, q; \theta) = \pi (w, q, \theta) + B(w, q) = pD(w, q; \theta) - C(D(w, q; \theta), q) + B(w, q),
\]

where \( p \) is the fixed price per patient treated and \( B(w, q) \) captures additional motivations to provide quality, \( B_q > 0 \), and to reduce waiting times, \( B_w < 0 \) that go beyond current profits. Public hospitals will care about profit because they are expected to break even. Managers and staff in all types of hospital will care directly about quality and waiting times because of intrinsic motivation (Bénabou and Tirole, 2006) or altruistic concerns toward the patients (McGuire, 2000). \( B(w, q) \) may also capture future effects on demand. Lower quality may risk unfavorable media coverage, audits by regulators, and possible worse future job prospects for hospital managers. A concern with waiting time could reflect penalties for breaching waiting times targets (Propper et al., 2010).

We assume that \( v(\bullet) \) is well behaved: strictly concave in \( w \) and \( q \) with continuous second order partial derivatives.

First order conditions at an interior solution \( (w > 0, q > 0) \) are,

\[
v_w(w, q; \theta) = [p - C_D(D(w, q; \theta))]D_w(w, q; \theta) + B_w(w, q) = 0,
\]

\(^4\) Subscripts denote derivatives. Note that relaxing constraints on patient choice of hospital could increase demand \( (D_\theta > 0) \) for providers near to patients whose restricted choice set did not include them or reduce it \( (D_\theta < 0) \) for providers far from patients whose restricted choice set included them.

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\[
v_q(w, q; \theta) = [p - C_D(D(w, q; \theta))] D_q(w, q; \theta) - C_q(D(w, q; \theta)) + B_q(w, q) = 0.
\]

For a hospital which has motivation that goes beyond profit, equation (2) implies, as \(B_q < 0\) and \(D_q < 0\), that the hospital will make a loss on marginal patients: \(p - C_D < 0\).

Notice that because demand is rationed by waiting time, a hospital which cares only about profit \((B_q = 0, B_q = 0)\) will, from (2), equate its marginal cost to the regulated price \((p = C_D)\) and, from (3), set quality to its minimum level because \(v_q = -C_q < 0\). Such a hospital will also not respond to shifts in demand when policy or market conditions \((\theta)\) change: it will just let waiting time adjust to clear the market.\(^5\)

The model can also be applied to private providers treating publicly funded patients at a fixed price. Although these providers may have a stronger emphasis on profits relative to other motivations, they will typically have lower waiting times than NHS providers because they treat fewer patients and have a lower marginal cost. A recent study covering a wide range of elective treatments, including hip and knee replacements, found that private and public providers do not differ in quality for NHS-funded patients, as measured by emergency readmission rates (Moscelli et al., 2018b).\(^6\) As mentioned above, we interpret the parameter \(\theta\) as the effects on public hospitals of the relaxation of constraints on choice of provider. It could also be interpreted more broadly as an increase in competitiveness due to entry of private providers.

Our focus is on the effects of changing market conditions (captured by \(\theta\)) on \(w\) and \(q\). These are ambiguous in general, as they depend on the derivatives of both \(v_q(w, q; \theta)\) and \(v_q(w, q; \theta)\) with respect to \(w, q,\) and \(\theta\) and thus on fine details of the cost, demand, and intrinsic motivation functions. We can obtain some intuition by making strong simplifying assumptions about the hospital’s non-profit motivation \(B(w, q): B_w = 0\); the demand function \(D(w, q; \theta)\): \(D_w = 0, D_q = 0, D_q = 0\); and that the marginal costs of output and quality are constant with respect to output: \(C_D = 0, C_q = 0\). With these assumptions (see web Appendix C),

\[
\text{sgn} \frac{\partial q}{\partial \theta} = \text{sgn} \left[ v_{ww} v_{wq} - v_{q} D_{q} \right] = \text{sgn} \left[ v_{q} \right] D_{q} = \text{sgn} (p - C_D) D_{q} ^\theta ,
\]

\[
\text{sgn} \frac{\partial w}{\partial \theta} = \text{sgn} \left[ v_{ww} v_{wq} - v_{q} D_{q} \right] = \text{sgn} \left[ v_{q} \right] D_{q} = \text{sgn} (p - C_D) D_{q} ^\theta .
\]

A direct concern with waiting time \((B_w < 0)\) leads the provider to increase output beyond the profit maximizing point and to operate where marginal cost exceeds the price: \(p < C_D\). As an increase in competition makes demand more responsive to quality \((D_q ^\theta > 0)\); it will increase the marginal loss from increase in quality and so the hospital will reduce quality. Similarly, the increased marginal loss from increasing volume to reduce waiting time will lead the hospital to increase waiting time.

Relaxing the strong assumptions made above means that the hospital may not increase waiting time and reduce quality when competition increases, but a provider which cares directly about quality and waiting time will find that its marginal losses from increasing quality and reducing waiting time will increase when greater competition makes demand more responsive to quality and waiting time and this will explain why it might reduce quality and increase waiting time.

4. Methods

\(\Box\) Model specification. We measure quality as a patient having an emergency readmission within 28 days of discharge from hospital after their elective procedure. For CABG patients, we

\(^5\) With a high enough regulated price, the provider will choose positive quality and a zero waiting time. Only models with stochastic waiting times, as in Gravelle and Schroyan (2020), can yield solutions in which a profit maximizing provider facing a regulated price will have positive quality and positive (expected) waiting time.

\(^6\) An earlier theoretical study (Brekke et al., 2012) shows that the effect of being a private versus a public hospital on quality is theoretically ambiguous. On one hand, private providers have a stronger incentive to attract demand and compete on quality. On the other hand, they have stronger incentives to skimp on quality to increase profits.
also measure quality as the patient dying in or outside hospital within 30 days of admission for a CABG procedure (first subsection of Section 5). We estimate linear probability models (LPM)

\[ q_{ih} = \beta_t + \mathbf{x}_{ih}' \psi_1 + \gamma \bar{M}_h A_t + \mathbf{x}_{ht}' \psi_2 + \mu_h + \epsilon_{it} + \epsilon_{ht}, \]

(6)

where \( q_{ih} \) is equal to 1 if patient \( i \) treated in NHS site \( h \) in year \( t (t = 2002/3, \ldots, 2010/11) \) had an emergency readmission within 28 days of hospital admission and zero otherwise; \( \beta_t \) is a year effect and \( \mathbf{x}_{ih} \) is a vector of patient covariates; \( \bar{M}_h \) is market structure, measured as the equivalent number of rivals (second subsection of Section 5), facing site \( h \) averaged across the years 2002/3 to 2005/6 before the relaxation of constraints on patient choice; \( A_t \) is the choice policy indicator, being equal to 0 in the four pre-choice reform years (2002/3 to 2005/6) and to 1 in the five post-reform years (2006/7 to 2010/11); \( \mathbf{x}_{ht} \) is a vector of hospital site time-varying covariates. \( \mu_h \) is a time-invariant hospital site effect; \( \epsilon_{it} \) is the effect of unobserved patient characteristics and \( \epsilon_{ht} \) is the effect of unobserved time-varying hospital characteristics.

Equation (6) describes a quasi difference-in-difference strategy (Card, 1992). The parameter of interest, \( \gamma \), is identified through differences in treatment intensity, rather than through the assignment to a defined treatment or control group (Angrist and Pischke, 2009). The treatment is the choice reform and its effect varies across providers exposed to different market structures. The effect of the 2006 choice reform on quality for a provider with \( \bar{M}_h \) rivals compared with a provider with no rivals is \( \gamma \bar{M}_h \): the policy reform pivots the quality function about its intercept on the quality axis in \((q, \bar{M}_h)\) space. We estimate Equation (6) with hospital site fixed effects \( \mu_h \) to control for unobserved time-invariant provider heterogeneity. Year dummies control for time-varying factors, including other policy changes, such as the phased introduction of prospective pricing, and technical progress. We use a rich set of patient characteristics to control for severity (third subsection of Section 5).\(^7\)

Like the bulk of the hospital competition literature, our outcome model is linear. Estimating LPMs has several advantages in our context. First, we can interpret the estimated coefficients as marginal effects because LPMs approximate conditional expectation functions, whether linear or non-linear (Angrist, 2001; Angrist and Pischke, 2009). Second, LPMs with hospital fixed effects are not subject to the incidental parameters problem that afflicts non-linear estimators for limited dependent variables (Lancaster, 2000; Greene, 2004). Third, unlike probit or logit estimators, LPMs are not biased if there is measurement error in the dependent variable (Hausman, 2001). Fourth, we use two control function strategies to allow for endogenous patient choice of hospital (third subsection of Section 4). A linear outcome model permits comparison between them which would not be possible with logit or probit outcome models.\(^8\)

\section*{Endogenous market structure.}

There are two main threats to identification of the change in the effects of market structure after the choice reform of 2006. The first is endogeneity of market structure. Our preferred measure of market structure is based on the Herfindahl–Hirschman Index (HHI): the sum of the square of provider market shares. Because observed market shares may depend on provider quality, we follow the standard practice (Kessler and McClellan, 2000) of computing the HHI using predicted market shares from a model in which patient choice of provider depends on distance and other covariates but does not depend on quality (web Appendix B), but using predicted HHI does not eliminate another source of potential endogeneity of market structure: new providers may choose to locate near poor quality incumbents. Hence, we follow

\(^7\) This baseline quasi-DiD strategy with hospital fixed effects is similar to those used by Cooper et al. (2011) and Gaynor et al. (2013) in their analyses of the effect of the reform on AMI mortality and Moscelli et al. (2018a) for hip fracture mortality, both emergency conditions.

\(^8\) In Table 9, we show that we get similar results to Cooper et al. (2011), Gaynor et al. (2013), and Moscelli et al. (2018a) when we use our specification to examine the effect of the choice reform on AMI and hip fracture mortality using measures of specialty (circulatory, musculoskeletal) market competition.

\(^9\) We also estimated logit outcome models with hospital fixed effects and a control function derived from a conditional logit first stage choice model and obtained very similar marginal effects (Appendix Table A8).
Gaynor et al. (2013) and use a measure of pre-choice time-invariant market structure (i.e., \( \bar{M}_h \), the average of the market structure measures over the pre-policy period) that is not affected by endogenous entry and exit decisions.

There were two main sources of changes in market structure over the period 2002/3 to 2010/11. From 2003/4, new private providers specializing in a small number of treatments, including hip and knee replacements, were encouraged to enter and locate in areas where NHS patients were experiencing long waiting times (Department of Health, 2004; Department of Health, 2006). Cooper et al. (2018) found that, while this entry was more likely where existing NHS providers had longer waiting times, it was not associated with changes in length of stay or quality. We include these new providers in our measure \( \bar{M}_h \) of pre-choice reform competition facing NHS providers.

From 2008/9, there was entry by existing private hospitals which had previously only treated private patients. If pressure on management to improve quality is driven by overall elective competition, as in Bloom et al. (2015), then the fact that private providers accounted for only 4% of all elective NHS-funded treatments (Hawkes, 2012) even at the end of our period also suggests that endogeneity may not be an important problem when market structure is measured at the level of all elective admissions, as it is in one of our specifications. We also add a time-varying measure of the number of local private providers to our baseline specification and find that our results are unchanged.

Endogenous patient selection of hospital. The second potential identification problem is that unobservable patient morbidity \( \varepsilon_{it} \), which will affect the probability of readmission or mortality \( q_{iht} \), may also affect patient choice of provider and bias the estimates of effects of market structure on hospital quality (Gowrisankaran and Town, 1999; Geweke et al., 2003).

The direction of the bias arising from the effect of unobserved morbidity on choice of hospital is not obvious \textit{a priori}. A patient’s choice of hospital will depend on their beliefs about its quality. The effect of hospital quality may vary with the morbidity of the patient. Morbidity may affect the importance that patients’ attach to quality relative to other attributes such as distance to hospitals. The choice reform widened patient choice sets and this could have changed the effect of morbidity on choice of provider.

If the effect of unobserved morbidity on patient choice of hospital is time-invariant, then the estimates of \( \gamma \) will be unbiased, thanks to the inclusion of hospital fixed effects \( \mu_h \) in our baseline quality model (equation (6)), but otherwise, we need to control for selection. We use a rich set of patient characteristics, including comorbidities and past emergency hospital admissions, to control for selection on observables and, to the extent that observable and unobservable morbidity are correlated, to reduce selection on unobservable morbidity.

We also use two control function strategies (Terza et al., 2008; Wooldridge, 2015) to tackle any remaining selection on unobservables. In these two stage residual inclusion (2SRI) strategies, the first stage is a model for the probability that a patient chooses a provider, with explanatories, such as patient distance to provider, which are uncorrelated with provider quality. In the second stage we add the residuals from the choice model to the model (equation (6)) for patient outcomes.

In the first strategy, we estimate \( H \) separate linear probability models (one for each provider) for the choice of provider \( h \) by patient \( i \) in year \( t \):

\[
C_{ih}^t = \sum_{r=2002/3}^{2010/11} D_t \left[ \alpha_{0h}^t + \alpha_{1h}^t d_{ih} + \alpha_{2h}^t d_{ih}^2 + \alpha_{3h}^t d_{ih}^3 + \alpha_{4h}^t \text{nearest}_{ih} + \varepsilon_{ih}^t \right], \tag{7}
\]

where \( C_{ih}^t = 1 \) if patient \( i \) chooses hospital \( h \) in year \( t \) and zero otherwise, \( D_t \) is a dummy for year \( t \), \( d_{ih} \) is the distance from provider \( h \) to the centroid of patient \( i \)’s small area of residence (Lower
Super Output Area, LSOA),10 nearestih is an indicator for h being the nearest provider to patient i, and ϵih is the error term.11 We then estimate the linear second stage outcome model as
\[
q_{ih} = \beta_i + x_{ih} \psi_i + \gamma \tilde{M}_h \lambda_i + x_{ih} \psi_2 + \tilde{r}_{ih}^{\text{PM}} \gamma + \mu_h + \epsilon_{ih},
\]
where \(\tilde{r}_{ih}^{\text{PM}} = [\tilde{r}_{1ih}^{\text{PM}}, \tilde{r}_{2ih}^{\text{PM}}, \ldots, \tilde{r}_{tih}^{\text{PM}}]\) and \(\tilde{r}_{ih}^{\text{PM}} = C_{ih} - \hat{C}_{ih}\) are the residuals from the linear first stage equation (7).

With linear first and second stage models, 2SRI will produce the same results as two stage least squares (2SLS). A joint test on the significance of the residuals can also be used as a simple Durbin-Wu-Hausman test for endogeneity of choice of provider (Terza et al., 2008; Wooldridge, 2015). In a robustness check for the LPM outcome specification, we use a non-linear (logit) outcome model. With such a non-linear second stage, a control function strategy (2SRI) will yield consistent estimates (Terza et al., 2008).

In the second control function strategy, we estimate a first stage conditional logit model for patient choice of hospital in which the utility obtained by patient i from provider h in year t is
\[
U_{ih} = V_{ih} + \xi_{ih} = \lambda_{ih} d_{ih} + \lambda_{ih} d_{ih}^{2} + \lambda_{ih} d_{ih}^{3} + \lambda_{ih} T_{ih} + \lambda_{ih} F_{ih} + \lambda_{ih} \lambda_{ih} nearest_{ih} + \xi_{ih},
\]
where \(T_{ih}, F_{ih}, \text{and } PO_{ih}\) are indicators for teaching, foundation trust, and privately owned status, and \(\xi_{ih}\) are random terms with i.i.d extreme value distributions. The probability that patient i chooses provider h in year t is (McFadden, 1974)
\[
P_{ih} = \exp(V_{ih}) \left[ \sum_{t' \in S_i} \exp(V_{ih'}) \right]^{-1},
\]
where the patient choice set \(S_i\) is the closest 50 providers (accounting for over 99% of choices in each year).12

Estimation of the conditional logit model across all hospitals in each year yields residuals \(\tilde{r}_{ih}^{\text{CLM}} = C_{ih} - \hat{P}_{ih}\), which we then include in the LPM second stage outcome regression, as in equation (8).13 Compared to linear 2SRI, identification requires slightly stronger assumptions (Blundell and Powell, 2003, 2004).1415

In both control function strategies, the inclusion of the residuals from the first stage choice model in the second stage quality model controls for endogenous patient selection into hospitals. The strategies are complements. Linear 2SRI is simpler and more robust. CL 2SRI requires stronger assumptions but has a more plausible first stage specification which should predict hospital choice more accurately (and cannot yield choice probabilities outside (0,1)) and so should produce more efficient estimates of \(\gamma\) (Newey and McFadden, 1994). Hence, if the two CF strategies produce similar parameter estimates of \(\gamma\), this is reassuring and we can trust the estimates produced by the more efficient CL 2SRI estimator.16

Our control function strategies use distances from patient’s residence to hospitals as instrumental variables (IVs) in first stage models of choice of provider. Distance IVs have been

10 In the period 2002 to 2010, there were 32,482 LSOAs with an average population of 1500.
11 Gowrisankaran and Town (1999) use a similar specification.
12 Wilson (2016) also uses a conditional logit choice model as the first stage choice model.
13 For hospitals not in the nearest 50, we set the residual to 1 unless the patient chose a hospital not in the nearest 50 (1% of patients), in which case we set the residual to 0 for the hospital chosen and to 1 for all other hospitals outside the nearest 50.
14 The key assumption is that \(E(\epsilon|X, g(\xi)) = E[\epsilon|g(\xi)] = E(\epsilon|\tilde{r}^{\text{CLM}}| = \psi_3 \tilde{r}^{\text{CLM}}\) where \(g(\cdot)\) is a function of the error terms \(\tilde{r}_{ih}\) from the first stage choice utility function in equation (9), and \(\psi_3\) is a correlation coefficients between the error terms \(\epsilon\) and \(g(\xi)\).
15 The conditional logit model does not have explicit error terms so the identification of the model relies on the correlation between the errors terms \(\epsilon\) from the outcome regression and a function, \(g(\tilde{r}_{ih}) = C_{ih} - P_{ih} = \tilde{r}_{ih}^{\text{CLM}},\) of the latent errors \(\tilde{r}_{ih}\) which are not directly observable.
16 We also estimated a three-step model in which the first step is a choice model, the second regresses patient outcomes on patient covariates, year by provider effects, and the choice residuals to obtain a hospital by year estimate of quality, and the third step regresses this on year effects, hospital covariates, hospital fixed effects, and interaction AiMh. Results (Appendix Table A9) are similar to those from our baseline two-step model.
common in the healthcare literature since McClellan et al. (1994) and Newhouse and McClellan (1998). Many studies show that distance is a good predictor of choice of hospital (for example, for England, see Gaynor et al., 2016; Gutacker et al., 2016; Moscelli et al., 2016). Distance also satisfies the exogeneity requirement for an IV: as Gowrisankaran and Town (1999) note, while distance to the chosen hospital may be correlated with morbidity, the distances from patient’s residence to hospitals in the choice set is not.\textsuperscript{17,18}

**Sample selection.** Our sample is NHS-funded patients treated in NHS hospitals. We exclude NHS-funded patients treated in the specialist private providers who entered the market from 2003/4 onward. Until 2009, these providers were not paid per patient treated (Naylor and Gregory, 2009) and were only moved onto HRG pricing per patient treated as their long-term contracts expired. Hence, they had little incentive to compete on quality for most of our period and including them could bias the estimate of $\gamma$ toward zero, nor do we include NHS patients treated in the other, non-specialist, private providers who started treating NHS-funded patients from 2008 onward as we cannot compute a pre-reform time-invariant market structure measure for them. Hence we estimate the effect of the choice reforms only for NHS patients treated in NHS hospitals, but we know that NHS patients treated in NHS providers were observedly and unobservedly more morbid than NHS patients treated in the private sector (Mason et al., 2010; Moscelli et al., 2018b) so that there is a risk of sample selection bias, in addition to unobserved selection of patients into individual NHS hospitals.

To test for possible sample selection bias, we also estimate an augmented outcome model, adding the Heckman selection correction term (inverse Mills ratio) from an additional first stage probit model for choice of NHS rather than private hospital (Heckman, 1979). We specify latent utility from treatment in an NHS provider as

$$NHS^*_t = \rho_0 + \rho_1 (d_{itNHS} - d_{itISP}) + x_{it}' \rho_2 + u_t,$$

with the patient choosing an NHS provider if and only if $NHS^*_t \geq 0$. $d_{itNHS}$ and $d_{itISP}$ are the distances from the centroid of the patient’s LSOA to the closest NHS hospital site and to the closest private provider hospital site. We assume, plausibly, that differential distance $d_{itNHS} - d_{itISP}$ satisfies the exclusion restriction.

In all outcome models, the standard errors are bootstrapped (1000 replications) to account for the sampling error resulting from the inclusion of the estimated residuals (Murphy and Topel, 1985). We report $t$-statistics based on robust standard errors clustered at hospital site level (Cameron and Miller, 2015; Moulton, 1990).

5. **Data**

Our main dataset is Hospital Episodes Statistics (HES) which has information on all admissions to NHS providers and all NHS-funded hospital admissions to private providers. We use data on NHS-funded elective hip replacement, knee replacement and CABG patients aged 35 and over (web Appendix B1 has detailed procedure codes).\textsuperscript{19}

\textsuperscript{17} There is no evidence of residential sorting for elective hospital care in England. It is possible that patients in need of repeated treatments, like hemodialysis or chemotherapy, may locate closer to hospitals to minimize travel, but patients are less likely to change their residence for one-off treatments like CABG or hip and knee replacement, especially after the reduction of hospital waits for elective treatments in England from 2005 onward.

\textsuperscript{18} The baseline model contains measures of direct patient level morbidity. It also includes claims for benefits for incapacity and invalidity benefits and measures of deprivation in the small area in which the patient lives, plus the distance from the patient to the nearest Type 1 Accident and Emergency Department (located only in large NHS hospitals). This further increases the plausibility of the assumption that the distance IVs are, conditional on the variables included in the outcome model, uncorrelated with the outcome.

\textsuperscript{19} As in Kessler and McClellan (2000), Gaynor et al. (2013), and Cooper et al. (2011), we include hospital sites only in years in which they had at least a threshold number of admissions (100 for hip replacement, 100 for knee replacement, and 20 for CABG).
Outcomes. We measure quality for elective hip and knee replacement and CABG by whether the patient had an emergency admission within 28 days of discharge after their initial elective procedure. Emergency readmissions are one of the performance indicators in the NHS Outcomes Framework and are a widely used in health economics and clinical studies (Ashton et al., 1997; Weissman et al., 1999; Balla et al., 2008; Billings et al., 2012; Blunt et al., 2015). As elective CABG treatment has a mortality risk of 1.1%, around four times larger than for hip and knee replacement, we also measure CABG quality by whether the patient died in any location (inside or outside the hospital) within 30 days of their index admission. Waiting time is the number of days from a patient being placed on the waiting list to being admitted to hospital. Length of stay is the number of days from admission to discharge from hospital.

Market structure. We construct measures of market structure facing NHS hospital sites providing hip replacements (232), knee replacements (238), and CABG (47) between 2002/3 and 2010/11. Our main measures are based on the HHI: the sum of the squared market shares of the providers in the market, whether NHS or private. We measure market structure as the reciprocal of the HHI, that is, the equivalent number of rivals—the number of equal-sized firms that would yield the same HHI. This make results easier to interpret, as a larger equivalent number of rivals means that competition is greater. It also facilitates comparison when we use a simple count of actual rivals as a robustness check. HHIs are computed from predicted patient flows (second subsection of Section 4, and web Appendix B2). It is possible that quality for a procedure depends on competition in the market for that procedure (hip replacement, knee replacement, CABG), in the market for the specialty (musculoskeletal, circulatory), or in the market for all elective admissions. We therefore compute the equivalent number of rivals using predicted HHIs for each of these three markets. As a robustness check, we also use a count of the actual number of rival hospital sites within 30 km.

Patients’ and hospitals characteristics. To control for patient characteristics, we use gender, age in 10 year bands, the number of co-morbidities based on ICD10 codes, the Charlson index based on morbidities predictive of future mortality (Charlson et al., 1987), and the number of emergency hospitalizations in the previous year as a measure of patient severity. We also attribute IMD income deprivation, IMD living environment deprivation, incapacity benefit claims rate, and disability claims rate by patient LSOA of residence. Hospital characteristics are captured by indicators for Foundation Trust status which gives greater financial flexibility (Marini et al., 2008) and for teaching hospital status. In robustness checks, we also use an indicator for the rurality of the hospital site and measures of population density.

Summary statistics. Table 1 reports descriptive statistics on NHS patients treated in NHS providers. Post-reform, the mean risk of an emergency readmission fell slightly for hip replacements but increased for knee replacements and CABGs. Mortality risk, length of stay, and waiting time fell for all three procedures. Mean ages for hip and knee replacement are 68 and 70 years, respectively, and 65 for CABG. The proportion of female patients is much higher for hip and knee replacement (60% and 58%) than for CABG (19%). Hip and knee replacement patients

---

20 We use the official definition of an emergency readmission (HSCIC 2016) https://files.digital.nhs.uk/C4/E99638/Spec_03K_520ISR7G.pdf. Emergency readmissions are attributed to the hospital where the index elective care was performed, not to the hospital that provided the emergency care.

21 We cannot use quality measures based on patient reported outcomes as these were not available for hip and knee replacements before 2009, and were never collected for CABG.

22 All our market structure measures, whether HHIs or count of rivals, are based on hospital sites with a minimum of at least 100 elective admissions of any type per year.

23 Index of Multiple Deprivation. See http://geoconvert.mimas.ac.uk/help/imd-2007-manual.pdf.
### TABLE 1 Patient-level Descriptive Statistics

|                      | Hip Replacement Patients | Knee Replacement Patients | CABG Patients |
|----------------------|--------------------------|---------------------------|---------------|
|                      | pre-Choice | post-Choice | pre-Choice | post-Choice | pre-Choice | post-Choice |
| **Outcomes**         |            |            |            |            |            |            |
| Emergency readmission within 28 days | 0.0574 | 0.2326 | 0.0570 | 0.2319 | 0.0169 | 0.1290 | 0.0207 | 0.1423 | 0.0399 | 0.1958 | 0.0422 | 0.2010 |
| Died within 30-days (anywhere) | 0.0033 | 0.0573 | 0.0021 | 0.0461 | 0.0028 | 0.0532 | 0.0019 | 0.0431 | 0.0120 | 0.1089 | 0.0105 | 0.1017 |
| Length of in-hospital stay | 9.87 | 9.73 | 7.06 | 7.81 | 9.67 | 9.10 | 6.98 | 7.64 | 9.39 | 7.34 | 8.90 | 6.80 |
| In-hospital waiting times | 207.16 | 141.46 | 106.14 | 72.84 | 229.58 | 149.46 | 112.69 | 78.79 | 107.55 | 94.29 | 58.25 | 45.19 |
| Logarithm of in-hospital waiting times | 5.02 | 4.44 | 0.75 | 5.16 | 0.90 | 4.51 | 0.72 | 4.21 | 1.14 | 3.74 | 0.93 |            |
| **Patient characteristics** |            |            |            |            |            |            |            |            |            |
| Emergency admissions in year before treatment | 0.06 | 0.29 | 0.07 | 0.31 | 0.06 | 0.28 | 0.06 | 0.30 | 0.26 | 0.63 | 0.31 | 0.67 |
| Age | 68.28 | 10.60 | 68.27 | 10.86 | 70.42 | 9.03 | 69.77 | 9.34 | 64.83 | 8.95 | 65.91 | 9.33 |
| Female | 0.60 | 0.49 | 0.60 | 0.49 | 0.58 | 0.49 | 0.58 | 0.49 | 0.19 | 0.39 | 0.18 | 0.38 |
| Number of diagnoses on admission | 2.54 | 1.77 | 3.23 | 2.15 | 2.61 | 1.78 | 3.37 | 2.15 | 4.88 | 2.61 | 6.55 | 3.05 |
| Charlson Index | 0.21 | 0.55 | 0.33 | 0.69 | 0.24 | 0.56 | 0.36 | 0.68 | 0.56 | 0.85 | 0.70 | 0.98 |
| Charlson Index: zero co-morbidities | 0.83 | 0.37 | 0.76 | 0.43 | 0.81 | 0.39 | 0.72 | 0.45 | 0.60 | 0.49 | 0.54 | 0.50 |
| Charlson Index: one co-morbidity | 0.13 | 0.34 | 0.18 | 0.39 | 0.16 | 0.37 | 0.22 | 0.41 | 0.29 | 0.45 | 0.31 | 0.46 |
| Charlson Index: more than one co-morbidity | 0.03 | 0.17 | 0.06 | 0.23 | 0.03 | 0.18 | 0.06 | 0.24 | 0.11 | 0.32 | 0.15 | 0.36 |
| IMD income deprivation | 0.12 | 0.10 | 0.13 | 0.10 | 0.13 | 0.10 | 0.14 | 0.11 | 0.14 | 0.11 | 0.15 | 0.11 |
| IMD living environment | 18.82 | 14.66 | 18.52 | 14.67 | 19.54 | 15.11 | 19.39 | 15.26 | 20.57 | 15.99 | 20.26 | 15.94 |
| Incapacity claims | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.04 | 0.02 | 0.04 | 0.02 |
| Disability claims | 0.05 | 0.03 | 0.05 | 0.03 | 0.05 | 0.03 | 0.05 | 0.03 | 0.05 | 0.03 | 0.05 | 0.03 |
| Distance to A&E type 1 hospital (km) | 9.24 | 8.00 | 9.24 | 8.00 | 8.72 | 7.76 | 8.56 | 7.62 | 7.97 | 7.26 | 8.32 | 7.54 |
| Differential distance closest NHS vs Private | −69.82 | 71.15 | −25.51 | 36.28 | −42.39 | 68.30 | −15.73 | 33.04 | . | . | . | . |
| Distance to closest NHS hospital site (km) | 11.95 | 9.71 | 13.10 | 10.43 | 16.51 | 21.21 | 16.79 | 25.33 | . | . | . | . |
| Distance to closest Private hospital site (km) | 38.72 | 31.02 | 38.61 | 36.39 | 58.90 | 65.37 | 32.52 | 32.12 | . | . | . | . |
| Distance to chosen hospital site (km) | 12.90 | 17.94 | 14.68 | 24.33 | 11.97 | 16.68 | 13.73 | 24.58 | 34.18 | 41.44 | 31.44 | 32.17 |

Notes: Non-emergency NHS funded patients treated in financial years 2002/3 to 2010/11 in NHS hospital sites only. Number of patients are: 414,433 (hip replacement); 463,953 (knee replacement); 114,291 (CABG). Pre-choice period: financial years 2002/3 to 2005/6. Post-choice period: financial years 2006/7 to 2010/11.
have an average of three co-morbidities while CABG patients have more than five, and also have fewer emergency admissions in the year prior to treatment.2425

Table 2 reports correlations among risk-adjusted NHS hospital site quality measures for our three elective procedures. They are generally small. The highest correlation (0.28) is between knee and hip replacement emergency readmission rates, which is to be expected given that they may be carried out by the same surgical teams. CABG readmission and mortality rates are also significantly positively correlated (0.17). The correlations between the CABG and the hip and knee replacement quality measures are weak. Given that the literature on hospital competition has focused on mortality rates for emergency admissions for conditions such as AMI, we also report, in italics, the correlations between our elective care quality measures with the mortality of two high volume emergency conditions (AMI and hip fracture) in the same specialties as CABG and hip and knee replacement. The emergency mortality rates are weakly associated with the elective care quality measures and the only significant correlations are negative.26 These correlations suggest that mortality for an emergency condition is not necessarily indicative of hospital quality for elective procedures, even within the same specialty.

Table 3 has summary statistics for market structure. Most of the competition measures relating to hip and knee replacements increased over the period between 15% and 23%, but CABG market structure was substantially unchanged as no private providers entered this market. The percentage increase in the actual number of NHS and private elective care providers within 30 km was very similar (24%) to that for the equivalent number (23%).27

Figure 2 compares the percentages of patients who chose their nth nearest provider before and after the relaxation of constraints on choice. For both hip and knee replacements, the percentage of patients choosing their nearest provider fell from just under 70% in 2002/03 to just over 46% in 2010/11. By contrast, there was a small increase in CABG patients choosing the nearest provider. Figure 3 compares patient volumes in the pre and post-choice periods for hospitals above and below median quality. Higher-quality providers have larger volumes than low-quality providers in both periods, but the volume difference is larger after 2006 when constraints on choice were relaxed. This suggests a “flight to quality,” with patient choice becoming more responsive to quality after the choice reform, as confirmed in Gaynor et al. (2016) for CABG and Moscelli et al. (2016) for hip replacement.

We estimated DID models for observed morbidity which shows that for the hip and knee replacement, the post-reform increase in some types of morbidity was greater for hospitals facing more pre-choice competition (web Appendix Table A3, Panel B). This suggests that it is possible that unobserved morbidity changed differentially for hospitals facing more or less competition.28

24 Hip and knee replacement procedures provided by NHS hospitals increased and then fell slightly between 2002/3–2010/11 (Appendix Figure A1). CABGs declined over the entire period.
25 Risk-adjusted elective care hospital quality declined (28-day standardized emergency readmissions increased) over the period (Appendix Figure A2), reflecting either a secular decline in provider quality or an increase in unobserved morbidity of admitted patients, possibly due to changes in GP referral and hospital admission thresholds.
26 Gravelle et al. (2014) used a larger set of measures for 2009/10 and also found find little evidence for a positive correlation between elective and emergency care hospital quality.
27 The correlations for the equivalent number of rival sites for all elective admissions with the equivalent numbers of rivals for the two specialties are at least 0.97 and for the three procedures are at least 0.85. The correlation with the actual numbers of rivals for all elective admissions is 0.78 (Appendix Table A2). Appendix Figure A3 plots the trends in the competition measures.
28 Appendix Table A3, panel A reports the differences in pre-reform patient outcomes and characteristics (aggregated to hospital site level) for providers facing below and above mean pre-reform competition. Providers facing above average competition had lower emergency readmission rates, shorter waiting times, and higher length of stay. Differences in patient health (past emergency readmissions, number of diagnosis, and Charlson Index) were statistically insignificant. Hip replacement and CABG providers facing more competition treated slightly younger patients.

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|                          | Elective hip | Elective knee | Elective CABG | Elective CABG | Emergency AMI |
|--------------------------|--------------|---------------|---------------|---------------|---------------|
| Readmissions             |              |               |               |               |               |
| Elective knee            | 0.2832***    | 1             |               |               |               |
| Elective CABG            | -0.097       | 0.037         | 1             |               |               |
| Mortality rate           |              |               |               |               |               |
| Elective CABG            | -0.132*      | 0.068         | 0.172***      | 1             |               |
| Emergency AMI            | 0.018        | -0.060**      | -0.094        | 0.203***      | 1             |
| Emergency hip fracture   | 0.025        | -0.054**      | 0.024         | 0.181**       | 0.205***      |

Notes: Readmissions: risk-adjusted emergency readmission rate within 28 days of discharge. Mortality: risk-adjusted mortality rate within 30 days from index admission. NHS hospital sites, 2002/3 to 2010/11. We follow HSCIC methodology in risk adjusting for patient casemix (HSCIC, 2015). We estimate risk-adjusted emergency readmissions (or CABG mortality) based on a logit model and controlling for Charlson index co-morbidities, number of diagnosis, age groups, gender, interactions of age groups with gender, income deprivation at LSOA level, day of the week, month and year of admission. * p<0.10, ** p<0.05, *** p<0.01.
### TABLE 3  Market Structure Measures

|                                | 2002/3–2005/6 |          |          |          | 2006/7–2010/11 |          |          |          |
|--------------------------------|--------------|----------|----------|----------|----------------|----------|----------|----------|
|                                | Mean  | SD     | Min     | Max     | Mean   | SD     | Min     | Max     |
| Equivalent number hospital sites within 30 km |          |          |          |          |          |          |          |          |
| All planned admissions          | 3.33  | 2.43   | 1       | 12.99   | 3.93   | 2.64   | 1       | 13.78   |
| Circulatory system admissions   | 3.42  | 2.49   | 1       | 12.32   | 3.90   | 2.74   | 1       | 12.15   |
| Musculoskeletal admissions      | 2.71  | 1.87   | 1       | 9.93    | 3.34   | 2.06   | 1       | 10.93   |
| Hip Replacement admissions      | 1.60  | 0.78   | 1       | 4.59    | 1.88   | 0.99   | 1       | 5.50    |
| Knee Replacement admissions     | 1.61  | 0.75   | 1       | 4.40    | 1.88   | 0.85   | 1       | 4.68    |
| CABG admissions                  | 2.03  | 1.40   | 1       | 5.04    | 2.00   | 1.44   | 1       | 4.91    |
| Number NHS & private sites within 30 km | 14.56 | 16.90  | 0       | 63      | 17.17  | 19.62  | 0       | 76      |
| Number private sites within 30 km | 0.14  | 0.42   | 0       | 2       | 1.66   | 2.11   | 0       | 12      |
| HHI within 30 km—Circulatory system admissions | 0.46  | 0.28   | 0.08    | 1       | 0.41   | 0.26   | 0.08    | 1       |
| HHI within 30 km—Musculoskeletal admissions | 0.53  | 0.28   | 0.10    | 1       | 0.43   | 0.25   | 0.09    | 1       |

Notes: Equivalent number: inverse of the predicted Herfindahl–Hirschman Index. Sites are those treating at least 100 NHS funded elective patients per year.
FIGURE 2

CHOICE OF HOSPITAL BY DISTANCE FROM PATIENT’S RESIDENCE [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 3

PATIENT VOLUME AT LOW AND HIGH QUALITY PROVIDERS PRE AND POST CHOICE REFORM. Notes: NHS hospital sites only. Hospital sites are classified as High Quality if their risk-adjusted quality indicator (28 days emergency readmission rates for hip and knee replacements; 30 day mortality rates for coronary bypass) was above median quality.
6. Estimation results

In this section, we report results from our quasi-difference in different models which investigate whether and how relaxation of constraints on choice led to greater changes in outcomes for providers facing more competition.

Baseline specifications. Table 4 reports the coefficient ($\gamma$) on the interaction between pre-2006 specialty market structure and the post-2006 choice reform indicator. Column (1) has results from models with only hospital and time fixed effects; column (2) adds covariates. Columns (3) and (4) are from models which also contain the residuals from first stage linear and conditional logit choice models.

Panel a has results for hip replacement. In all four specifications, the positive coefficient $\gamma$ on the Post-Choice Policy*Market structure interaction implies that relaxation of constraints on choice had a larger positive effect on readmissions (a larger reduction in quality) for providers facing more pre-2006 competition. Adding covariates (column (2) vs column (1)) reduces $\gamma$ slightly and adding the first-stage residuals increases it, though it is not statistically significant for the linear 2SRI model (column (3)). The first-stage choice model residuals are jointly statistically significant for both the CL and linear specifications, indicating that there was endogenous selection. Allowing for endogenous selection has a relatively modest effect on the estimates of $\gamma$, increasing them by about a fifth and the confidence intervals from the models with and without residuals overlap.

Panel b is for knee replacement and again all four specifications suggest that the relaxation of constraints on choice increased emergency readmissions. The effect is statistically significant in all cases and is doubled with the CL 2SRI and Linear 2SRI models compared to the model (column (2)) which does not allow for endogenous selection.

Panels c and d for CABG report small, generally negative, and statistically insignificant effects on emergency readmissions and on mortality for all four specifications, whether or not we control for endogenous selection.

Given a pre-reform average equivalent number of rivals of 2.71, measured at musculoskeletal specialty level, the choice reform increased emergency readmissions by 0.57% ($\gamma \bar{M}_h$) after hip replacement for a hospital with the average number of rivals pre-reform compared to a hospital with no rivals. The mean pre-reform hip replacement readmission risk was 5.74%. For knee replacement the increased readmission risk was 0.30% compared to the mean pre-reform risk of 1.69%.

Robustness checks.

Measure of market structure. In Table 5, we examine if our results are sensitive to the way in which market structure is measured using the equivalent number of rivals for all admissions (columns (1) to (3)), for procedure (columns (4) to (6)), and using a simple count of rivals within 30 km (columns (7) to (9)). The patterns of results for these three market structure measures are very similar to those with the specialty-based measure in Table 4. The magnitude of the

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29 The 1st stage F-statistics for the linear 2SRI models are very large (Appendix Table A4). For the CL 2SRI, in the absence of a formal test for instrument strength, we find (Appendix Table A5) that the first stage conditional logit choice models have a very high goodness of fit. For example, Cragg and Uhler’s R-Squared is over 0.989 in all years.

30 The Oster (2019) test for coefficient stability (Appendix Table A6), obtained using the psacalc Stata function, suggests that the bias in the coefficient on $A_t \bar{M}_h$ due to unobservables is in the same direction as the bias due to the omission of observable confounders.

31 Appendix Table A7 has the full estimation results for the outcome for the CL 2SRI strategy in column (4) of Table 4. In Appendix Table A8, we report the marginal effects from the logit outcome second stage using the residuals from the conditional logit first stage choice model. Results are very similar to those in Table 4.

32 In Appendix Table A9, we report the results from the three-step model mentioned in Section 4 (endnote 16), which are very similar to those from our two-step approach in Table 4.
### TABLE 4 Post Choice Reform Change in Effect of Pre-Reform Specialty Based Market Structure on Elective Quality

|                          | FE Model without Covariates | FE Model with Covariates | Linear 2SRI Residuals for All Providers | CL 2SRI Residuals for All Providers |
|--------------------------|-----------------------------|--------------------------|----------------------------------------|-------------------------------------|
|                          | (1)                         | (2)                      | (3)                                    | (4)                                 |
| **Post-Choice Policy**   |                             |                          |                                        |                                     |
| **Market Structure**     |                             |                          |                                        |                                     |
| a. Hip Replacement       | 0.0020**                    | 0.0017**                 | 0.0020                                 | 0.0021**                            |
| Emergency Readmission    |                             |                          |                                        |                                     |
| (Patients: 412,464;      | (2.405)                     | (2.017)                  | (1.545)                                | (2.149)                             |
| hospital sites: 232)     |                             |                          |                                        |                                     |
| p-value joint Chi² test | 0.005                       | 0.011                    | 0.012                                  | 0.012                               |
| residuals coefficients   |                             |                          |                                        |                                     |
| = 0                      |                             |                          |                                        |                                     |
| b. Knee Replacement      | 0.0007***                   | 0.0005**                 | 0.0011**                               | 0.0011***                           |
| Emergency Readmission    |                             |                          |                                        |                                     |
| (Patients: 461,594;      | (2.648)                     | (2.152)                  | (2.386)                                | (3.897)                             |
| hospital sites: 238)     |                             |                          |                                        |                                     |
| p-value joint Chi² test | 0.002                       | 0.003                    | 0.004                                  | 0.004                               |
| residuals coefficients   |                             |                          |                                        |                                     |
| = 0                      |                             |                          |                                        |                                     |
| c. CABG Emergency        | -0.0001                     | -0.0002                  | 0.0001                                 | -0.0004                             |
| Readmission              |                             |                          |                                        |                                     |
| (Patients: 112,844;      | (-0.275)                    | (-0.417)                 | (0.236)                                | (-0.817)                            |
| hospital sites: 47)      |                             |                          |                                        |                                     |
| p-value joint Chi² test | 0.001                       | 0.003                    | 0.004                                  | 0.003                               |
| residuals coefficients   |                             |                          |                                        |                                     |
| = 0                      |                             |                          |                                        |                                     |
| d. CABG Mortality        | 0.0001                      | -0.0001                  | -0.0002                                | -0.0004                             |
| (Patients: 114,291;      | (0.195)                     | (-0.162)                 | (-0.250)                               | (-0.637)                            |
| hospital sites: 47)      |                             |                          |                                        |                                     |
| p-value joint Chi² test | 0.001                       | 0.016                    | 0.016                                  | 0.016                               |
| residuals coefficients   |                             |                          |                                        |                                     |
| = 0                      |                             |                          |                                        |                                     |

Notes: Dependent variable: Patient in NHS provider had emergency readmission within 28 days from discharge following admission, or CABG patient in NHS provider died within 30 days. Choice Policy: indicator for 2006/7 onward. Market structure: average of estimated equivalent number of rival hospital sites (= 1/(predicted HHI)) for patients in hospital specialty during period 2002/3 to 2005/6. Column (1) models include only hospital and year fixed effects; Column (2) as column (1) plus covariates. Column (3) as column (2) plus residuals for all hospitals from linear first stage choice model. Column (4) as column (2) plus residuals for all hospitals from conditional logit first stage choice model. Financial years: 2002/3–2010/11. *p < 0.1, ** p < 0.05, *** p < 0.01.
| Post-Choice Policy * Market Structure | All admissions Predicted HHI | Procedure-based Predicted HHI | Number of rivals |
|--------------------------------------|-----------------------------|-------------------------------|-----------------|
| FE Model with Covariates             | Linear 2SRI Residuals for All Providers | Linear 2SRI Residuals for All Providers | Linear 2SRI Residuals for All Providers |
|                                      | (1)                         | (2)                          | (3)             |
| Post-Choice Policy                   | 0.0012*                     | 0.0009                       | 0.0013          |
|                                      | (1.747)                     | (0.904)                      | (1.577)         |
| joint Chi^2 test residuals coefficients = 0 | 641                         | 497                          |                 |
| p-value joint χ^2 test residuals coefficients = 0 | 0.0000                      | 0.0000                       |                 |
| R^2                                  | 0.011                       | 0.012                        | 0.012           |
| a. Hip Replacement Emergency Readmission (Patients: 412,464; hospital sites: 232) |                            |                              |                 |
| Post-Choice Policy                   | 0.0004*                     | 0.0007**                     | 0.0008***       |
|                                      | (1.865)                     | (2.015)                      | (3.375)         |
| joint Chi^2 test residuals coefficients = 0 | 766                         | 554                          |                 |
| p-value joint χ^2 test residuals coefficients = 0 | 0.0000                      | 0.0000                       |                 |
| R^2                                  | 0.003                       | 0.004                        | 0.004           |
| b. Knee Replacement Emergency Readmission (Patients: 461,594; hospital sites: 238) |                            |                              |                 |
| Post-Choice Policy                   | 0.0002                      | 0.0001                       | −0.0004         |
|                                      | (−0.384)                    | (0.145)                      | (−0.828)        |
| joint Chi^2 test residuals coefficients = 0 | 247.2                       | 75.4                         |                 |
| p-value joint χ^2 test residuals coefficients = 0 | 0.0000                      | 0.0003                       |                 |
| R^2                                  | 0.003                       | 0.004                        | 0.003           |
| c. CABG Emergency Readmission (Patients: 112,844; hospital sites: 47) |                            |                              |                 |
| Post-Choice Policy                   | −0.0000                     | −0.0001                      | −0.0003         |
|                                      | (−0.101)                    | (−0.211)                     | (−0.535)        |
| joint Chi^2 test residuals coefficients = 0 | 270                         | 176                          |                 |
| p-value joint χ^2 test residuals coefficients = 0 | 0.0000                      | 0.0000                       |                 |
| R^2                                  | 0.016                       | 0.016                        | 0.016           |
| d. CABG Mortality (Patients: 114,291; hospital sites: 47) |                            |                              |                 |
| Post-Choice Policy                   | −0.0000                     | −0.0001                      | −0.0003         |
|                                      | (−0.101)                    | (−0.211)                     | (−0.535)        |
| joint Chi^2 test residuals coefficients = 0 | 270                         | 176                          |                 |
| p-value joint χ^2 test residuals coefficients = 0 | 0.0000                      | 0.0000                       |                 |
| R^2                                  | 0.016                       | 0.016                        | 0.016           |

Notes: Dependent variable: Patient in NHS provider had emergency readmission within 28 days from discharge following admission, or CABG patient in NHS provider died within 30 days. Choice Policy: indicator for 2006/7 onwards. Market structure: average of estimated equivalent number of rival hospital sites (=1/(predicted HHI)) from patient flows in year 2002/3 to 2005/6. Market defined as: all elective patients (columns 1 to 3), all patients treated for the relevant elective procedure of admission (columns 4 to 6); the number of rivals within 30 km of treating hospital. Columns (2), (5), and (8) use residuals from linear first stage choice models. Columns (3), (6), and (9) models add residuals from conditional logit first stage choice model. Financial years: 2002/3-2010/11. t-statistics in parentheses, based on bootstrapped hospital site cluster-robust standard errors with 1000 replications. *p < 0.1, ** p < 0.05, *** p < 0.01.
estimated $\gamma$ coefficients on Post-Choice Policy*Market Structure vary across the market structure measures, but this is mostly due to differences in the scale of this measure. As Table 1 shows, the mean pre-choice reform equivalent number of providers for musculoskeletal admissions is larger than for either hip or knee replacement admissions, smaller than the all elective admissions and much smaller than the simple count of rivals. This is the reverse of the rankings of the estimated $\gamma$ coefficients across the market structure measures.\footnote{Results (Appendix Table A10) using HHI rather than equivalent numbers (1/HHI) produce very similar results (allowing for changes in the scale of the competition measure).}

As the choice of measure makes little substantive difference to our results, we use market structure at specialty level in subsequent models. The HHI based on all elective patients combines very heterogeneous procedures, creating a risk of measurement error. Procedure-level HHI might be more prone to procedure-specific measurement error arising from large changes in HHIs due to temporary entry or exit of providers in the pre-policy period. The simple count of rivals ignores their size and distance from the hospital. A specification in which market structure is time-varying, rather than being fixed at its pre 2006 value, produces similar results to Table 4 (web Appendix Table A13), suggesting that our measure of market structure is not endogenous.

Timing of choice reform. In web Appendix Table A14, we report estimates from specifications where we allow the effect of the 2008 choice extension to any qualified provider to differ from the effect of the initial relaxation of constraints on choice in 2006. There is no statistically significant difference in effects of the initial 2006 relaxation and the 2008 extension of choice and both are very similar to the results in Table 4.

Post choice reform change in covariate effects. It is possible that the effects of covariates on quality differed before and after the choice reform. The roll out of prospective pricing over the period could have led to changes in coding practice\footnote{The quality model is now $q_{iht} = \beta_0 + \mathbf{x}_{iht}' \psi_1 + \gamma \bar{M} A_t + \mathbf{x}_{iht}' \omega_1 A_t + \mathbf{x}_{iht}' \omega_2 A_t + \mu_h + \epsilon_{iht}$.} and there could be trends in age- and gender-specific readmission or mortality over our 9-year period. If so, $\gamma$ may be biased (Meyer, 1995). To allow for this, we re-estimated the baseline model adding interactions of the post-choice indicator and all the covariates (Abadie, 2005).\footnote{As Table 1 shows the number of diagnoses on admission and the Charlson index increased after the choice reform.} The results are in Table 6. The pattern and magnitude of the estimated effect of the choice reform on quality are essentially unchanged. If anything, allowing covariate effects to differ pre and post the choice reform somewhat strengthens the results: $\hat{\gamma}$ increases in magnitude and is more precisely estimated for hip and knee replacements. There is little change in the CABG results.\footnote{In Appendix Table A15, we estimate a model similar to the one in Table 6 but with Post-Choice interacted only with the number of diagnoses and Charlson Index, to test whether potential post-choice upcoding from hospitals biases our results. The estimation results confirm our main findings.}

Sample selection. In our baseline models, we estimate the effect of the choice reform on NHS-funded patients treated in NHS hospitals. To test if this creates sample selection bias, because NHS-funded hip and knee replacement patients could also have chosen NHS-funded treatment in private providers, we estimate models with Heckman selection corrections in which we use the difference in distance between the nearest NHS and nearest private providers of care in an additional first stage probit model (equation (11)) of choice between NHS and private provider. Results in Table 7 columns (1) and (2) are very similar to those in Table 4. The coefficient of

\footnote{We also estimated models using the first principal component from a principal components analysis of equivalent numbers of rivals derived from HHIs based on all elective admissions, specialty admissions, procedure admissions, and number of rival hospital sites within 30 km. The weights of the different market structure measures in the first principal component of the composite PCA-based market structure measure are given by the eigenvectors reported in Appendix Table A11. All market structure measures are positively correlated with the first principal component, with larger and similar weights for the all elective admissions and elective specialty-level predicted HHIs. Results from the quality models using the first principal component as the measure of market structure were very similar to those from the model with equivalent numbers derived from specialty HHI (Appendix Table A12).}
| Post-Choice Policy * Market Structure | Hip Replacement - Emergency Readmissions (1) | Knee Replacement - Emergency Readmissions (2) | CABG - Emergency Readmissions (3) | CABG - Mortality (4) |
|--------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------|---------------------|
| Post-Choice Policy * Market Structure | 0.0023** (2.304) | 0.0013*** (3.812) | −0.0008 (−1.275) | −0.0002 (−0.317) |
| joint $\chi^2$ test residuals coefficients=0 | 505.5439 | 559.1953 | 79.7451 | 160.0936 |
| joint $\chi^2$ test Choice*covariates coefficients=0 | 63.6272 | 74.0259 | 282.5588 | 187.6139 |
| $R^2$ | 0.012 | 0.004 | 0.004 | 0.017 |

Notes: CL 2SRI baseline model of Table 4 plus interactions of post-choice reform indicator with all covariates. $t$-statistics in parentheses, based on bootstrapped hospital site cluster-robust standard errors with 1000 replications. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Results for models with hospitals fixed effects only or with hospitals fixed effects and Linear 2SRI are also similar to those in Table 4 and available from the authors upon request.
# TABLE 7  Post-Choice Reform Change in Effect of Pre-Reform Specialty Based Market Structure, Allowing for Selection into Private Providers

| Dependent Variable | Hip Replacement Emergency Readmission | Knee Replacement Emergency Readmission |
|--------------------|----------------------------------------|----------------------------------------|
| Specification      | *Heckman selection model - sample of patients treated by NHS hospitals only* | *Baseline model - sample of patients treated by NHS and Private hospitals* |
| (1)                | (2)                                    | (3)                                    | (4)                                    |
| Post-Choice Policy * Market Structure | 0.0021** (2.181) | 0.0011*** (3.876) | 0.0021** (2.208) | 0.0011*** (3.865) |
| IMR (Inverse Mills Ratio) | −0.0075 (−1.221) | 0.0010 (0.334) |                |                |
| Joint Chi² test residuals coefficients=0 | 500.4340 | 549.3528 | 578.5689 | 538.6782 |
| p-value joint χ² test residuals coefficients=0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| R² | 0.012 | 0.004 | 0.014 | 0.004 |
| Patients | 412,464 | 461,594 | 490,520 | 490,520 |
| Hospital sites | 232 | 238 | 277 | 288 |

Notes: Baseline model of Table 4 with CL 2SRI with (a) selection correction for choice of NHS provider (cols (1), (2)) or (b) estimated for all NHS patients treated in NHS or private providers (cols (3), (4)). Models in columns (1) and (2) include the IMR from a first stage probit regression of treatment in NHS hospital using the differential distance between closest NHS and closest private hospital sites plus patient’s case-mix covariates. The first stage probit sample includes NHS-funded elective hip and knee replacement patients treated in both NHS and private providers. NHS + Private hip replacement sample: 436,950 patients in 279 hospital sites; NHS + Private knee replacement sample: 491,395 patients in 290 hospital sites. For models in columns (3) and (4), the sample includes NHS-funded planned hip and knee replacement patients treated in NHS and Private providers. The small differences in the samples size compared with the first stage probit models in web Appendix Table A4 arise because two private hospital sites with a missing competition measure did not have any close NHS hospital site rival within 30 km, and so their patients were excluded from estimation.
the selection correction term is negative for hip replacement and positive for knee replacement, but not statistically significant,\textsuperscript{38} possibly because most of the selection related to use of private hospitals is already controlled by the inclusion of hospital fixed-effects, the extensive set of case-mix variables, and the inclusion of the choice residuals.

As a second check excluding NHS-funded patients treated by private hospitals does not bias our results, we also estimate the baseline model on a sample of all NHS-funded patients, whether treated in NHS or private providers. As most of the private providers were not present in the market before 2006, we proxy their missing competition measure with the pre-2006 competition measure of their closest NHS hospital site within 30 km. The results, in columns (3) and (4) of Table 7, are again very similar to those in Table 4 estimated on the sample of NHS patients treated in NHS providers.

If NHS providers facing more competition pre-reform also faced more entry by private providers post-reform, this could bias the estimate of effect of the interaction of the choice reform and NHS provider pre-reform market structure. There could be greater cream-skimming of unobservedly healthier NHS patients by private providers (Moscelli et al., 2018b) or NHS providers could change quality in response to post-reform private competition, especially if private rivals are more aggressive competitors. To allow for these possibilities, we added the time-varying number of private hospital sites within 30 km of the NHS provider to our baseline model. As Table 8 shows, this does not change our results.

Finally, we allow for mortality-based selection or survivorship bias. If poor quality care increases patient mortality immediately after discharge from the index elective treatment, then this will reduce the probability of emergency readmission within 30 days of discharge. This suggests that we might have estimated our readmission models on a healthier sub-sample of patients. We therefore added a Heckman correction term, derived from a first stage CABG mortality probit model to our baseline CABG emergency readmission model. (The low mortality rates for elective hip and knee replacements—see Table 1—suggest that survivorship bias is not a problem with these treatments.) We find (web Appendix Table A17) that the selection correction term is statistically insignificant and the effect of the choice reform on CABG readmission remains small and statistically insignificant.

Hospital rurality and population density. In more densely populated areas, there are more providers to cope with the larger demand for healthcare. Hospitals in rural areas usually treat fewer patients and may benefit less from economies of scale and experience. They may also find it difficult to attract high quality staff. We address the concern that the estimated effect of predicted HHI is at least in part due to its correlation with population density or rurality in two ways. First, we interact a time-invariant indicator of the rurality of LSOA in which the hospital site is located with the pre-2006 competition measure. We find (web Appendix Table A18) that rurality interaction terms are never statistically significant and the estimated $\gamma$ coefficients are unaffected. Second, we add time-varying measures of population density to our baseline specification and again find that this made no difference to our estimate of $\gamma$ (web Appendix Table A19).

\textbf{Mechanisms.} Having established the robustness of our estimates of the post-choice reform change in the effect of market structure on elective quality, we next consider possible mechanisms which could have led to this change. For policy, it is important to know the extent to which the reform led directly to changes in elective quality and the extent to which it changed other aspects of hospital behavior which in turn indirectly affected elective quality.

\textsuperscript{38} In the yearly first stage probit models for the choice of public versus private hospital, the marginal effects of the differential distance between the closest public and private hospital sites are always statistically significant at 1%, and the p-values of the Chi-squared tests of the overall significance of the first stage probit regressions are also significant at 1% (Appendix Table A16).
TABLE 8 Post-Choice Reform Change in Effect of Pre-Reform Specialty Based Market Structure, allowing for Changing Number of Rival Private Hospitals

|                          | Hip Replacement Emergency Readmissions | Knee Replacement Emergency Readmissions | CABG Emergency Readmissions | CABG Mortality |
|--------------------------|----------------------------------------|----------------------------------------|----------------------------|----------------|
| Post-Choice Policy * Market Structure | 0.0021**                              | 0.0010***                             | −0.0003                   | −0.0003        |
|                          | (2.148)                                | (3.444)                               | (−0.525)                  | (−0.518)       |
| Number of private hospital site within 30 km | −0.0000                               | 0.0002                                | −0.0007                   | −0.0004        |
|                          | (−0.034)                               | (0.675)                               | (−0.850)                  | (−0.697)       |
| Joint $\chi^2$ test residuals coefficients = 0 | 498.5960                              | 558.7277                              | 76.3224                   | 177.0431       |
| $R^2$                    | 0.012                                  | 0.004                                 | 0.003                      | 0.016          |

Notes: Baseline model of Table 4 with CL 2SRI plus time varying number of private rivals sites. *-Statistics in parentheses, based on bootstrapped hospital site cluster-robust standard errors with 1,000 replications. *p < 0.1, ** p < 0.05, *** p < 0.01. Results for models with hospitals fixed effects only or with hospitals fixed effects and Linear 2SRI are similar to those in Table 4 and available from the authors upon request.
FIGURE 4

CHANGES IN LOG-WAITING TIMES IN HIGH AND LOW COMPETITION PROVIDERS. Notes. Competition is defined, consistently with equation (6), as the average of the pre-2006 inverse HHI. High competition = 3rd tercile of the inverse HHI distribution (i.e., large number of equivalent sized rivals in the market); Low competition = 1st and 2nd terciles [Color figure can be viewed at wileyonlinelibrary.com]

Waiting times. Our theory model in the first subsection of Section 3 suggested that changes in choice policy could affect waiting times as well as quality. Table 9 Panel A reports results for models of waiting times which have the same explanatory as our baseline model of emergency readmissions. Having an additional rival pre-choice increased waiting times by 5.5% for hip replacement and 6.5% for knee replacement, thus confirming the smaller leftward shift in the distribution of waiting times for hospitals facing more competition shown in Figure 4. As it is possible that longer waiting times for treatment worsen patient outcomes (Nikolova et al., 2015; Reichert and Jacobs, 2018), some of the increased probability of an emergency readmission in providers facing more pre-choice competition may be due to the effect of the choice reform on waiting times.

Length of stay. Providers could react to increased competition by reducing patient length of stay in order to reduce costs and to free up beds to treat more patients. Panel B of Table 9 reports results from models of length of stay using the same form and explainatories as the baseline CL 2SRI quality model. Length of stay for hip and knee replacement patients decreased more after 2006 in hospitals facing more competition, suggesting that patients were indeed discharged faster in the post choice period. The effect is negative and statistically significant at 5% (1%) for knee (hip) replacement, and negative but not statistically significant for CABG patients. 39

Earlier discharge of patients can in general worsen health outcomes (Epstein et al., 1990; Martin and Smith, 1996; Sudell et al., 1991). However, the long-term trend reduction in length

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39 Gaynor et al. (2013) find that, post-reform, hospitals facing more competition had shorter length of stay for all patients and Cooper et al. (2018) that the choice reform reduced pre-operative length of stay for hip replacement.
### TABLE 9  Post-Choice Reform Change in Effect of Pre-Reform Specialty Based Market Structure on Waiting Times and Length of Stay

|                      | Musculoskeletal |                          | Circulatory system |
|----------------------|-----------------|--------------------------|--------------------|
|                      | Hip Replacement | Knee Replacement | CABG               |
| Panel A. Effect of pre-reform market structure on logarithm of patient waiting time |                  |                          |                    |
| Post-Choice Policy * Market Structure | 0.0540*** 3.558 | 0.0647*** 4.044 | 0.0209 0.785 |
| joint $\chi^2$ test residuals coefficients=0 | 464.0301 | 523.3858 | 88.6372 |
| $p$-value joint $\chi^2$ test residuals coefficients=0 | 0.0000 | 0.0000 | 0.0002 |
| $R^2$ | 0.237 | 0.289 | 0.182 |

Panel B. Effect of pre-reform market structure on patient in-hospital length of stay

|                      | Musculoskeletal |                          | Circulatory system |
|----------------------|-----------------|--------------------------|--------------------|
|                      | Hip Replacement | Knee Replacement | CABG               |
| Post-Choice Policy * Market Structure | $-0.1734*** (-2.606)$ | $-0.1191** (-2.029)$ | $-0.0578 (-0.477)$ |
| joint $\chi^2$ test residuals coefficients=0 | 698.4368 | 594.4042 | 66.3769 |
| $p$-value joint $\chi^2$ test residuals coefficients=0 | 0.0000 | 0.0000 | 0.0327 |
| $R^2$ | 0.192 | 0.169 | 0.129 |

Panel C. Effect of pre-reform market structure on mortality for emergency care

|                      | Hip fracture | AMI |
|----------------------|--------------|-----|
| Post-Choice Policy * Market Structure | $-0.0022** (-2.078)$ | $-0.0038*** (-2.804)$ |
| Patients | 288,279 | 91,005 |
| Sites | 238 | 213 |

Notes: Models for waiting time and length of stay have same explanatories and specification as Table 4 model of emergency readmissions as do models for 30 day mortality for emergency hip fracture and AMI except that there are no choice residuals in the emergency admissions models. Competition is at specialty level (orthopedics for hip and knee replacement and hip fracture, cardiovascular system for CAG and AMI). t-statistics in parentheses are based on hospital site cluster-robust standard errors. *$p<0.1$, **$p<0.05$, ***$p<0.01$. © The RAND Corporation 2021.
of stay for hip and knee replacement (Burn et al., 2018) is in part due to enhanced recovery programs intended to get patients “back on their feet” and recovering better outside hospital. Thus, not all reductions in length of stay increase readmission rates, but if the relationship between length of stay and emergency readmissions is U-shaped, then providers facing more competition who reacted to the choice reform with a greater reduction in length of stay could have experienced increased emergency readmission rates relative to providers with smaller reductions in length of stay.

Effort diversion: quality of emergency care. Propper et al. (2008), Gaynor et al. (2013), Katz (2013), and Skellern (2018) suggest that hospital management might convey information about quality through hospital mortality rates. If patients did not observe indicators for elective care quality, then the choice reform could have induced a diversion of hospital efforts toward quality for emergency services, where mortality is high compared with elective care, thereby reducing quality for elective care. Cooper et al. (2011) and Gaynor et al. (2013) found that the choice reform led to lower emergency AMI mortality for providers exposed to more rivals. In Panel C of Table 9, we report results from linear probability models for mortality within 30 days following admissions for AMI and hip fracture. The specification is the same as our baseline model for emergency readmissions with a full set of covariates and hospital fixed effects (Table 4, column (2)) but with no need to allow for endogenous patient choice of hospital. We measure competition at circulatory and musculoskeletal specialty level, rather than for all electives as in previous models of emergency mortality. We find that providers exposed to more rivals pre-reform had larger reductions in mortality after the choice reform, lending some support to the effort diversion hypothesis. Given that the specification is the same as that for elective quality (equation (6)), the similarity of our results to those of Cooper et al. (2011) and Gaynor et al. (2013) for AMI and Moscelli et al. (2018a) for hip fracture suggests that our results for elective quality are not due to some peculiarity of the specification, even though we find negative effects on quality for two elective musculoskeletal procedures and no effect for an elective circulatory procedure (CABG). The lack of any effect for elective CABG, compared with a negative effect for emergency AMI quality may be because there are only 47 CABG providers compared with 213 providers of AMI care.

Hospital profit on elective procedures. The theory model sketched in Section 3 and the bulk of the theory literature (Brekke et al., 2014) suggest that whether greater competition increases or reduces, quality depends, *inter alia*, on whether the revenue from marginal patients who would be attracted by higher quality is greater or smaller than their cost. We do not have information on the marginal cost of patients but we can make some back-of-the-envelope estimates of the average profit or loss per patient. It is plausible that capacity constraints in NHS hospitals mean that they produce where cost per patient is increasing and so marginal cost is greater than average cost. Hence, if a hospital makes a loss per patient, its marginal cost will exceed the price it receives and so it will not want to attract additional patients by improving quality.

Hospitals are paid a fixed tariff \( P_{jt} = P_{jt} \times MFF_{ht} \) per patient in HRG \( j \) in year \( t \) where the national tariff \( P_{jt} \) is based on average reported costs for all hospitals in the two previous years and \( MFF_{ht} \) is a local adjustment for input prices. It is therefore possible that, if costs increase over time, perhaps because of changes in medical technology or the morbidity of patients, or changes in input prices, the HRG tariff could be less than the unit cost of the procedure.

To check whether this is the case, we computed per patient profit for our three procedures. Let \( AC_{jt} \) denote the national unit cost for HRG \( j \) in financial year \( t \) and \( CI_{ht} \) the reference cost index for all elective procedures in hospital \( h \) in year \( t \). \( CI_{ht} \) compares the cost of hospital \( h \)'s mix of outputs with the average national cost for the same mix. We assume that the average cost of

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40 We also added provider hip fracture (AMI) mortality rates to our baseline models for elective hip or knee hip replacement (elective CABG) with competition measured at specialty level as additional controls for unobserved hospital level factors. This made very little difference to the results (Appendix Table A20).
HRG $j$ in year $t$ for hospital $h$ is $(CI_{ht} / 100) \times AC_{jt}$, and compute per patient profit on HRG $j$ in hospital $h$ in year $t$ as $MFF_{ht} \times P_{jt} - (CI_{ht} / 100) \times AC_{jt}$. (See web Appendix Table A21 for details.)

Over the 2 years (2009/10, 2010/11) for which we have data, NHS hospitals made an average loss for each patient of £750 for knee replacement, £485 for hip replacement, and £370 for CABG. They sustained much larger losses on the procedures (hip and knee replacements) where we find a decrease in quality after the choice reform and had smaller losses for CABG patients where we found no effect of the choice reform on quality. The calculations are necessarily rough because of data limitations, but we think they are suggestive of why hospitals in more competitive environments responded to the choice reform by reducing quality.

7. Conclusions

We investigated whether the relaxation of constraints on patient choice in the English NHS in 2006 changed the relationship between market structure and quality for three common elective treatments. We used control function strategies to address possible bias induced by time-varying patient selection into hospitals. Controlling for this bias produces larger and more precise estimates of the effects of the choice reforms on elective quality. For hip and knee replacements, the 2006 choice reforms led to $1/10$th and $1/5$th increases in the risk of emergency readmissions within 28 days of discharge, an increase in waiting times, and a reduction in length of stay. The choice reform had no effect on emergency readmissions, mortality, waiting times, or length of stay for CABG patients.

Our results are robust to measures of market structure, patient selection into NHS providers, allowing the effects of covariates to vary pre and post-choice reform. The effects on quality are relatively modest, possibly because demand elasticity with respect to quality is generally low (about 0.1) for CABG (Gaynor et al., 2016) and hip replacement (Moscelli et al., 2016).

Negative effects of competition on quality have been found in other empirical studies (second subsection of Section 2). They are compatible with previous theoretical models (Brekke et al., 2011) and with the new model of quality and waiting time sketched in Section 3. In these models, hospitals motivated by altruistic or intrinsic concerns may make a loss on marginal patients. If demand becomes more responsive to quality and waiting time because of increased competition, providers may reduce quality and increase waiting times to reduce demand and thus losses on marginal patients. Our back-of-the-envelope computations for 2009 and 2010 suggest that hospitals were making losses on elective hip and knee replacements, but less so for CABG patients for whom there was less evidence of a reduction in quality.

Our results for elective care are also compatible with those for emergency care which use a similar identification strategy to ours but find that the choice reform reduced mortality for AMI (Cooper et al., 2011; Gaynor et al., 2013) and hip fracture (Moscelli et al., 2018a) for hospitals facing more competitors. If emergency mortality is used by elective patients as a salient signal of overall hospital quality, then patient choice could increase emergency quality and reduce elective care quality as the result of diverted effort (Katz, 2013; Skellern, 2018). Moreover, the reductions in mortality are likely to have generated health benefits which are larger than the health losses for elective patients as measured by higher emergency readmissions for hip and knee replacement patients.

In contrast with our results, Gaynor et al. (2016) find that mortality for CABG patients was reduced by the choice reform. However, their focus was on the effect of the reform on the choices made by patients. After the reform, patients who placed a greater relative valuation on

$^{41}$ Publicly available reference costs data for years 2006/7, 2007/8, and 2008/9 was reported used HRG4, whereas the national tariff for the same years was reported using HRG3.5, which makes it difficult to compute hospital profit and losses by HRGs in those years.

$^{42}$ They also, indirectly, investigate the effect of the reform on hospital quality by showing that hospitals with a greater increase in the elasticity of demand with respect to mortality had a greater reduction in mortality, though, as they note, this investigation uses only a sample of 27 providers, and it may be subject to reverse causality.
quality versus distance could exercise their right to choose from a wider set of hospitals and were treated in higher-quality providers. This reduced the average mortality for patients. Our focus is on the effect of the reform on the behavior of providers—the change in the quality they provided. We find that the reduction in CABG provider mortality rates was very small and statistically insignificant.

The reductions in quality for knee and hip replacement procedures that we find do not mean that the 2006 choice reform was welfare reducing overall. Patients undergoing elective procedures may gain from being able to switch to previously unobtainable providers with higher quality (as in Gaynor et al., 2016). The evidence suggests that patient choice of hospital for non-emergency treatments became more sensitive to quality after the choice reforms (Gaynor et al., 2016). Moreover, patients may place an intrinsic value on having a choice of provider (Dixon et al., 2010). Last, but not the least, the choice reform also improved the quality of some types of emergency procedures (Cooper et al., 2011; Gaynor et al., 2013; Moscelli et al., 2018a).

Our findings contribute to the heated debate on the effect of competition on hospital quality (Bloom et al., 2011, 2012; Pollock et al., 2011a, 2011b) in two ways: we show that the English choice reforms had mixed effects on hospital quality; and we link our findings to a theory of hospital competition on quality and waiting time, thereby shedding more light on the “black-box” competition mechanism. Further research using better data on hospital costs and hospital staff behavior is needed to fully uncover the mechanisms behind the effects of provider competition, but our work suggests that competition policies are not a “magic bullet” and should be handled with care by policymakers, especially in systems where healthcare is rationed by waiting.

References

ABADIE, A. (2005). Semiparametric Difference-In-Differences Estimators. The Review of Economic Studies, 72(1), 1–19.
ANGRIST, J. (2001). Estimation of Limited Dependent Variable Models with Dummy Endogenous Regressors: simple Strategies for Empirical Practice. Journal of Business & Economic Statistics, 19(1), 2–28.
ANGRIST, J., Pischke, J.S. (2009). Mostly Harmless Econometrics: an Empiricist’s Companion. Princeton, NJ: Princeton University Press.
ARORA, S., CHARLESWORTH, A., KELLY, E., STOVE, G. (2013). Public Payment and Private Provision. The Changing Landscape of Health Care in the 2000s. Nuffield Trust and Institute for Fiscal Studies. www.nuffieldtrust.org.uk.
ASHTON, C., DEL JUNCO, D., SOUCHEK, J., WRAY, N., MANSURI, C. (1997). The Association Between the Quality of Inpatient Care and Early Readmission: a Meta-Analysis of the Evidence. Medical Care, 35(10), 1044-1059.
BALLA, U., MALNICK, S., SCHATTNER, A. (2008). Early Readmissions to the Department of Medicine as a Screening Tool for Monitoring Quality of Care Problems. Medicine, 87(5), 294–300.
BECKERT, W. (2018). Choice in the Presence of Experts: the Role of General Practitioners in Patients’ Hospital Choice. Journal of Health Economics, 60, 98–117.
BÉNABOU, R., TIROLE, J. (2006). Incentives and Prosocial Behavior. American Economic Review, 96(5), 1652–1678.
BILLINGS, J., BLUNT, I., STEVENTON, A., GEORGHIOU, T., LEWIS, G., BARDSLEY, M., (2012). Development of a Predictive Model to Identify Inpatients at Risk of Re-Admission within 30 Days of Discharge (PARR-30). BMJ Open, 2 (4). https://doi.org/10.1136/bmjopen-2012-001667.
BLÖCHLIGER, H. (2008), Market Mechanisms in Public Service provision. OECD Economics Department Working Papers, No. 626, OECD Publishing. https://doi.org/10.1787/241001625762
BLOOM, N., PROPPER, C., SEILER, S., VAN REENEN, J. (2015). The Impact of Competition on Management Quality: evidence from Public Hospitals. The Review of Economic Studies, 82(2), 457–489.
BLOOM, N., COOPER, Z., GAYNOR, M., GIBBONS, S., JONES, S., McGUIRE, A., MORENO-SERRA, R., PROPPER, C., VAN REENEN, J., SEILER, S. (2011). In Defence of Our Research on Competition in England’s National Health Service. The Lancet, December 17/24/31, 2064–2065.
BLOOM, N., COOPER, Z., GAYNOR, M., GIBBONS, S., JONES, S., McGUIRE, A., MORENO-SERRA, R., PROPPER, C., VAN REENEN, J., SEILER, S. (2012). A Response to Pollock et al., www.bristol.ac.uk/cmpo/publications/other/crespone.pdf.
BLUNDELL, R., POWELL, J. (2003). Endogeneity in Nonparametric and Semiparametric Regression Models. In M. Dewatripont, L. Hansen and S. Turnovsky, eds., Advances in Economics and Econometrics: theory and Applications, Eighth World Congress, Vol. II. Cambridge: Cambridge University Press.
BLUNDELL, R. W., & POWELL, J. L. (2004). Endogeneity in Semiparametric Binary Response Models. The Review of Economic Studies, 71(3), 655–679.

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Gravelle, H., Santos, R., Siciliani, L. (2014). Hospital quality Competition under Fixed Prices. *Regional Science and Urban Economics*, 49, 203–216.

Gravelle, H., Schroyen, F. (2020). Optimal Hospital Payment Rules under Rationing by Waiting. *Journal of Health Economics*, Vol. 70. https://doi.org/10.1016/j.jhealeco.2019.102277

Greene, W. (2004). The Behaviour of the Maximum Likelihood Estimator of Limited Dependent Variable Models in the Presence Of Fixed Effects. *The Econometrics Journal*, 7(1), 98–119.

Gutacker, N., Siciliani, L., Moscelli, G., Gravelle, H. (2016). Choice of Hospital: which Type of Quality Matters? *Journal of Health Economics*, 50, 230–246.

Hausman, J. A. (1978). Specification Tests in Econometrics. *Econometrica*, 1251–1271.

Hausman, J. (2001). Mismeasured Variables in Econometric Analysis: problems from the Right and Problems from the Left. *Journal of Economic Perspectives*, 15(4), 57–67.

Hawkes, N. (2012). Private Hospitals Look to NHS for Elective Operations as Private Medical Insurance Falls. *BMJ: British Medical Journal (Online)*, 345.

Heckman, J. (1979). Sample Selection Bias as a Specification Error. *Econometrica*, 47(1), 153–161. https://doi.org/10.2307/1912352.

HSCIC (2016). *Compendium of Population Health Indicators*. files.digital.nhs.uk/C4/E99638/Spec_03K_520ISR7G.pdf.

Katz, M. L. (2013). Provider Competition and Healthcare quality: more Bang for the Buck?. *International Journal of Industrial Organization*, 31(5), 612–625.

Kessler, D., McClellan, M. (2000). Is Hospital Competition Socially Wasteful? *The Quarterly Journal of Economics*, 115(2), 577–615.

Kessler, D., Geppert, J. (2005). The Effects of Competition on Variation in the Quality and Cost of Medical Care. *Journal of Economics and Management Strategy*, 14(3), 575–589.

Kristensen, S. (2017). Financial Penalties for Performance in Health Care. *Health economics*, 26(2), 143–148.

Lancaster, T. (2000). The Incidental Parameter Problem Since 1948. *Journal of Econometrics*, 95(2), 391–413.

Le Grand, J. (2003). *Motivation, Agency, and Public Policy: of Knights & Knaves, Pawns & Queens*. Oxford: Oxford University Press.

Lindsay, C., Feigenbaum, B. (1984). Rationing by Waiting Lists. *American Economic Review* 74, 404–417.

Marini, G., Miraldo, M., Jacobs, R., Goddard, M. (2008). Giving Greater Financial Independence to Hospitals—Does It Make a Difference? The Case of English NHS Trusts. *Health Economics*, 17(6), 751–775.

Martin, S., & Smith, P. (1996). Explaining Variations in Inpatient Length of Stay in the National Health Service. *Journal of Health Economics*, 15(3), 279–304.

Mason, A., Street, A., Verzulli, R. (2010). Private Sector Treatment Centres Are Treating Less Complex Patients than the NHS. *Journal of the Royal Society of Medicine* 103 (8), 322–331.

McClellan, M., McNeil, B., Newhouse, J. (1994). Does More Intensive Treatment of Acute Myocardial Infarction in the Elderly Reduce Mortality? Analysis Using Instrumental Variables. *Journal of the American Medical Association*, 272(11), 859–866.

McFadden, D. (1974). Conditional Logit Analysis of Qualitative Choice Behavior. In Zarembka, P., ed., *Frontiers in Economics*, vol. 4. New York: Academic Press, pp. 105–142.

McGuire, T. (2000). Physician agency. In A. Culyer and J. Newhouse, eds., *Handbook of Health Economics*, Volume 1A. North-Holland. Amsterdam.

Meyer, B. (1995). Natural and quasi-experiments in economics, *Journal of Business and Economic Statistics*, 13, 151–161.

Monitor (2013). A Guide to the Market Forces Factor. assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/300859/A_guide_to_the_Market_Forces_Factor.pdf.

Moscelli, G., Siciliani, L., Gutacker, N., Gravelle, H. (2016). Location, Quality and Choice of Hospital: evidence from England 2002–2013. *Regional Science and Urban Economics*, 60, 112–124.

Moscelli, G., Gravelle, H., Siciliani, L., Santos, R. (2018a). Heterogeneous Effects of Patient Choice and Hospital Competition on Mortality. *Social Science & Medicine*, 216, 50–58.

Moscelli, G., Gravelle, H., Siciliani, L., Gutacker, N. (2018b). The Effect of Hospital Ownership on Quality of Care: evidence from England. *Journal of Economic Behavior & Organization*, 153, 322–344.

Moulton, B. (1990). An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Units. *Review of Economics and Statistics*, Vol. 72, pp. 334–338.

Mukamel, D., Zwanziger, J., Tomaszewski, K.J. (2001). HMO Penetration, Competition and Risk-Adjusted Hospital Mortality. *Health Services Research*, 36, 1019–1035.

Murphy, K., Topel, R. (1985). Estimation and Inference in Two-Step Econometric Models. *Journal of Business and Economic Statistics*, 3(4), 370–379.

Naylor, C., Gregory, S. (2009). *Independent Sector Treatment Centres*. London: King’s Fund.

Newey, W., McFadden, D. (1994). Large Sample Estimation and Hypothesis Testing. In Engle, R., McFadden, D., eds., *Handbook of Econometrics*, Vol. IV, pp. 2111–2245.

Newhouse, J., McClellan, M. (1998). Econometrics in Outcomes Research: the Use of Instrumental Variables. *Annual Review of Public Health*, 19(1), 17–34.
NICOR (2012). National Adult Cardiac Surgery Audit Report. Annual Report 2010–2011. www.ucl.ac.uk/nicor/audits/adultcardiac/documents/reports/annualreport2010-11.

NIKOLova, S., HARRISON, M., SUTTON, M. (2015). The Impact of Waiting Time on Health Gains from Surgery: evidence from a National Patient-Reported Outcome Dataset. *Health Economics*, 25, 955–968.

OECD (2012). Competition in Hospital Services, OECD Policy Roundtables, Directorate for Financial and Enterprise Affairs Competition Committee. www.oecd.org/daf/competition/50527122.pdf.

OECD (2019). *OECD Health Statistics 2019*. http://www.oecd.org/els/health-systems/health-data.htm

OSTER, E. (2019). Unobservable Selection and Coefficient Stability: theory and Evidence. *Journal of Business & Economic Statistics*, 37, 187–204

POLLOCK, A., MACFARLANE, A., KIRKWOOD, G., MAJEEED, A., GREENER, I., MORRELLI, C., BOYLE, S., MELLETT, H., GODDEN, S., PRICE, D., BRIHLKOVA, P. (2011a). No Evidence that Patient Choice in the NHS Saves Lives. *The Lancet*, 378, 2057–2060.

POLLOCK, A., MAJEEED, A., MACFARLANE, A., GREENER, I., KIRKWOOD, G., MELLETT, H., GODDEN, S., BOYLE, S., MORRELLI, C., BRHLIKOVA, P. (2011b). Authors’ Reply. *The Lancet*, 378, December 17/24/31, 2065–2066.

PROPPER, C., BURGESS, S., GREEN, K. (2004). Does Competition between Hospitals Improve the Quality of Care? Hospital Death Rates and the NHS Internal Market, *Journal of Public Economics*, 88, 1247–1272.

PROPPER, C., BURGESS, S., GOSSAGE, D. (2008). Competition and Quality: evidence from the NHS Internal Market 1991–9. *The Economic Journal*, 118, 138–170.

PROPPER, C., SUTTON, M., WHITNALL, C., WINDMEIER, F. (2010). Incentives and Targets in Hospital Care: evidence from a Natural Experiment. *Journal of Public Economics*, 94 (3), 318–335.

REICHERT, A., JACOBS, R. (2018). The Impact of Waiting Time on Patient Outcomes: evidence from Early Intervention in Psychosis Services in England. *Health Economics*, 27(11), 1772–1787.

SA, L., STRAUME, O.R., SICILIANI, L. (2019). Dynamic Hospital Competition under Rationing by Waiting Times, *Journal of Health Economics*, 66, 260–282.

SHEN, Y. (2003). The Effect of Financial Pressure on the Quality of Care in Hospitals. *Journal of Health Economics*, 22, 243–269.

SICILIANI, L., BOROWITZ, V., MORAN (2013), *Waiting Time Policies in the Health Sector: what Works?*. Paris: OECD Publishing. https://doi.org/10.1787/9789264179080-en.

SICILIANI, L., CHALKLEY, M., GRAVELLE, H. (2017). Policies Towards Hospital and GP Competition in Five European Countries. *Health Policy*, 121, 103–110.

SKELLERN, M. (2018). The hospital as a multi-product firm: the effect of hospital competition on value-added indicators of clinical quality. Centre for Economic Performance Research Paper CEPDP 1484.

SUDELL, A. J., HORNER, J. S., JOLLY, U., & PAIN, C. H. (1991). Length of Stay in General Medical Beds; Implications for the NHS White Paper of Variance within One Performance Indicator. *Journal of Public Health*, 13(2), 88–95.

TERZA, J. V., BASU, A., RATHOUZ, P.J. (2008). Two-Stage Residual Inclusion Estimation: addressing Endogeneity in Health Econometric Modeling. *Journal of Health Economics*, 27(3), 531–543.

WEISSMAN, J., AYANIAN, J., CHASAN-TABER, S., SHERWOOD, M., ROTH, C., EPSTEIN, A. (1999). Hospital Readmissions and Quality of Care. *Medical Care*, 37(5), 490–501.

WILSON, N., (2016). Market Structure as a Determinant of Patient Care Quality. *American Journal of Health Economics*, 2(2), 241–271.

WOOLDRIDGE, J. (2015). Control Function Methods in Applied Econometrics. *Journal of Human Resources*, 50(2), 420–445.

**Supporting information**

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix A. Additional descriptive statistics and results

Appendix B.

Appendix C: Theory model: competition, choice and quality.