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The effect of hospital choice and competition on inequalities in waiting times

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A B S T R A C T

We use a quasi difference-in-difference approach to examine whether the 2006 relaxation of constraints on patient choice of hospital in the English National Health Service (NHS) affected waiting times inequalities for three common elective treatments (coronary bypass, hip replacement and knee replacement) in hospitals which faced more potential competition (number of rivals) before the choice reform was introduced relative to those which faced less competition. After the 2006 choice reform hospitals which had more rivals before 2006 had longer waits for hip and knee replacement, with one additional rival increasing the median waiting time by 2.5% and 4.0%, and the 75th quantile waiting time by 4.2% and 7.1%. There was no effect on waiting times for coronary bypass patients up to the 75th quantile of the wait distribution. The choice reform and market structure had no effect on the standard deviation of waiting times within hospitals but did increase waiting time variation within small geographical areas. Older hip replacement patients had shorter waits pre-choice reform but the gradient disappeared after it and was not affected by market structure. Before the choice reform, more deprived patients had longer waits but post-reform there was no deprivation gradient in waiting times, and the reduction in the gradient was not affected by pre-reform market structure. Overall, the results suggest that the choice reform led to longer and more dispersed waiting times in more competitive areas but deprivation related inequity was smaller in the post-choice period.

1. Introduction

The demand for health care has risen because of the ageing of the population, increased prevalence of chronic conditions, and technological development. In publicly-funded health systems, increases in supply do not always keep up with the increase in demand, leading to longer waiting times for health care (OECD, 2020). There is pressure to make health spending growth more sustainable, with countries under pressure to introduce reforms that contain costs while maintaining or improving the quality of health services.

Waiting times for elective healthcare arise from the mismatch between demand and supply, and are therefore at the core of the tension between rising demand and efforts to make spending sustainable. Waiting times are a key policy concern in

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many high-income countries which combine public insurance and limited co-payments (Siciliani, et al., 2013). Economists have argued that waiting times act as a non-price rationing mechanism that equilibrates the demand for and supply of health care (Lindsay and Feigenbaum, 1984). Longer waiting times are costly for patients: the health gains from treatment are delayed, the capacity to gain may be reduced (Nikolova et al., 2015; Reichert and Jacobs, 2018), and patients may be unable to work whilst waiting (Aakvik et al., 2015). Given that patients differ in urgency and severity, they are usually prioritised on the waiting list according to characteristics thought to reflect their need for care (Gravelle and Siciliani, 2008). However, there is evidence of inequity: waiting times can vary with socioeconomic status, rather than need, even within public health systems (Moscelli et al., 2018b).

A range of policies have been implemented, with varying success, to reduce waiting times (Siciliani, et al., 2013). Waiting time targets or guarantees are the most common policy. Patient choice and hospital competition have also been promoted as policy levers to reduce waiting times based on the argument that competing hospitals have greater incentive to reduce waiting times to attract patients and increase revenue. However, theory models suggest that whilst profit-maximising hospitals facing regulated prices have an incentive to increase quality in response to competition (Gaynor et al., 2006), this is not necessarily the case for providers with sufficiently high altruism (Brekke et al., 2011). Similar arguments apply to competition and waiting times in the presence of altruism and limited capacity or increasing marginal cost of supply: the effects of increased choice and competition on waiting times could be positive or negative. With capacity constraints, providers could be working at a negative profit margin with providers competing to *avoid* rather than to attract patients, as it is too costly to accommodate additional patients with limited capacity (Brekke et al., 2008). Even if competition reduces waiting times (or more broadly increases quality), it could increase inequalities across and within hospitals (Siciliani and Straume, 2019).

In this study, we first develop a theory model of the effect of competition on waiting times in semi-altruistic public hospitals facing regulated prices. We then investigate empirically the effects on waiting times of a policy which gave patients greater choice of provider and thus potentially stimulated competition. We focus on three common elective treatments: coronary bypass, hip replacement, and knee replacement. Using a quasi difference-in-difference (DID) approach, we exploit the relaxation of constraints on patient choice of hospital in the English National Health Service (NHS). We test whether waiting times differed post policy between *more* and *less* competitive areas, therefore focussing on the interaction between the post-choice period and market structure. Before 2006 contractual arrangements between NHS hospitals and patients' local health authorities limited the choice of hospital for non-emergency treatment. After 2006 these constraints were relaxed and patients had to be offered a choice of at least four providers, later extended to all hospitals in England. Our DID model compares hospitals in more and less competitive areas pre- and post choice by interacting a post-policy dummy with a continuous variable related to degree of competitiveness faced by each hospital (the equivalent number of rivals).

Given the costs that waiting impose on patients, differences in waiting times are often perceived by the public and policy makers as a sign of lack of responsiveness and health system failure. Within our quasi DID framework, we therefore examine the effect of the policy and the interaction with market structure on three aspects of the distribution of waiting times. The first is the effect on *inequalities* in waiting times, i.e. on differences in waiting times for patients with similar characteristics.[1] We investigate how the choice reform affected patients at different points along the waiting time distribution by estimating an unconditional quantile regression (UQR) model, following the approach suggested by Firpo et al. (2009) and Borgen (2016). Thus, we can test, for example, if the reform led to a bigger increase or reduction in waiting time for patients at the upper end of the waiting time distribution than those at the lower end. We also examine whether the patient choice and competition policies increased or reduced inequalities in waiting times experienced by patients within small areas and within hospitals where they receive care. We investigate whether the standard deviation in waiting times in the same hospital, or the same small area, in more competitive areas increased or decreased following the patient choice reform.

Second, we examine how choice and competition affected the *prioritisation* rules used by hospitals to determine how long patients with different needs have to wait. We consider how waiting times varied with indicators of need for healthcare (morbidity and age), and whether this was affected by the choice policy and competition faced by providers.

Third, we investigate whether and how the choice reform affected socioeconomic *inequity* in waiting times (Wagstaff et al., 1991). We define inequity as waiting times varying with patient deprivation, conditional on patient need. Controlling for need (proxied by age and measures of morbidity), we test whether more deprived patients have shorter or longer waiting times before and after the choice reform, and whether the effect of the reform on this gradient varied with market structure. We also examine the combined effects of choice reform and competition on a summary measure of deprivation related inequity – the concentration index of waiting time against deprivation – using an improved method suggested by Heckley et al. (2016).

We find that the change in the effect of market structure due to the 2006 choice reforms led to an increase in median waiting time for hip and knee replacement by 2.5% and 4.0%, the 75th quantile waiting time by 4.2% and 7.1%. Thus, the waiting time distribution was shifted to the right and by more in hospitals facing greater pre-reform competition. The choice reform and market structure had no effect on waiting times for coronary bypass up to the 75th quantile of the wait distribution. In more competitive areas, the choice reforms increased for the three procedures the variation in waiting times across patients within small geographical areas, but not within hospitals.

[1] A prominent example of concern about inequalities is publicity about "postcode rationing" when patients in geographically contiguous and similar small areas have different access to care (Iacobucci, 2017).

Waiting time prioritisation with respect to morbidity and age for hip and knee replacements generally reduced in the post-choice period, though this was not related to pre-reform competition. In the post-choice period, socioeconomic inequities also reduced: pre-reform more deprived patients had longer waits but post-reform there was no deprivation gradient in waiting times. This reduction in inequity was not affected by pre-reform market structure. The reduction in deprivation related inequity in waiting times observed post-reform for all three treatments was reflected in the concentration index of the logarithm of waiting times against deprivation. Overall, the results suggest that the choice reform led to longer and more dispersed waiting times in more competitive areas. Deprivation related waiting time inequity was however smaller in the post-choice period.

Our study adds to the limited literature on the effect of hospital competition on waiting times. Using cross-sectional methods, Siciliani and Martin (2007) find that hospitals facing more rivals had shorter waiting times, controlling for exogenous demand and supply factors, but the effect was modest and non-linear: an extra hospital in a catchment area with about five hospitals reduced the mean wait by around 1–2% and increased it for hospitals facing more than 11 rivals. Dawson et al. (2007) analyse the impact of the London Patient Choice Project on ophthalmology waiting times where patients at risk of breaching inpatient waiting time targets were offered the choice of an alternative hospital with a guaranteed shorter wait. Using a difference-in-differences approach with hospitals outside London as controls, the study finds a modest reduction in waiting times, and a reduction in variation in waiting times within London.

Propper et al (2008a) investigate the effect of competition on quality and waiting times during the early nineties when hospitals prices were not fixed but instead negotiated with Health Authorities, and good clinical quality indicators were generally not available. Using a difference-in-difference design, they find competition led to a large reduction in waiting times (about a month difference between monopolistic and competitive areas) but also to a reduction in quality in the form of higher heart attack mortality rates. A more recent paper by Gaynor et al. (2013) for a period when hospitals faced fixed prices tests, *inter alia*, whether, after the 2006 choice reforms, hospitals facing more a more competitive market structure and finds no effect of the choice reform on the proportion of patients waiting more than three months (Gaynor et al., 2013, footnote 16). As part of a study which focussed on quality as measured by emergency readmissions and mortality and did not examine inequity and inequality, Moscelli et al. (2021) found that the choice reform increased *mean* waiting times and did so by more in hospitals exposed to less competition pre reform but did not examine the effect on inequality and inequity in waiting times.

Our study also contributes to the broader literature on the effect of competition on quality (broadly defined), following the seminal papers by Kessler and McClellan (2000) and Kessler and Geppert (2005) in the US (see Gaynor and Town, 2011, for a review). Most of these studies focus on the quality of emergency care, particularly mortality after heart attack and generally find that greater competition reduced mortality. [2] For elective care, Colla et al. (2016) 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 and Moscelli et al. (2021) find that competition increased post-surgery emergency hospital readmissions for elective hip and knee replacement patients, but not for CABG. Our study is also related to the literature, reviewed in Siciliani (2016), which finds socioeconomic related inequity in waiting times: Cooper et al. (2009) and Laudicella et al. (2012) for hip replacement in England in 2000; Moscelli et al. (2018b) for coronary bypass and angioplasty in England; Monstad et al. (2014) for hip replacement, and Kaarboe and Carlsen (2014) for all elective treatments in Norway; and Johar et al. (2013) and Sharma et al. (2013) for Australia. Cookson et al. (2013) found that the pro-competition reforms in the English NHS weakened the negative area level association of overall elective admissions and deprivation in areas with more competition.

2. Institutional background, data and methods

2.1. Institutional background

NHS hospital treatment in England is tax funded and free of charge. To access hospital for elective (non-emergency) treatment, patients need a referral from their general practitioner. Most hospital care for NHS funded patients is provided by NHS Trusts which are public hospitals bodies subject to financial and regulatory control and expected to break even. 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 hospitals, with the provider receiving a lump sum for agreeing to treat all patients from the PCT who were referred by their GP. 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 was rolled out, with the proportion of treatments covered increasing over time. Under prospective pricing, hospitals can increase their profits if they attract more patients and the cost of treatment is smaller than the nationally fixed per patient tariff.

[2] For the English NHS Cooper et al. (2011), and Bloom et al. (2015) find that competition reduced AMI mortality. Moscelli et al. (2018a) control more finely for diagnosis and find no effect on AMI or stroke mortality but do find that after the choice reform hospitals facing more competition had lower mortality from hip fracture.

Until 2006, the amount of choice for elective care varied across PCTs and general practices, depending on the set of hospital with which the PCT had placed block contracts and GPs' willingness to refer outside this set.[3] In January 2006, NHS elective patients were given the right to be offered a choice of at least four providers. From April 2008 onwards, they had the right to choose any qualified provider, public or private. To complement the choice reform, an electronic booking service for outpatient appointments was rolled out from 2005 to help patients and their GPs make a firm booking during a consultation (Dusheiko and Gravelle, 2018). In 2007 the NHS Choices website was established to provide public information on services and quality of providers.

From 2003/4 private sector providers (Independent Sector Treatment Centres - ISTCs) were encouraged to enter the market. By 2010/11, they treated 4% of NHS elective patients, concentrating on a small number of high volume procedures such as hip replacements (Hawkes, 2012) where they treated around 10%.

Between 2002 and 2010, the NHS underwent a period of sustained expenditure growth driven by the perception that the NHS had been previously under-funded, and that quality was low (Moran, 1999). Funding was provided for additional beds in existing hospitals, new hospitals and care centres, and the employment of additional doctors, nurses and support staff. The expansion in capacity was also accompanied by centrally imposed waiting time targets with associated penalties on hospital management. The maximum waiting time for planned procedures was reduced from 18 months to 12 months in 2003, 9 months in 2004 and 6 months in 2005. The maximum waiting time from referral to treatment was further reduced to 18 weeks (NHS England, 2015). These measures contributed to a reduction in waiting times for elective surgeries without detrimental effects on quality (Propper et al., 2008b, 2010).

2.2. Data

Our main data are from Hospital Episodes Statistics (HES). HES includes all admissions of NHS funded and privately funded patients in NHS providers and all NHS funded admissions to private providers in contract with the NHS. We therefore use a panel data from financial year 2002/3 to 2010/11 for all NHS funded patients admitted to hospitals in England for three non-emergency procedures: hip replacement, knee replacement and coronary artery bypass (CABG). We include NHS funded patients aged 35 and over treated in NHS hospital sites (see Appendix A for details on procedure codes).[4] We do not include NHS patients treated by private providers because of concerns about the accuracy of coding of data on patient morbidity and other characteristics in the early part of our period (Healthcare Commission, 2008).[5] We use information on private providers and the number of their NHS patients when constructing measures of market structure. Our analysis is conducted at the patient level, which allows to control accurately for patient case-mix, while market structure is measured at the hospital level. Although the analysis is at the patient level, we exploit variation in market structure at the provider level interacted with the post policy period to identify the effects of interest within a *quasi* DID approach. The regression analysis is based on the multi-level data structure of patients (cross-sectional observations) admitted to hospital sites (panel observations). Each patient is observed only once. We estimate separate regressions for each elective procedure, thus if the same patient is treated for more than one procedure, they are treated as different observations and appear in any of the three elective procedure subsamples.

2.2.1. Waiting times

We measure individual patient waiting time for elective hip replacement, knee replacement, and CABG as the time in days from the patient being added to the waiting list by the hospital to their admission date, thus excluding the time from referral by their GP to their being added to the waiting list. Given that the distribution of waiting times is skewed with a relatively small proportion of patients with a long wait, so that the mean waiting time is above the median, we use the natural logarithm of waiting time as our main dependent variable.[6]

2.2.2. Market Structure

We measure market structure facing NHS hospital sites in two ways. First, we construct a measure based on the Herfindhal-Hirschman Index (HHI): the sum of the squared market shares of the providers in the market, whether NHS or private. We measure the equivalent number of rivals as the reciprocal of the HHI which is the number of equal sized hospitals which would yield the same HHI. Using actual patient flows to compute HHI could induce reverse causality bias

[3] For life-threatening conditions, including those requiring revascularisation procedures such as CABG surgery and angioplasty (Department of Health, 2002), hospital choice was offered from July 2002. From that date, patients who had been waiting for more than six months were given the option to choose from a range of alternative providers.

[4] We perform an inner search for patients with the same pseudonymized identifier within the HES APC in order to fill missing variables like year of birth, gender, and LSOA of residence. The time variables are all derived from the admission date to hospital. Table A1 reports the observation lost at each step of the sample construction. We start with a total of 1,085,553 observations. We exclude 39,635 over the three procedures for patients admitted to small hospitals treating less than 100 admissions per year-procedure. We exclude 45,926 that have missing waiting times variables. Finally, we exclude 43,158 NHS-funded patients treated in private providers and mainly treated for elective hip or knee replacement.

[5] We do test for and find evidence of patient selection into hospitals based on unobservables. However, this self-selection does not appear to bias the coefficients of interest of the effects of competition on waiting times.

[6] The distribution of the log of waiting times is also skewed when the sample is split by co-morbidities, deprivation, gender and age groups. See Appendix D, Figs. D1, D2, D3, D4.

since the number of patients choosing a hospital will be affected by its quality and its waiting time (Kessler and McClellan, 2000). We therefore follow the standard practice of using HHIs computed from patient flows predicted from a model of patient choice of provider based on distance and other hospital characteristics but excluding hospital quality and waiting time. (Details are in Appendix B.) In more detail, we estimate a choice model for each year and obtain predicted market shares for each hospital in a given year, which we then use the compute the HHI for each hospital in a given year (based on Eq. B1 in Appendix B). Last, for each hospital we compute the HHI averaged across years in the pre-policy period, which is therefore time-invariant.

We also control for the number of private rival hospital sites within 30 kilometres which treat at least 100 elective NHS patients per year.

2.2.3. Case-mix

To examine how hospitals prioritise patients according to severity or urgency of treatment, we use data on patient level covariates: gender, age in 10 year bands (from 35 to over 95 years), 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 hospitalization in the previous year, which we use as a proxy of patient observable severity or need. We also use the proportion of residents of the Lower Super Output Area (LSOA)[7] in which the patient lives who are receiving incapacity or disability social security benefits as a measure of morbidity.

2.2.4. Socioeconomic status

We measure socioeconomic status through the income domain of the Economic Deprivation Index (EDI) (Gill, 2012). The EDI measures the proportion of people aged 18 to 59 in each LSOA who are living in low-income households (benefit units) that are claiming out-of-work means-tested social security benefits (Income Support or income-based Jobseeker's Allowance). We attribute the EDI to patients using their LSOA of residence. The EDI deprivation index is originally measured as a score, according to which LSOAs are ranked across England, from the most to the least income deprived (lower to higher EDI score). We use annual data and generate dummy variables for the five quintile groups of the resulting distribution of the EDI across LSOAs, with the first (fifth) quintile corresponding to the most (least) income deprived LSOAs of residence.

2.2.5. Other controls

We include an indicator for whether a site is in a Trust with which has teaching hospital status, which may proxy a more severe case-mix or different organizational, technical and labour endowments compared to non-teaching hospitals. We also include an indicator for the site being part of a hospital with Foundation Trust status, which allows greater financial flexibility to hospitals (Marini et al., 2008). We also include indicators for month of the year in which the patient was placed on the waiting list and the day of week on which they were admitted.

3. Methods

3.1. Theory model of choice and waiting times

We first present a simplified theoretical model to examine the circumstances in which greater patient choice could lead to an increase in waiting times for patients.[8] A semi-altruistic hospital provides elective treatment for which NHS patients are not charged but instead are rationed by waiting time w. Patient demand is $D(w,\theta)$, which is decreasing in waiting time, $D_w < 0$. θ is a policy parameter, such as the amount of choice available to patients or the amount of competition facing the provider. Increases in θ make demand more responsive to waiting time as the demand curve becomes flatter (less negative slope) in (w, quantity) space and hence steeper (more negative slope) in (D, w) space: $D_{w\theta}(w,\theta) < 0$. We will not model how an increase in choice or competition will also increase ($D_\theta > 0$) or reduce ($D_\theta < 0$) demand at the hospital: this would complicate the specification and would not affect the message from our simple model.[9]

We assume that waiting time is always positive and adjusts to equate demand and supply, as in the Lindsay-Feigenbaum (1984) model:

$$D(w,\theta) - S = 0 \tag{1}$$

where S is the supply of care by the provider (the number of patients the hospital chooses to treat). The equilibrium waiting time $w(S,\theta)$ is decreasing in supply S since, using the implicit function theorem on (1), $w_S(S,\theta) = \frac{1}{D_w} < 0$. Even with S held constant, the effect of greater choice or competition is ambiguous: $w_\theta(S,\theta) = -\frac{D_\theta}{D_w} = -D_\theta w_S$.

[7] There were 32,482 LSOAs in England with a mean population of 1,500.

[8] See Brekke et al. (2008) for a model with strategic interaction across providers, comparative statics with respect to different competition measures, and welfare analysis. Moscelli et al (2021) examines the effect of competition on waiting time and quality.

[9] For example, the effect of greater choice on demand for a hospital will depend on how its quality compares with that of rival hospitals and modelling this would require specification of a model of competition.

The provider chooses S to maximise a semi-altruistic objective function which is a weighted sum of profit and the cost of waiting for patients:

$$V(S;\theta) = p\ D(w(S,\theta),\theta) - C(S) - \alpha\ g(w(S,\theta)) \tag{2}$$

where $g(w)$ ($g_w > 0$, $g_{ww} > 0$) is the patient cost of waiting and $\alpha \in [0,1]$ is the provider's degree of altruism. The first order condition on supply is, using $w_S(S,\theta) = \frac{1}{D_w}$,

$$V_S(S;\theta) = p - C_S(S) - \alpha g_w(w(S,\theta))w_S(S,\theta) = 0 \tag{3}$$

Note that if the hospital is partially altruistic ($\alpha > 0$), the first order condition (3) implies that it increases supply beyond the profit maximising level (where $p = C_S$) because of the gain to patients ($-g_w w_S > 0$) from the reduction in waiting time.

From (3), supply $S(\theta)$ depends on the competition parameter[10] and so the effect of competition on waiting time is

$$\frac{dw(S(\theta),\theta)}{d\theta} = w_S S_\theta + w_\theta = \frac{1}{D_w}(S_\theta - D_\theta) \tag{4}$$

Changes in competition policy have two effects on the waiting time: via supply decisions by the provider and via shifts in the demand function.

Applying the implicit function theorem to the provider's first order condition (3), the effect of an increase in competition on supply is

$$\begin{aligned} S_\theta &= -\frac{V_{S\theta}(S;\theta)}{V_{SS}} = \frac{\alpha}{V_{SS}}\ (g_{ww}w_S\ w_\theta + g_w w_{S\theta}) \\ &= -\frac{\alpha g_w}{V_{SS}(D_w)^2}\left[D_{w\theta} - D_\theta\left(\frac{D_{ww}}{D_w} - \frac{g_{ww}}{g_w}\right)\right] \end{aligned} \tag{5}$$

where the last line follows from repeated application of the implicit function theorem to the market clearing condition.[11] S_θ has the same sign as the expression in square brackets. This is because the marginal cost of waiting is positive ($g_w > 0$) by assumption and $V_{SS} < 0$ from the second order condition on the hospital's choice of S.

We can distinguish between two main effects of the effect of choice on supply. First, by assumption, the choice reform increases the responsiveness of demand to the waiting time ($D_{w\theta} < 0$). As seen in (3), the provider works at a negative profit margin, as $p - C_S < 0$. Therefore, more competition tends to increase waiting time, and *reduce* supply, as providers have stronger incentives to increase waiting times to avoid patients and reduce losses, which is a form of negative externality.

Second, greater choice could increase or reduce demand for the provider, as $D_\theta > 0$ or $D_\theta < 0$. Whether this reinforces or counteracts the first effect depends on the term in parenthesis, which requires assumptions about the second order conditions of the demand function and patient cost function with respect to waiting times. But these are in principle indeterminate, as longer waiting time could make demand responsiveness smaller or larger. Similarly, the patient marginal cost of waiting could reduce or increase with the time waited. In general, the supply response to greater choice is ambiguous.

If we assume that the demand and patient waiting time cost functions are linear in w then (5) simplifies to

$$S_\theta = \frac{\alpha g_w}{V_{SS}} w_{S\theta} = \underbrace{\overbrace{\frac{\alpha g_w}{V_{SS}}}^{+}}_{-}\ \frac{\overbrace{(-D_{w\theta})}^{+}}{(D_w)^2} < 0 \tag{6}$$

In this case, only the first effect remains. As mentioned above, the provider is making a loss on the marginal patient ($p < C_S$) which is just offset by the marginal altruistic gain from the reduction in waiting time ($\alpha g_w w_S > 0$) from treating an extra patient. When competition increases and demand becomes more sensitive to waiting time an increase in supply leads to a *smaller reduction* in the waiting time ($w_{S\theta} = -D_{w\theta}/(D_w)^2 > 0$) and so produces less benefit to patients. Hence, the hospital will be less willing to supply more than the profit maximising output.

The above describes how competition affects *supply*, but does not illustrate the effect of competition on *waiting time*, which is what we test empirically below. As shown in (4), whether competition increases or reduces waiting time depends on two factors. The first factor is whether competition increases or reduces supply: above we have identified conditions under which competition reduces supply. The second factor in (4) relates to whether competition increases or reduces demand. Even if competition reduces supply, and therefore tends to increase waiting times, this effect could be reinforced or weakened depending on whether the relaxation of constraints on choice increases or reduces demand. Thus, empirical

[10] It also depends on the degree of provider altruism α but we do not include this in the supply function to reduce notational clutter. Unsurprisingly providers with greater altruism choose a greater supply, and thus a lower waiting time since sgn $\partial S/\partial\alpha$ = sgn$V_{S\alpha} = -g_w > 0$ and $dw(S,\theta)/d\alpha = w_S \partial S/\partial\alpha > 0$. Since altruism only affects supply and not demand, the effect of altruism is entirely determined by its effect on supply.

[11] First note that $w_S(S,\theta)w_\theta(S,\theta) = -(w_S)^2 D_\theta$. Then rearrange $w_S(S,\theta) = 1/D(w,\theta)$ to get $w_S(S,\theta)D(w,\theta) - 1 = 0$ and using the implicit function theorem on this expression we have $\frac{d[D_w(w(S,\theta),\theta)w_S(S,\theta)-1]}{d\theta} = D_{ww}w_\theta w_S + D_{w\theta}w_S + D_w w_{S\theta} = 0$. Rearranging, and making use of the expressions for $w_S = 1/D_w$ and $w_\theta = -D_\theta/D_w$, we get $w_{S\theta} = (\frac{D_{ww}}{D_w}D_\theta - D_{w\theta})(D_w)^{-2}$.

investigation is required to determine the sign, let alone the magnitude, of the effect of greater competition or choice on waiting time.

The model above assumes that waiting time is homogenous across patients, and can be used as a framework to test empirically if competition affects the average waiting time. However, patients are heterogenous. Doctors prioritise patients based on need, and patients with higher need tend to wait less (Gravelle and Siciliani, 2008). In Appendix C, we sketch a model of prioritisation in which the hospital has two types of patient and chooses supply, and thus waiting time, for each type. Whether greater competition increases or reduces the difference in waiting times, and therefore its dispersion in the patient population, also depends on fine details of demand and cost functions and provider preferences. This motivates our empirical analysis in different directions. First, given that less severe patients tend to wait longer, we test whether choice and competition affect waiting times also at the upper end of the distribution through a quantile regression approach (see Section 3.2.1). Second, to test if competition affects differently patients with varying severity, we look at the effect of choice and competition on the waiting time for patients differing in morbidity and age (see Section 3.2.3). Third, we test empirically whether patient choice and competition reduces dispersion in waiting times within hospitals. In the model presented in Appendix C with two types of patients, this is equivalent to testing the effect of choice and competition on the difference in waiting times between the two groups (Section 3.2.2).

The theory model by Siciliani and Straume (2019) investigates whether competition increases or reduces quality dispersion across hospitals. The study suggests that the effect of competition on quality differences between hospitals depends on the degree of concavity of the health benefit function, and differences in costs across hospitals, and is generally ambiguous. If we interpret waiting time as a negative dimension of quality, we can use this model to motivate our empirical analysis which looks at the effect of competition and choice on the dispersion in waiting time for all patients living in a given small geographical area (Section 3.2.2). Brekke, Holmas, Monstad and Straume, 2018) provide a simple model of inequities of access by socioeconomic status in GP treatment decision but do not model choice and competition. We conjecture that patients with higher socioeconomic status may exercise choice more actively by choosing hospitals with shorter waiting times. On the other hand, patients with higher socioeconomic status may give more weight to clinical quality rather than waiting time considerations and choose hospitals with higher quality and longer waiting times. We test whether patients with higher socioeconomic status benefitted from reduced waiting times following the patient choice policy in more competitive areas.

3.2. Competition and waiting times: empirical specifications

We estimate a variety of models to examine how competition, captured by market structure *and* the relaxation of constraints on choice, affected the distribution of waiting times, inequalities in waiting times within hospitals and small areas, waiting time for patients with different need (prioritisation) and socioeconomic inequities in waiting times.

The models have similar sets of explanatories, but differ in levels of aggregation (patient, hospital, small area) and whether competition interacts with other explanatories such as deprivation. They also differ in terms of whether the aim is to investigate the effect of competition on the quantiles of the distribution of waiting times, or on measures of inequality within hospitals and small areas, or socioeconomic inequities in waiting times.

3.2.1. Effects of competition along the unconditional waiting time distribution

Using a quasi DID model, we investigate how the choice reform (post-policy period) changed the effect of competition (intensity of treatment) on the unconditional *distribution* of the log of waiting times by estimating

$$RIF(\ln w_{iht}; q_\tau) = \beta_t + \beta_d + \boldsymbol{x}'_{1iht}\boldsymbol{\beta}_1 + \gamma \bar{M}_h A_t + \boldsymbol{x}'_{2ht}\boldsymbol{\beta}_2 + \alpha_h + \hat{\boldsymbol{r}}^{CL'}_{iht}\psi_1 + \varepsilon_{iht} \quad (7)$$

where $\ln w_{iht}$ is the natural logarithm of waiting time for patient i treated in hospital site h in year t (t = 2002,...,2010) and the dependent variable $RIF(\ln w_{iht}; q_\tau)$ is the recentered influence function evaluated at the τ-th unconditional quantile of the distribution of the waiting time (Firpo et al., 2009; Borgen, 2016).[12] [13]

$\bar{M}_h$ is a time-invariant (frozen) measure of market structure, measured as the number of (equivalent) hospital rivals facing site h averaged across the pre-choice years 2002/3 to 2005/6. The estimated coefficients γ are the post-choice change in the expected effect of a hospital having more rivals on the quantiles of the distribution of ln w. $\boldsymbol{x}_{1iht}$ is a vector of patient covariates. $\boldsymbol{x}_{2ht}$ are hospital site covariates, including whether the hospital has is a teaching hospital or Foundation Trust and the number of private hospital sites within 30km which admit at least 100 NHS funded elective patients in the year. A_t is an indicator for the choice policy, equal to one in the post-choice years (2006/7 to 2010/11) and to zero in the pre-choice years. Year effects β_t are included to allow for unobserved time varying factors common to all sites, such as the roll out of

[12] Since the distributions of w_{ith} and ln w_{ith} have the same quantiles RIF is calculated as RIF(w_{iht}; q_τ) = q_τ + (τ-1[$w_{iht} \le q_\tau$])/ $f_y(q_\tau)$, where q_τ is the τ-th quantile of ln w_{iht}, 1[$w_{iht} \le q_\tau$] is a dummy equal to one when w_{iht} is below q_τ, and $f_y(q_\tau)$ is the estimated density function at q_τ. The density function is estimated assuming a Gaussian kernel and using the bandwidth that minimises the mean integrated squared error. We use the Stata package *xtrifreg* for the RIF regressions. Standard errors for estimates of both Eq. (10) and (11) are clustered bootstrapped at hospital site level with 1,000 replications.

[13] Unconditional quantile regressions estimated through RIF-OLS regressions have the advantage over conditional quantile regressions that the regression coefficients can be interpreted as the effect of shifting the distribution of outcome variable (ln w_{iht}) by a change in the independent variable of interest (e.g. $\bar{M}_h A_t$). This preserves a policy interpretation; for this to happen, the RIF of each unit observation must be used instead of the simple unconditional quantile indicator (Firpo et al., 2009).

healthcare resource group pricing and changing national policies to reduce waiting times. Hospital effects α_h are included to control for time-invariant unobserved hospital characteristics. β_d is a vector of indicator variables for the month and the day of the week. This allows, for example, for there being more emergency hip fractures during winter months thereby reducing the hospital's ability to carry hip replacements for elective patients, or there being reduced capacity due to summer due to staff holidays.

There is a potential endogeneity problem if patients who differ unobservedly in characteristics which affect their waiting time via hospital prioritisation rules base their choice of hospital on waiting time.[14] To allow for such unobserved patient selection into NHS hospitals we use control functions (Terza et al., 2008; Wooldridge, 2015). We estimate a first stage conditional logit hospital choice model using patient distance to providers and provider characteristics excluding waiting time.[15] We create auxiliary residual variables $\hat{\boldsymbol{r}}^{CL}_{iht}$ from the estimated predicted choice probabilities and include them in the waiting time regressions from Eq. (7).

The key coefficient of interest in Eq. (7) is γ: the change in the effect of pre-policy market structure after the choice reform evaluated at the τ-th unconditional quantile of the distribution of the waiting time. We test if differences across hospitals in the changes in waiting times after the relaxation of constraints on choice of hospital are determined by differences in the market conditions hospitals face, where the latter is captured by the time-invariant measure of number of (equivalent) hospital rivals in the pre-choice years.

The specification is a quasi DID model (Card, 1992; Angrist and Pischke, 2009, pp 235-236). The parameter of interest, γ, which gives the effect on waiting time at the τ-th unconditional quantile, is identified through differences in *treatment intensity*: the change in the effect of market structure after the relaxation of constraints on patient choice in 2006. The effect of the 2006 choice reform on the dependent variable (usually the logarithm of waiting time) for a provider with $\bar{M}_h$ compared to one with no rivals is $\gamma\bar{M}_h$. Thus, the sign of γ conveys useful policy information about the how the effect of the choice reform on a provider varied with the number of its rivals. If we make the relatively mild assumption that the distribution of the errors in (7) is independent of $A_t\bar{M}_h$ conditional on β_t, β_d, α_h, x_{iht}, x_{ht}, then, when y_{iht} is ln w_{ith}, the proportionate size of the effect of the reform on the waiting time for patient i in hospital h in year t compared to one with no rivals is $\gamma\bar{M}_h$.

Our calculation of the pre-reform mean number of rivals $\bar{M}_h$ allows for both NHS and private sector rivals. There were relative few pre-reform private rivals (Table 1) but there was a large increase in the number of private rivals post-reform. These private rivals treated less complex patients, so that NHS providers were left with the more complex patients requiring longer lengths of stay and so would face higher costs to treat a given number of patients. This, as our theory model suggests, could lead them to reduce their willingness to increase supply to reduce waiting times. Although our patient covariates control for some types of patient morbidity, and we allow for unobserved selection in a robustness check, we include the time-varying number of private rivals in all our models as an additional control. It is never statistically significant.

3.2.2. Effect of competition on waiting time inequalities within hospitals and within small areas

The UQR specification provides very detailed information on the change in the distribution of waiting times at different quantiles due to choice and competition. We complement it by investigating if competition affected inequalities in waiting times measured by the dispersion in the waiting time experienced by patients. We first look at dispersion within hospitals, to test if in more competitive areas patients attending the same hospital experienced more unequal waiting times. Second, we look at dispersions at small area, to test if in more competitive areas patients living within the same area experienced more unequal waiting times, therefore including higher variation across hospitals.

To test for the effect of competition on waiting time inequalities within hospitals, we specify more aggregated models of the effect of competition on a summary measure of the variation of waiting times across patients within hospitals:

$$v_{ht} = \beta_t + \gamma\bar{M}_h A_t + \boldsymbol{x}'_{ht}\boldsymbol{\beta} + \alpha_h + \varepsilon_{ht} \tag{8}$$

where v_{ht} is the *standard deviation* of waiting times for patients in hospital h in year t: $v_{ht} = (n_{ht}^{-1}\sum_i (w_{iht} - \bar{w}_{ht})^2)^{\frac{1}{2}}$, and $\boldsymbol{x}_{ht}$ is a vector of the mean hospital patient and hospital site characteristics.

To test for the effect of competition on waiting time inequalities at small area level, we also estimate a model similar to (8) at the Medium Super Output Area (MSOA) level, taking MSOA patient weighted means of the hospital characteristics and using MSOA fixed effects. We use the larger MSOA area rather than the smaller LSOA level, because under the latter our dispersion variable would be based on a small number of observations making it more sensitive to outliers. Each of the 6,781 MSOAs is composed of around 5 LSOAs and has a mean population of 7,200.

The key coefficient in both Eq. (8) and its MSOA-level version is γ, with $\hat{\gamma} < 0$ implying that after the choice reform patients attending providers with more rivals experienced less variation and inequalities in waiting time within hospitals (Eq. 8) or within their small area (Eq. 8 at MSOA-level).

[14] See Gowrisankaran and Town (1999) for a related discussion of the bias in estimates of hospital quality when there is unobserved selection on the basis of quality

[15] For the details of this procedure, see Moscelli et al. (2021).

Table 1
Descriptive statistics - Elective patients treated in NHS hospitals.

	Elective Hip Replacement					Elective Knee Replacement					Elective Coronary Bypass (CABG)				
	Low Competition		High Competition		t-test H0: $\mu_{HC}=\mu_{LC}$	Low Competition		High Competition		t-test H0: $\mu_{HC}=\mu_{LC}$	Low Competition		High Competition		t-test H0: $\mu_{HC}=\mu_{LC}$
	Mean	St.Dev.	Mean	St.Dev.		Mean	St.Dev.	Mean	St.Dev.		Mean	St.Dev.	Mean	St.Dev.	
Waiting time (days)	142.69	102.99	143.21	104.15	0.11	153.54	110.31	154.29	111.36	0.15	84.87	71.13	75.88	67.80	-1.67
log Waiting time (days)	4.67	0.86	4.66	0.89	-0.21	4.75	0.83	4.75	0.86	-0.11	4.05	1.02	3.88	1.08	-1.88
EDI income 1st quintile (most deprived)	0.10	0.29	0.18	0.38	5.70	0.11	0.31	0.22	0.41	6.76	0.15	0.36	0.22	0.42	2.47
EDI income 2nd quintile	0.17	0.38	0.19	0.39	2.40	0.18	0.39	0.21	0.41	3.49	0.18	0.39	0.22	0.41	3.24
EDI income 3rd quintile	0.24	0.43	0.20	0.40	-4.86	0.24	0.43	0.20	0.40	-5.04	0.22	0.42	0.20	0.40	-2.09
EDI income 4th quintile	0.26	0.44	0.21	0.41	-4.86	0.25	0.43	0.19	0.39	-6.62	0.23	0.42	0.19	0.39	-3.75
EDI income 5th quintile (least deprived)	0.23	0.42	0.22	0.41	-0.89	0.22	0.41	0.18	0.38	-2.45	0.21	0.41	0.18	0.38	-1.71
Number of emergency admissions (past year)	0.06	0.29	0.06	0.31	1.43	0.06	0.28	0.06	0.30	2.50	0.28	0.63	0.28	0.66	-0.01
Age	68.81	10.49	67.68	10.99	-4.43	70.31	9.13	69.76	9.31	-3.35	65.68	9.11	65.11	9.17	-1.91
Female	0.60	0.49	0.60	0.49	-0.29	0.58	0.49	0.59	0.49	2.77	0.18	0.38	0.18	0.39	0.26
Number of co-morbidity diagnosis	2.93	2.01	2.96	2.05	0.38	3.02	2.00	3.11	2.08	0.95	5.75	2.88	5.70	3.01	-0.10
Charlson index = 0	0.27	0.64	0.28	0.64	-0.46	0.31	0.63	0.32	0.64	-1.61	0.60	0.89	0.66	0.93	-1.27
Charlson index = 1	0.16	0.37	0.17	0.37	0.41	0.19	0.39	0.20	0.40	1.77	0.29	0.45	0.30	0.46	0.56
Charlson index > 1	0.05	0.21	0.05	0.21	0.44	0.05	0.22	0.05	0.22	0.84	0.12	0.33	0.15	0.35	1.76
Incapacity claims	0.03	0.02	0.03	0.02	3.33	0.03	0.02	0.04	0.02	4.04	0.03	0.02	0.04	0.02	0.98
Disability claims	0.05	0.02	0.05	0.03	2.87	0.05	0.02	0.06	0.03	3.25	0.05	0.03	0.06	0.03	0.59
Put on waiting list in January	0.08	0.28	0.08	0.28	-0.07	0.08	0.27	0.08	0.28	1.98	0.09	0.28	0.08	0.28	-0.96
Put on waiting list in February	0.08	0.26	0.08	0.27	1.60	0.07	0.26	0.08	0.27	2.05	0.08	0.27	0.08	0.27	-1.47
Put on waiting list in March	0.08	0.28	0.08	0.28	0.16	0.08	0.27	0.08	0.28	0.94	0.09	0.28	0.09	0.28	0.10
Put on waiting list in April	0.08	0.27	0.08	0.27	1.70	0.08	0.27	0.08	0.27	2.26	0.08	0.27	0.08	0.28	1.27
Put on waiting list in May	0.08	0.27	0.08	0.28	0.30	0.08	0.27	0.08	0.27	-0.75	0.08	0.27	0.08	0.27	0.05
Put on waiting list in June	0.09	0.28	0.09	0.28	-0.67	0.09	0.28	0.09	0.28	-0.81	0.09	0.28	0.09	0.28	-0.44
Put on waiting list in July	0.09	0.28	0.09	0.28	1.74	0.09	0.28	0.09	0.28	-1.09	0.09	0.28	0.09	0.28	-0.01
Put on waiting list in August	0.08	0.27	0.08	0.27	1.07	0.08	0.27	0.08	0.27	-0.42	0.08	0.27	0.08	0.27	1.16
Put on waiting list in September	0.09	0.29	0.09	0.28	-2.15	0.09	0.29	0.09	0.29	-1.65	0.09	0.28	0.08	0.28	-1.04
Put on waiting list in October	0.09	0.29	0.09	0.29	0.04	0.09	0.29	0.09	0.29	0.40	0.09	0.29	0.09	0.29	-0.07
Put on waiting list in November	0.09	0.29	0.09	0.29	-1.60	0.09	0.29	0.09	0.29	-1.08	0.09	0.28	0.09	0.29	1.12
Put on waiting list in December	0.07	0.26	0.07	0.26	-1.91	0.07	0.26	0.07	0.26	-1.46	0.07	0.26	0.07	0.26	0.78
Treated on Monday	0.10	0.30	0.09	0.29	-1.31	0.10	0.30	0.09	0.29	-1.17	0.20	0.40	0.20	0.40	0.26
Treated on Tuesday	0.19	0.39	0.19	0.39	-0.79	0.19	0.39	0.20	0.40	0.38	0.22	0.41	0.21	0.41	-0.43
Treated on Wednesday	0.19	0.40	0.19	0.39	-1.19	0.19	0.39	0.18	0.39	-1.13	0.21	0.41	0.21	0.40	-0.23
Treated on Thursday	0.20	0.40	0.20	0.40	0.21	0.19	0.39	0.19	0.39	-0.15	0.20	0.40	0.18	0.38	-2.37
Treated on Friday	0.18	0.38	0.18	0.38	0.06	0.18	0.39	0.18	0.39	-0.46	0.13	0.33	0.14	0.35	1.11
Treated on Saturday	0.11	0.31	0.12	0.32	1.40	0.11	0.31	0.12	0.32	0.97	0.04	0.20	0.05	0.23	1.16
Treated on Sunday	0.03	0.17	0.04	0.20	2.53	0.03	0.17	0.04	0.20	2.37	0.01	0.11	0.01	0.10	-0.05
Admitted from home	0.99	0.07	1.00	0.05	1.25	0.99	0.07	1.00	0.05	1.24	0.99	0.08	1.00	0.06	1.32
Choosing the closest hospital	0.67	0.47	0.56	0.50	-3.65	0.68	0.47	0.58	0.49	-3.17	0.71	0.45	0.55	0.50	-1.55

Notes. Low (High) Competition: binary indicator for pre-2006 1/predicted HHI being below (above) the median. The column *t-test H0:* $\mu_{HC}=\mu_{LC}$ reports the Wald t-stat for equality of means.

3.2.3. Effect of competition on prioritisation of patients with different levels of need

We next examine if the choice reform had different effects on waiting times for patients with different levels of need for treatment as proxied by their morbidity and age. We estimate a waiting time model in which we allow the effects of morbidity and age to change after the choice reform *and* with the amount of competition facing the hospital:

$$\begin{aligned}\ln w_{iht} = {} & \beta_t + \beta_d + \boldsymbol{s}'_{iht}\boldsymbol{\delta}_0 + A_t\boldsymbol{s}'_{iht}\boldsymbol{\delta}_1 + \left(\bar{M}_h - \bar{M}\right)A_t\boldsymbol{s}'_{iht}\boldsymbol{\delta}_2 \\ & + \gamma\bar{M}_hA_t + \boldsymbol{x}'_{1iht}\boldsymbol{\beta}_1 + \boldsymbol{x}'_{2ht}\boldsymbol{\beta}_2 + \alpha_h + \hat{\boldsymbol{r}}^{CL'}_{iht}\psi_1 + \varepsilon_{iht}\end{aligned} \tag{9}$$

$\boldsymbol{s}_{iht}$ is the vector of morbidity measures (age bands, emergency admissions in previous year, Charlson index, comorbidities) and $\boldsymbol{x}_{1ht}$ is now the vector of patient characteristics other than morbidity.[16] $\bar{M}_h - \bar{M}$ is the difference between the average pre-reform competition facing hospital h and the average pre-reform competition over all providers. The key coefficients of interests are $\boldsymbol{\delta}_2$ which, in line with the interpretation of γ, relate to the interaction between market structure and the post-choice period. These coefficients tell us if the prioritisation of patients by morbidity and age changed differentially post choice in hospitals facing different degrees of competition.

3.2.4. Effect of competition on socioeconomic inequity in waiting time

There is socioeconomic related *inequity* in waiting times if patient waiting times vary with socioeconomic status rather than with patient need. Socioeconomic status (z_{iht}) for patient i in site h in year t is measured by the economic deprivation index (EDI) which ranks patients from *most* to *least* deprived so that lower z_{iht} means higher deprivation. We test for pro-rich or pro-poor inequity and whether this was affected differently by the choice reform in more competitive hospitals by estimating

$$\begin{aligned}\ln w_{iht} = {} & \beta_t + \beta_d + \boldsymbol{z}'_{iht}\boldsymbol{\delta}_0 + A_t\boldsymbol{z}'_{iht}\boldsymbol{\delta}_1 + \left(\bar{M}_h - \bar{M}\right)A_t\boldsymbol{z}'_{iht}\boldsymbol{\delta}_2 + \gamma\bar{M}_hA_t \\ & + \boldsymbol{x}'_{1iht}\boldsymbol{\beta}_1 + \boldsymbol{x}'_{2ht}\boldsymbol{\beta}_2 + \alpha_h + \hat{\boldsymbol{r}}^{CL'}_{iht}\psi_1 + \varepsilon_{iht}\end{aligned} \tag{10}$$

$\boldsymbol{z}_{iht}$ is a vector of indicators for patient deprivation quintiles ordered from the 1st (most deprived) to the 4th quintile (second least deprived), with the 5th quintile used as the reference group (least deprived). $\boldsymbol{x}_{1iht}$ is a vector of patient covariates, which control for patient's need, and includes gender, age, number of co-morbidities, the Charlson index, and the number of emergency hospitalization in the previous year.

Conditional on patient need, there is pro-rich waiting time inequity pre-choice reform if $\boldsymbol{\delta}_0 > 0$ so that more deprived patients have longer waits than those in the least deprived baseline fifth quintile. Pro-rich waiting time inequity is increased or decreased post-choice for patients in a hospital facing mean pre-choice competition if $\boldsymbol{\delta}_1$ is positive or negative. If $\boldsymbol{\delta}_2$ is positive then pro-rich inequity is worse post-choice in providers facing more rivals. γ is the post-choice effect of facing higher $\bar{M}_h$ for all patients.

Within the health economics literature, a common summary measure of socioeconomic inequities is the concentration index, which is given by twice the area between the concentration curve[17] and the line of equality (or the 45-degree line) and has been extensively used to compare socioeconomic inequities in health and healthcare utilisation within and across countries (Wagstaff et al., 1991). As shown by Wagstaff (2002), the concentration index embodies a particular set of value judgments about aversion to inequity. The share of healthcare utilisation is weighted by twice the complement of the patient's fractional socioeconomic rank, with the poorest patients given a weight of two and the richest patient a weight of zero, with the weight decreasing linearly with the fractional rank.

We follow Heckley et al. (2016, page 95) and use the RIF of the Concentration Index of ln w_{iht} against income deprivation rank (2Cov(ln w, $F(R)$)/(E(ln w), where $F(R)$ is the cumulative distribution of deprivation rank), to estimate the combined effect of choice and competition on deprivation related inequity in the logarithm of waiting time.[18] Note that because ln w is a bad, rather than a good, and we rank individuals from most to the least deprived, the concentration index of waiting time against deprivation is *negative* when waiting time is longest for the most deprived (Wagstaff et al., 1991, page 549). Hence a *positive* effect of the choice policy on the concentration index corresponds to a *reduction* in pro-rich related inequity in waiting time. We also examine the sensitivity of the results to using the Erreygers Index (2Cov(ln w, $F(R)$/[(max(ln w)−min(ln w)]) as the index of inequity.

[16] Our assumption about the conditional error distribution avoids the retransformation problem (Manning, 1998). With respect to the Eq. (7) model, the conditional expectation of the waiting time at the mean is $E[w_{iht}|\beta_t, \beta_d, \alpha_h, \boldsymbol{x}_{1iht}, \boldsymbol{x}_{2ht}, A_t\bar{M}_h] = \exp(\beta_t + \beta_d + \boldsymbol{x}'_{1iht}\boldsymbol{\beta}_1 + \gamma\bar{M}_hA_t + \boldsymbol{x}'_{2ht}\boldsymbol{\beta}_2 + \alpha_h)\ E[\exp(\varepsilon_{iht}|\beta_t, \beta_d, \alpha_h, \boldsymbol{x}_{1iht}, \boldsymbol{x}_{2ht})]$and so the log percentage change (Tornqvist et al, 1985) in the conditional expected wait from switching on the policy is $\ln(E[w_{iht}|\beta_t, \beta_d, \alpha_h, \boldsymbol{x}_{1iht}, \boldsymbol{x}_{2ht}, \bar{M}_h]/E[w_{iht}|\beta_t, \beta_d, \alpha_h, \boldsymbol{x}_{1iht}, \boldsymbol{x}_{2ht}, 0]) = \ln(\exp(\gamma)) = \gamma$.

[17] The concentration curve plots the cumulative percentage of the health care utilisation variable (y-axis), in our case the waiting time experienced by the patient, against the cumulative percentage of the patient population, ranked by socioeconomic status from most (first quintile) to least (fifth quintile) deprived (x-axis).

[18] Using Eq. (A17) from Heckley et al. (2016). Our dependent variable is $RIF(w,\ F_{EDI}\ (edi);\ \upsilon^{CI}) =\ \upsilon^{CI}(F_{W,\ \ F_{EDI}}) + \mu_W^{-2}\ \ (\mu_W -\ w) \cdot 2Cov(W, F_{EDI}) + \mu_W^{-1}IF(w,\ F_{EDI}\ (edi);\ 2Cov(W, F_{EDI}))$, with $2Cov(W, F_{EDI})$ being the absolute Concentration Index.

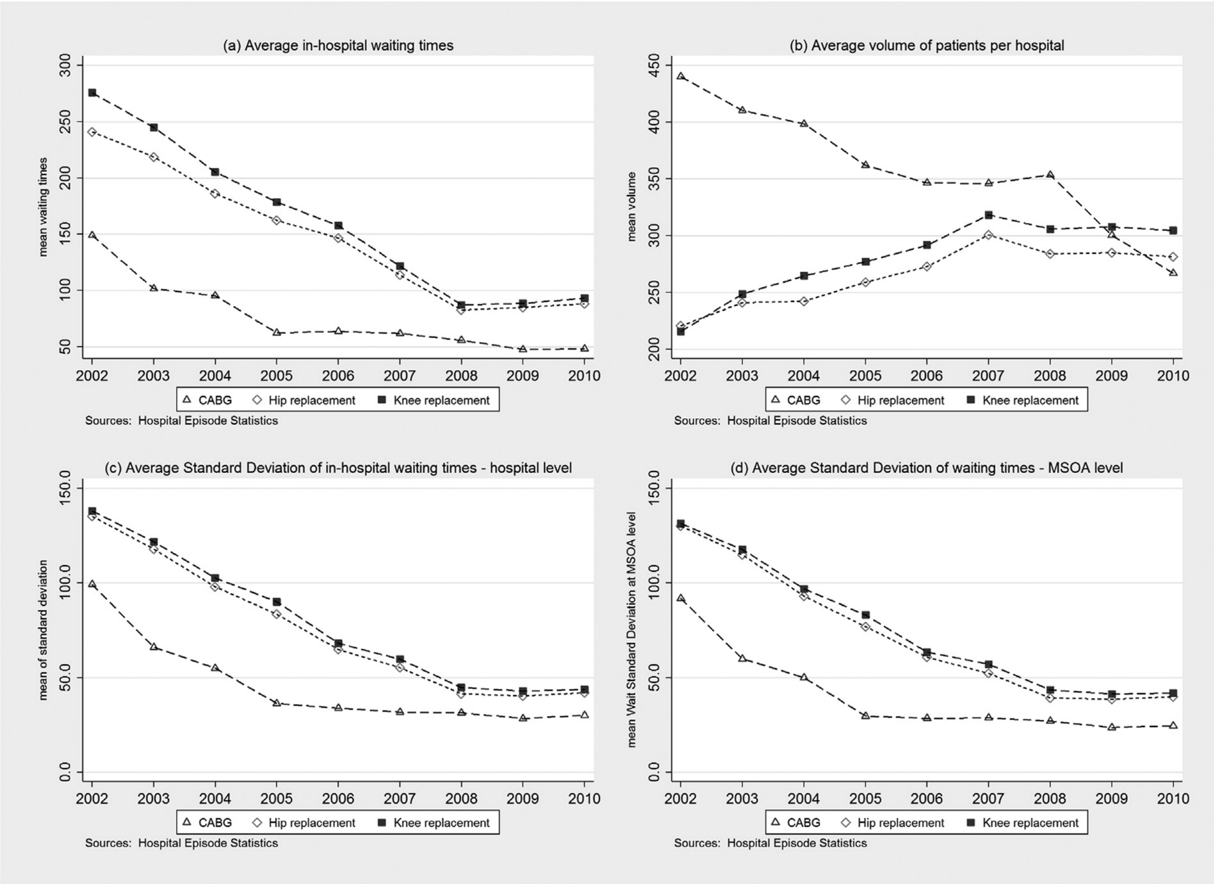

Fig. 1. In-hospital waiting times, volume of patients and standard deviation of in-hospital waits, by year and procedure.

4. Results

4.1. Summary statistics

Fig. 1**a** shows the trends in waiting times. For hip and knee replacements, waiting times were on average 240 days or over in 2002 and declined steadily to around 90 days in 2008-10. Average waiting times for CABG also fell, from 150 days in 2002 to 50 days in 2010. Although, on average waiting times were lower in the post-choice reform period, we are interested in whether the change in waiting times for a hospital after the 2006 choice reform was affected by the number of rivals it faced.

In Fig. 1**b** we see that the average number of hip and knee replacements increased from about 200 patients per site in 2002 to over 250 patients in 2010. By contrast coronary bypass operations fell over the period from 450 patients per site in 2002 to 275 patients in 2010. Figs. 1**c** shows the trends in the mean of the standard deviation of waiting times within providers. Fig. 1**d** reports trends in the standard deviation of waiting times across patients measured at the MSOA level. The trends of waiting times standard deviation within hospitals and MSOAs show a reduction in waiting times dispersion for all three procedures. [25]

Table 1 reports the descriptive statistics on NHS patients treated in NHS providers. Mean ages are 68 for hip replacement, 70 for knee replacement and 65 years for CABG. The proportion of female patients is higher for hip and knee replacement (60% and 58%) and low for CABG (18%). Hip and knee replacement patients have an average of three co-morbidities, while CABG patients have six. Hip and knee replacement patients had fewer emergency admission in the year prior to treatment than CABG ones. For all three procedures, the patients are evenly distributed with respect to the month they joined the waiting list, except for a slightly lower proportion admitted in December. CABG patients are evenly distributed across deprivation quintiles, while there are fewer hip and knee replacement patients in the two most income-deprived quintiles. Before the choice reform providers had an average 3.16 equivalent number of rivals.

[25] Appendix Figs. D1, D2, D3 and D4 show the distribution of log waiting times with respect to different levels of co-morbidities, income deprivation, patient age, and gender.

4.2. Testing the parallel trend assumption (PTA)

Appendix Fig. E1 reports time trends of waiting times for hospitals facing low and high competition, which is a binary indicator defined as a hospital site having a pre-2006 average market structure $\bar{M}_h$ below or above the median. These waiting times trends appear similar across procedures, at the mean, the median and at the 10th, 25th, 75th and 90th percentiles of the wait distributions. In order to interpret our estimates of interest as *causal effects*, our identification strategy relies on the parallel trend assumption (PTA). To test the plausibility of this assumption, we estimate event-study specifications, where we interact our measure of market structure with year dummies for each year in the sample, using financial year 2005/06 as the reference group.[19] We perform joint Wald tests of equality of the estimates of the time-varying γ_t pre-choice policy coefficients, γ_{2002}, γ_{2003}, γ_{2004}, to assess the plausibility of the (conditional) parallel trend assumption, in two versions: equality of the pre-choice coefficients to zero, and also a milder equality of pre-choice coefficients without imposing the equality to zero. The results are reported in Appendix Figs. F1 and F2, and Table F1. For the effects at the mean, the joint Wald test of the interactions between years and the competition measure cannot reject (at 1% and 5% levels) the null that the conditional PTA holds (see Fig. F1 and *p*-values in Table F1) for all three elective procedures. With regards to the effects along the wait distribution, the conditional PTA holds at 1% and 5% levels for estimates at the 10th, 25th and 50th quantiles with both versions of the Wald test, and with the weaker version of joint equality for the estimates at the 75th quantiles (see Fig. F2 and *p*-values in Table F1). For the 90th quantiles estimates, instead, there is evidence of pre-trends that invalidate the conditional PTA. Therefore, in the remainder of the article we interpret all the estimates as causal effects, with the sole exception for the UQR estimates at 90th quantile, which can be interpreted only as interesting associations.[20]

4.3. Effects of competition along the unconditional wait distribution

Table 2 has UQR estimates $\hat{\gamma}$ of the post-reform effect of more pre-reform competition for various percentiles of the unconditional distribution of ln *w*. In all three procedures a higher number of pre-reform rivals (our measure of competition) is associated with a post-choice reform increase in the logarithm of waiting time at all the percentiles: the distribution of log waiting times is shifted to the right. However, in the case of coronary bypass, the effect is statistically significant at the conventional 5% level only at the 90th percentile of the log waiting time distribution.

The change in the effect of market structure due to the 2006 choice reforms was to increase waiting times for hip and knee replacement, with one additional rival increasing the median waiting time by 2.5% and 4.0%, the 75th quantile waiting time by 4.2% and 7.1%. The association between post-policy competition and waiting times at the 90th percentile is of 5.0% and 6.2% respectively for hip and knee replacement, and of 3.9% for coronary bypass patients. For hip and knee replacement the post choice reform change in the effect of the number of equivalent rivals is more pronounced at percentiles above the median. The median of the ln *w* distribution for hip and knee patients is greater for NHS providers with more competition from private providers. In Appendix E, we show that pre-policy waiting times were shorter in more competitive areas relative to less competitive ones. Our results, therefore, imply that the difference in waiting times between more and less competitive areas fell in the post choice period.

For hip and knee replacement procedures the choice residuals are jointly significant at all quantiles, suggesting that there was unobservable selection into hospitals for hip and knee patients. The choice residuals are not significant for the CABG model.

4.4. Effect of competition on inequality in waiting time within hospitals and within small areas

Table 3 reports the results for model (8) of the standard deviation in waiting times within hospitals. The choice reform increased this measure of dispersion in more competitive areas for all three treatments though the effect is small relative to the pre-reform standard deviation and statistically insignificant. This suggests that patients attending the same hospital did not experience a greater dispersion in their waiting time in more competitive areas.

Table 4 has the results from models examining the effect of choice and competition on the dispersion in waiting times for patients resident in small areas (MSOAs). For all three procedures, we see that after the choice reform areas where there was more competition had greater dispersion in waiting times. The contrast with the results for dispersion within hospitals may

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[19] We employ two event-study specifications: one for the effects at the mean, which is estimated through Eq. (11)

$$\ln w_{iht} = \beta_t + \beta_d + \boldsymbol{z}'_{iht}\boldsymbol{\delta}_0 + A_t\boldsymbol{z}'_{iht}\boldsymbol{\delta}_1 + (\bar{M}_h - \bar{M})A_t\boldsymbol{z}'_{iht}\boldsymbol{\delta}_2 + \gamma_t\bar{M}_h I_t + \boldsymbol{x}'_{1iht}\boldsymbol{\beta}_1 + \boldsymbol{x}'_{2ht}\boldsymbol{\beta}_2 + \alpha_h + \hat{\boldsymbol{r}}^{CL'}_{iht}\psi_1 + \varepsilon_{iht} \tag{11}$$

and the other for the effects along the unconditional waiting time distributions, estimated through Eq. (12)

$$RIF(\ln w_{iht}; q_\tau) = \beta_t + \beta_d + \boldsymbol{x}'_{1iht}\boldsymbol{\beta}_1 + \gamma_t\bar{M}_h I_t + \boldsymbol{x}'_{2ht}\boldsymbol{\beta}_2 + \alpha_h + \hat{\boldsymbol{r}}^{CL'}_{iht}\psi_1 + \varepsilon_{iht} \tag{12}$$

In both event-study specifications, the pre-2006 market structure $\bar{M}_h$ is interacted with year dummy indicators I_t for the financial years of admission of the patient. Financial year 2005/06 (April 2005 to March 2006) is used as baseline, consistently with Gaynor et al. (2016), who define the pre-choice period using data up until March 2005, and with Moscelli et al (2021).

[20] Roth (2022) highlights the perils of pre-trends test in event studies. While our estimates and their interpretation are not immune to this critique, our pre-tests are less likely to be affected by the low power issue of the empirical studies reviewed by Roth (2022), given the very large sample sizes that are used for the estimation of both event studies and difference-in-difference specification.

Table 2
Competition and waiting times: effects along the unconditional wait distribution accounting for endogenous selection into hospitals.

	(1) τ=10	(2) τ=25	(3) τ=50	(4) τ=75	(5) τ=90
Hip Replacement					
Choice Policy* Market Structure	0.0448*	0.0259*	0.0246**	0.0421***	0.0502***
	(1.9233)	(1.8009)	(2.4556)	(3.1135)	(2.8668)
Number of Private hospital sites in 30km	0.0046	0.0125	0.0179**	0.0060	-0.0098
	(0.2940)	(1.2036)	(2.4777)	(0.8599)	(-1.1879)
1st quintile EDI income (Most deprived)	0.0568**	0.0223*	0.0157*	0.0047	0.0073
	(2.5513)	(1.7450)	(1.9432)	(0.6333)	(0.7118)
2nd quintile EDI income	0.0457***	0.0177*	0.0098	0.0044	0.0084
	(2.6377)	(1.8355)	(1.6129)	(0.7768)	(1.1283)
3rd quintile EDI income	0.0413***	0.0186**	0.0113**	-0.0003	0.0034
	(3.2531)	(2.5243)	(2.4040)	(-0.0650)	(0.5707)
4th quintile EDI income	0.0295***	0.0183***	0.0079**	-0.0017	-0.0012
	(2.6744)	(2.7247)	(2.0036)	(-0.4282)	(-0.2204)
Joint test choice residuals – Chi-squared stat p-value	0.0001	0.0000	0.0000	0.0000	0.0000
Patients	400,862	400,862	400,862	400,862	400,862
Hospital Sites	232	232	232	232	232
Knee Replacement					
Choice Policy* Market Structure	0.0557**	0.0395***	0.0396***	0.0710***	0.0618***
	(2.3549)	(2.6357)	(3.6027)	(3.6936)	(3.1027)
Number of Private hospital sites in 30km	-0.0002	0.0132	0.0141**	0.0022	-0.0108
	(-0.0124)	(1.2343)	(2.0817)	(0.2625)	(-1.3842)
1st quintile EDI income (Most deprived)	0.0689***	0.0236**	0.0099	0.0211*	0.0334***
	(2.6627)	(2.0041)	(1.1924)	(1.8764)	(3.0212)
2nd quintile EDI income	0.0573***	0.0194**	0.0091	0.0188**	0.0224***
	(3.2264)	(2.0871)	(1.4863)	(2.3377)	(2.8016)
3rd quintile EDI income	0.0356**	0.0147*	0.0044	0.0071	0.0047
	(2.3823)	(1.8725)	(0.9020)	(1.1779)	(0.6701)
4th quintile EDI income	0.0215*	0.0119*	-0.0006	-0.0014	0.0019
	(1.7283)	(1.7730)	(-0.1457)	(-0.2613)	(0.3346)
Joint test choice residuals – Chi-squared stat p-value	0.0000	0.0000	0.0000	0.0000	0.0000
Patients	447,644	447,644	447,644	447,644	447,644
Hospital Sites	239	239	239	239	239
CABG					
Choice Policy* Market Structure	0.0137	0.0085	0.0057	0.0265	0.0385**
	(0.3968)	(0.2237)	(0.2064)	(1.4642)	(2.1825)
Number of Private hospital sites in 30km	-0.0493	-0.0698*	-0.0151	0.0099	0.0147
	(-1.5537)	(-1.7945)	(-0.6094)	(0.5709)	(1.3085)
1st quintile EDI income (Most deprived)	0.1619***	0.1711***	0.1083***	0.0885***	0.0897***
	(2.8282)	(4.3992)	(4.4832)	(4.2442)	(5.5058)
2nd quintile EDI income	0.1765***	0.1551***	0.0888***	0.0675***	0.0780***
	(3.8480)	(4.9435)	(4.9400)	(4.7496)	(5.5997)
3rd quintile EDI income	0.1215***	0.1369***	0.0656***	0.0485***	0.0506***
	(3.3031)	(5.1414)	(4.7121)	(3.7980)	(4.8120)
4th quintile EDI income	0.0702***	0.0719***	0.0390***	0.0215**	0.0265***
	(2.6943)	(3.4935)	(4.4588)	(2.1438)	(2.7466)
Joint test choice residuals – Chi-squared stat p-value	0.5357	0.1473	0.2903	0.6218	0.6704
Patients	108,328	108,328	108,328	108,328	108,328
Hospital Sites	47	47	47	47	47

Notes. Models: unconditional quantile regressions for logarithm of waiting time. Models include hospital fixed effects, patient and provider characteristics. τ: τ-th quantile of the log wait distribution. t-statistics from standard errors bootstrapped with 1,000 replications and clustered at hospital site level; * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

Table 3
Competition and standard deviation of waiting times within hospitals.

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
Choice Policy* Market Structure	0.8740	1.0381	0.5725
	(1.3982)	(1.5749)	(1.3102)
R^2	0.9190	0.8989	0.9219
Hospital Sites	232	239	47
Number of year-hospital observations	1,512	1,588	302

Notes. Dependent variable: standard deviation of waiting times in hospital in year. Market Structure: equivalent number of rivals within 30km. Models include hospital fixed effects, hospital level means of patient characteristics and hospital characteristics. t-statistics from robust standard errors clustered at site level; * $p<0.10$.

Table 4
Competition and standard deviation of waiting times within small areas.

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
Choice Policy* Market Structure	0.6116***	0.4099***	0.3492**
	(4.0792)	(2.7414)	(2.0293)
R^2	0.5555	0.5085	0.5143
Number of MSOAs	6,747	6,776	6,594
Number of year-MSOA observations	55,174	57,432	29,934

Notes. Dependent variable: standard deviation of waiting times within MSOA in year. Market Structure: equivalent number of rivals within 30km. Models include MSOA level means of patient characteristics and the characteristics of hospitals they attended. t-statistics from robust standard errors clustered at MSOA level; ** $p<0.05$; *** $p<0.01$.

be because dispersion for patients in an MSOA depends on the average variation within hospitals that patients choose and on the variation in the mean waiting time across hospitals these hospitals. Higher competition within an MSOA could induce an increase in waiting time by more desirable providers and a reduction in waiting time by the less desirable providers within the same competition area, therefore increasing dispersion at the MSOA level. Moreover, after the choice reform the average number of providers (hospital sites) used by patients in an MSOA increased substantially for hip replacements (21.06 to 27.90) and knee replacements (22.21 to 30.73). The increase in the number of providers is consistent with the significant increase in volume depicted in Fig. 1(b).[21] However, the number of CABG providers used fell slightly (8.25 to 8.11). The results therefore suggests that patients living within the same small geographical area had a greater dispersion in their waiting time experience in more competitive areas.

4.5. Effect of competition on prioritisation of patients with different levels of need

Table 5 reports results from models (9) which test whether choice and competition changed the way in which patients were prioritised. Patients with more emergency admissions in the previous year had lower waiting times and this did not change post-choice or with the level of competition. The number of diagnoses did not affect waiting times for hip replacement, pre or post-choice. For knee replacement those with more diagnoses had longer waits and this effect increased post choice. CABG patients with more diagnoses also waited longer but this was not affected by choice policy or competition. A high Charlson Index was associated with shorter waiting times, though the reduction was smaller post-choice reform.

Older hip and knee replacement patients had shorter waits pre-choice reform. The age gradient became less steep post reform and those in the highest age bands had longer waits. CABG patients below 65 years had shorter waits though the gradient became flatter for them post choice.

4.6. Choice policy, market structure and socioeconomic inequity in waiting time

The UQR coefficients on deprivation in Table 2 suggest that there is pro-rich inequity in waiting times with the most deprived (lower quartiles) having longer waits. For hip replacement the SES gradient is significant at the 5% level up to the median with more deprived patients having longer waits, though the gradient becomes flatter at higher quantiles. There is also a gradient, though less steep, for knee replacement. Pro-rich wait inequity is pervasive across all quantiles of the unconditional wait distribution for CABG, with longer waits for the most deprived patients ranging from 16% at the 10th quintile to 9% at the 90% quintile of the distribution. The model in Table 2 suggests that there was deprivation related inequity in waiting times on average over the whole 2002/3-20010/11 period, but does not indicate whether choice policy and competition changed the deprivation gradient in waiting time.

Table 6 reports results from specification (10) which tests for effects of choice and market structure on the gradient of waiting time with respect to deprivation. Pre-reform there was a strong pro-rich gradient with patients in more deprived quintiles waiting longer for all three treatments. Relative to the least deprived, waiting times for the most deprived for hip, knee replacement and CABG were longer by 7.3%, 5.6% and 18.2%. After the reform, this gradient was greatly reduced for hip and knee replacements and somewhat reduced for CABG. The slackening of the gradient was not related to the level of pre-reform competition, as suggested by the general lack of statistical significance between deprivation post-choice and market structure (third set of coefficients in Table 6, δ_2).[22] Thus, pre-reform market structure did not affect the change in the waiting time gradient that we observe pre- and post-policy.

In Table 7 we report the combined effect of choice and competition on a summary measure of deprivation related inequity – the concentration index of waiting time against income deprivation. We measure socioeconomic status negatively

[21] Note also that the increase in the number of providers refers to hospital sites, as opposed to hospital Trusts, with each Trust potentially having several sites.

[22] The only exception is the 4th deprivation quintile for hip replacement which is significant at the 5% level. The coefficient is however small, less than one percentage point (0.0081).

Table 5
Heterogeneous effects of competition on prioritisation by morbidity and age.

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
Choice Policy* Mkt Structure.	0.0323**	0.0478***	0.0149
	(2.4538)	(3.3082)	(0.5707)
Number of emergency admissions (past 12 months)	-0.1325***	-0.0432***	-0.2136***
	(-9.573)	(-5.347)	(-18.364)
Choice Policy* Num. of emergency admissions (past 12 months)	0.0097	0.0066	-0.0185
	(1.3879)	(0.9369)	(-0.9528)
Choice Policy* Mkt Structure* Num. of emer. adm. (past 12mth)	0.0040	-0.0003	-0.0040
	(1.2305)	(-0.1626)	(-1.5206)
Number of diagnoses	0.0024	0.0056*	0.0186***
	(0.6559)	(1.7253)	(2.7927)
Choice Policy* Number of diagnoses	0.0252	0.0978***	-0.0063
	(1.2765)	(2.7431)	(-0.1375)
Choice Policy* Mkt Structure* Number of diagnoses	-0.0004	0.0003	0.0002
	(-0.3601)	(0.3082)	(0.1155)
age 35-44 years	0.0716***	-0.0870***	-0.1427***
	(2.7357)	(-3.1001)	(-3.7998)
age 45-54 years	0.0546***	-0.0093	-0.0785***
	(4.2372)	(-0.7456)	(-4.0785)
age 55-64 years	0.0287***	0.0061	-0.0513***
	(4.0982)	(0.9239)	(-4.5145)
age 75-84 years	-0.0754***	-0.0374***	-0.0233
	(-11.6130)	(-7.3050)	(-1.5257)
age 85-94 years	-0.1991***	-0.0948***	-0.0615
	(-11.4735)	(-7.5574)	(-0.5567)
age 95-over years	-0.6374***	-0.1317	0.3375***
	(-5.2498)	(-0.8931)	(5.4477)
Choice Policy* age 35-44 years	0.0195	0.0429***	0.0033
	(1.5066)	(2.9675)	(0.1215)
Choice Policy* age 45-54 years	0.0165**	0.0227***	0.0132
	(2.2260)	(3.2209)	(0.9547)
Choice Policy* age 55-64 years	0.0384***	0.0167***	0.0458**
	(4.9555)	(2.7692)	(2.3832)
Choice Policy* age 75-84 years	0.1301***	0.0572***	0.0207
	(6.8175)	(3.4832)	(0.1682)
Choice Policy* age 85-94 years	0.4945***	-0.1212	-0.0063
	(3.5701)	(-0.7542)	(-0.1375)
Choice Policy* age 95-over years	0.0252	0.0978***	
	(1.2765)	(2.7431)	
Choice Policy* Mkt Structure* age 35-44 years	0.0072	0.0023	0.0038
	(0.9241)	(0.2807)	(0.4508)
Choice Policy* Mkt Structure* age 45-54 years	-0.0014	0.0005	0.0000
	(-0.3494)	(0.1400)	(0.0039)
Choice Policy* Mkt Structure* age 55-64 years	0.0043**	-0.0028	0.0025
	(2.0106)	(-1.3134)	(0.7064)
Choice Policy* Mkt Structure* age 75-84 years	0.0042*	0.0020	0.0047
	(1.8777)	(0.8956)	(1.1669)
Choice Policy* Mkt Structure* age 85-94 years	0.0111**	-0.0067	0.0105
	(2.4373)	(-1.3113)	(0.6339)
Choice Policy* Mkt Structure* age 95-over years	-0.0039	-0.0731**	
	(-0.0863)	(-2.0121)	
Charlson Index - Medium severity	0.0021	0.0122	0.0306**
	(0.2642)	(1.5188)	(2.0827)
Charlson Index - High severity	-0.0994***	0.0023	0.0250
	(-6.0169)	(0.1700)	(1.1659)
Choice Policy* Charlson Index - Medium severity	-0.0012	-0.0142	0.0023
	(-0.1265)	(-1.5441)	(0.1096)
Choice Policy* Charlson Index - High severity	0.0439**	-0.0168	-0.0019
	(2.2612)	(-1.0149)	(-0.0594)
Choice Policy* Mkt Structure* Charlson Index - Medium severity	-0.0034	-0.0003	-0.0009
	(-1.3463)	(-0.1256)	(-0.2167)
Choice Policy* Mkt Structure* Charlson Index - High severity	-0.0042	-0.0052	-0.0042
	(-0.6953)	(-1.1318)	(-0.6139)
R^2	0.239	0.292	0.184
Joint test choice residuals – Chi-squared stat p-value	0.0000	0.0000	0.0001
Patients	400,862	447,644	108,328
Hospital Sites	232		
	239	47	

Notes. Dependent variable: natural logarithm of patient waiting time. Market Structure: Equivalent Number of Rivals withing 30 km. t-statistics from bootstrapped (1,000 replications) standard errors clustered at hospital site level; * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

Table 6
Competition and deprivation related inequity in waiting times.

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
Choice Policy* Market Structure (γ)	0.0311**	0.0454***	0.0166
	(2.3286)	(3.1407)	(0.6610)
Effect of deprivation pre-choice reform (δ_0)			
1st quintile EDI (Most deprived)	0.0739***	0.0559***	0.1822***
	(4.5371)	(3.4761)	(6.7306)
2nd quintile EDI	0.0471***	0.0478***	0.1326***
	(3.5846)	(3.7861)	(5.2001)
3rd quintile EDI	0.0395***	0.0218*	0.1135***
	(3.2668)	(1.7839)	(5.0360)
4th quintile EDI	0.0245***	0.0095	0.0491***
	(2.8574)	(1.0749)	(3.3183)
Change in effect of deprivation post-choice for provider facing average competition (δ_1)			
1st quintile EDI (Most deprived)* Choice Policy	-0.0761***	-0.0344*	-0.1403***
	(-3.7569)	(-1.8858)	(-4.4165)
2nd quintile EDI* Choice Policy	-0.0429***	-0.0325**	-0.0664***
	(-2.6027)	(-2.2683)	(-2.6926)
3rd quintile EDI* Choice Policy	-0.0345**	-0.0092	-0.0740***
	(-2.1772)	(-0.6313)	(-2.8832)
4th quintile EDI* Choice Policy	-0.0122	-0.0005	-0.0238
	(-1.0666)	(-0.0449)	(-1.2572)
Change in effect of deprivation post choice for provider facing more competition (δ_2)			
1st quintile EDI (Most deprived)* Choice Policy*Market Structure (demeaned)	0.0080	0.0005	-0.0013
	(1.5234)	(0.1153)	(-0.2000)
2nd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0047	0.0066*	0.0049
	(1.0664)	(1.6841)	(0.9359)
3rd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0043	0.0047	0.0040
	(1.0902)	(1.1883)	(0.6314)
4th quintile EDI* Choice Policy* Market Structure (demeaned)	0.0081**	0.0051*	0.0017
	(2.4054)	(1.6782)	(0.4318)
Number of Private hospital sites in 30km	0.0097	0.0066	-0.0188
	(1.3905)	(0.9365)	(-0.9319)
R^2	0.239	0.292	0.183
Joint test choice residuals – Chi-squared stat p-value	0.0000	0.0000	0.0001
Patients	400,862	447,644	108,328
Hospital Sites	232	239	47

Notes. Dependent variable: natural logarithm of patient waiting time. Models include hospital fixed effects, patient and provider characteristics. EDI: Economic Deprivation Index. t-statistics from bootstrapped (1,000 replications) standard errors clustered at hospital site level; * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

Table 7
Competition and choice: effect on concentration index of waiting time against deprivation.

	Hip replacement	Knee replacement	CABG
Concentration Index			
Choice Policy* Market Structure	0.0041***	0.0063***	0.0022**
	(3.7853)	(6.2848)	(2.0328)
Erreygers Concentration Index			
Choice Policy* Market Structure	0.0092***	0.0144***	0.0042**
	(3.7667)	(6.3512)	(2.0793)

Notes. t-statistics from bootstrapped (1,000 replications) standard errors clustered at hospital site level; Concentration index: 2Cov(ln w, $F(R)$/(E(ln w), where $F(R)$ is the cumulative distribution of deprivation rank. *Erreygers Concentration Index*: 2Cov(ln w, $F(R)$/[(max(ln w)−min(ln w)]. Deprivation is *greatest* in the first quintile, so a positive effect implies a pro-deprived change in the distribution of waiting time (a bad). * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

by income deprivation quintiles so that those in the first quintile are the most deprived. The results in Table 6 showed that more deprived patients waited longer in the pre-choice period and so the concentration index is negative before the choice reform: the most deprived had a greater share of a bad (Wagstaff et al, 1991, page 549). Table 6 shows that the pro-rich gradient in waiting times was *reduced* by the choice reform. Table 7 shows, the *combined* effect of the choice reform and market competition in the post-policy period was to *increase* the concentration index and so *reduce* deprivation related inequity in waiting times for all three treatments.

4.7. Robustness checks

In the regression models presented above, we control for the number of private rival hospital sites within 30 kilometres. This variable has the advantage of being time-varying but does not control for market shares of private providers (which in the pre-choice period were close to zero). As a robustness check, we estimated a patient choice model for all admissions in the post-policy period, including those at new private providers and then predict the market share of each private hospital. For each patient, we then compute the predicted market share of private hospitals in the catchment area where the patient resides, and use this variable as an alternative control for private provision.[23] The results in Appendix Table G1 for the unconditional wait distribution model are very similar to those in Table 2 and those in Appendix Table G2 are similar to those in Table 6 on inequity in waiting times by socioeconomic status.

Given that the private sector treated very few NHS patients before the choice policy, we excluded patients treated in private providers from our regression sample. As a robustness check, we estimated models for the equivalent of Tables 2 and 6 on inequity in waiting times by deprivation, where we also include NHS-funded patients treated by private hospitals as well as NHS patients treated in NHS providers. The results in Appendix Tables G3 and G4 and are very similar respectively to those in Tables 2 and 6 for NHS patients treated only in NHS providers.

Our analysis is restricted to patients over 35 years old. Given that most hip and knee replacement patients are older, as a robustness check we excluded all patients younger than 60. The results are provided in Table G5 for inequities in waiting times (equivalent to Table 6) and are robust to this further exclusion restriction.

Last, given that we have multiple outcomes, we correct for multiple hypotheses testing using the Sidak-Bonferroni correction. The results are in Tables G6 and G7. As expected, we lose some statistical significance but overall the impact of the correction is very limited. Comparing Table G6 with Table 2 on the effect on the unconditional wait distribution, all the coefficients for hip and knee replacement in the 50th to 90th quintile that were significant at 1% level remain so also after the correction, while the other significant coefficients move either from 10% significant level to not significant, or from 5% to 10% significance level.

5. Conclusions

We find that the change in the effect of market structure, as measured by the predicted equivalent number of rivals, due to the 2006 choice reforms was to increase waiting times for hip and knee replacement, with one additional rival increasing the median waiting time by 2.5% and 4.0%, the 75th quantile waiting time by 4.2% and 7.1%, and was positively associated with waiting time increases at the 90th percentile of 5.0% and 6.2%. Thus, the waiting time distribution was shifted to the right and by more in hospitals facing pre-reform competition. There was no effect on waiting times for coronary bypass patients, except a positive association equal to a 3.9% wait increase at the 90th percentile. Given that waiting times in the pre-policy period were shorter in more competitive areas relative to less competitive ones, our results also imply that the difference in waiting times between more and less competitive areas fell in the post choice period.

Predictions from economic theory of the effect of competition on waiting times are ambiguous. One possible explanation (sketched in the simple theory model in Section 3.1) for the apparently perverse effect of competition on waiting times is that providers have altruistic preferences and care directly about the time patients wait for treatment. They will then be willing to increase supply beyond the profit maximising level in order to reduce waiting times, despite making a loss on the marginal patients (Siciliani, 2005; Brekke et al., 2008; Siciliani et al., 2013). But if competition and choice make patient choice of hospital more responsive to waiting time, thereby flattening the demand curve and reducing the effect of supply on waiting time, hospitals will perceive less benefit to patients from an unprofitable increase in supply and so will reduce supply. This will, other things equal, increase waiting time.

Perhaps, as a result of the longer waiting times due to competition, patients in more competitive areas experienced a higher dispersion post-reform in waiting times within small geographical areas in which they live. They may be due to higher dispersion in waiting times across hospitals serving a geographical area. We observe no effect on the dispersion in waiting times for patients attending the same hospital.

We also find no effect of market structure on socioeconomic inequities in waiting times. Before the choice reform more deprived patients had longer waits. Post-reform there was no deprivation gradient in waiting times, though the reduction in the gradient was not affected by pre-reform market structure. Overall, there was less deprivation related inequity in the post-choice period.

Our study has some limitations. We focus only on the waiting time measured from specialist addition to the list to treatment, also known as the inpatient waiting time. Patients also wait for an outpatient appointment with a specialist before being added to the waiting list. In recent years, there is availability of data measuring the referral-to-treatment waiting time, from GP referral to final treatment, which captures the wait along the whole patient pathway. However, these are available only by specialty rather than by procedure and only for the post choice period. Future work could focus on referral to treatment waiting times. Second, our study focuses on England. Future work could investigate the relation between competition and waiting time inequalities in other health systems that differ in regulatory and reimbursement arrangements, and test whether different health system infrastructure and capacity leads to a different relationship between patient choice, competition and waiting time inequalities.

[23] In the post-2006 hospital sites sample, the correlation between the predicted ISP market shares and the pre-2006 negative predicted HHI is 0.132, while the correlation between the number of ISP rivals within 30 km and the predicted ISP market shares (the pre-2006 negative predicted HHI) is 0.321 (0.297), all significant at 1% level. In Fig. G1 we also report the distribution of all competition measures, for financial years 2007/08 and 2010/11.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data availability

The authors do not have permission to share data.

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Appendix A. Elective procedure codes and sample construction/restrictions

Hip replacement admissions are those with (i) a first OPCS procedure code: W371, W381, W391, W931, W941, W951, W378, W379, W388, W389, W398, W399, W938, W939, W948, W949, W958, W959; (ii) W581 as the 1st procedure and Z843 in 2nd to 4th procedure fields.

Knee replacement admissions are those with (i) a first OPCS procedure code W401, W411, W421, W408, W408, W418, W419, W428, W429; (ii) W581 as the 1st procedure and Z846 in 2nd to 4th procedure fields.

CABG admissions are those with (i) a first OPCS procedure code K40, K41, K42, K43, K44, K45, K46 excluding patients simultaneously undergoing a heart valve replacement (any procedure being coded from K23 to K38) or a dominant angioplasty (PTCA) operation (in the first procedure coded as K751, K752, K753, K754, K758, K759, K49, K501, K504, K508, K509).

Circulatory admissions are those with a main ICD10 diagnostic code starting with I (diseases of the circulatory system) or main procedure OPCS code starting with K or L (heart, arteries and veins procedures). Musculoskeletal admissions are those with main ICD10 diagnostic code starting with M (diseases of the musculoskeletal system) main procedure OPCS code starting with V or W (bones and joints procedures).

Table A2

Table A1
Sample size restrictions and missing values, by elective procedure.

	Hip Replacement	Knee Replacement	Coronary Bypass	Total observations excluded
Initial sample	460,994	509,973	114,586	
Sample excluding hospitals treating less than 100 CIPS per year	438,423	492,909	114,586	39,635
Sample excluding patients missing waiting time variable in HES APC	420,389	471,036	108,567	45,926
Final sample excluding NHS patients treated by private providers (ISP)	400,862	447,644	108,328	43,158

Table A2
Age distribution of patients in the sample, by procedures and age categories.

	Elective Procedures			
Age categories	Hip Replacement	Knee Replacement	Coronary Bypass	Total
35-44	10,904	3,102	1,955	15,961
% of total	*2.7%*	*0.7%*	*1.8%*	*1.7%*
45-59	69,592	56,009	25,915	151,516
% of total	*17.4%*	*12.5%*	*23.9%*	*15.8%*
60-74	198,520	235,175	62,416	496,111
% of total	*49.5%*	*52.5%*	*57.6%*	*51.8%*
75-89	118,952	151,224	18,026	288,202
% of total	*29.7%*	*33.8%*	*16.6%*	*30.1%*
90+	2,894	2,134	16	5,044
% of total	*0.7%*	*0.5%*	*0.0%*	*0.5%*
Total	400,862	447,644	108,328	956,834

Appendix B. Construction of Herfindahl-Hirschman Index

Our main market structure measure is based on the Herfindahl-Hirschman Index (HHI): the sum of the square of provider market shares. For a market with N firms, it varies between 1 (monopoly) and $1/N$. The HHI for patients in LSOA j is the sum of the squared shares of their planned admissions at the providers they use. It is a measure of the amount of choice they have amongst planned care providers. We compute the HHI for site h as a weighted average of the HHIs for patients in LSOAs within 30 km of site h:

$$HHI_h = \sum_j s_{hj} \times HHI_j = \sum_j s_{hj} \times \left[\sum_h \left(s_{jh}\right)^2 \right] \tag{B1}$$

where j=1,…,J indexes English LSOAs, s_{jh} is the proportion of patients from LSOA j treated at a site h within 30km of their LSOA, and s_{hj} is the proportion of site h patients from LSOA j within 30km of site h.

To remove possible bias arising from the effect of quality and waiting times on utilisation we compute *predicted HHIs* derived from models of patient choice of provider (NHS and private sites) for planned care in which choice is not allowed to depend on quality or waiting time (Kessler and McClellan, 2000). We estimate Poisson choice models with the number of planned patients from LSOA j choosing provider h in year t having conditional mean

$$\mathrm{E}\left(n_{jht}|\xi_j, d_{jh}, X_{ht}\right) = \exp\left\{\xi_{jt} + \lambda_{1t}d_{jh} + \lambda_{2t}d_{jh}^2 + X_{ht}\lambda_t + d_{jh}X_{ht}\lambda_{1t}^X + d_{jh}^2X_{ht}\lambda_{2t}^X\right\} \tag{B2}$$

where d_{jh} is the distance from the centroid of LSOA j to hospital site h within 30km. X_{ht} is a vector of dummies for hospital characteristics (belonging to a Foundation Trust, belonging to a teaching Trust). NHS Foundation Trusts have more discretion in paying staff, using surpluses, do not have to break even each year and can borrow from the capital market (Marini *et al*., 2008). Foundation Trusts status was introduced in 2004 and by 2010 60% of NHS Trusts were Foundation Trusts. About 20% of NHS hospitals have Teaching status, undertaking additional activities including teaching and research, and treating more complex patients.

HES defines planned admissions as those "where the decision to admit could be separated in time from the actual admission". We exclude planned patients whose admissions were part of a planned course of treatment (for example, patients on dialysis, or cancer patients on chemotherapy).

The Poisson model yields the same estimated coefficients as the conditional logit model (Guimaraes *et al*., 2003; Guimaraes, 2004) but is quicker to estimate. Models interacting patient characteristics with hospital site characteristics yielded very similar predicted patient flows.

The predicted $\hat{n}_{jht}$ from Eq. (B2) are used to compute the predicted shares $\hat{s}_{jht} = \hat{n}_{jht}/\sum_h \hat{n}_{jht}$ and $\hat{s}_{hjt} = \hat{n}_{jht}/\sum_j \hat{n}_{jht}$, and used in Eq. (B1), instead of the actual flows, to compute the predicted HHI indices. Since the reciprocal of the HHI is the number of equal sized firms, which would yield the HHI, we use the *reciprocal of the predicted HHI* as the measure of competition facing a provider.

Appendix C. Prioritisation and competition

The theory model in Section 3.1 assumes that all patients have the same treatment cost and the same health cost of waiting and thus does not examine the effect of greater competition θ the prioritisation of different types of patient. Suppose now that there are two types of patient with different health costs of waiting $g^k(w^k)$ (k = 1,2) but, for simplicity, the total treatment cost depends only on the total number of patients treated: $S = S^1{+}S^2$. Demand from type k patients $D^k(w^k,\theta)$ is decreasing in their waiting time which is determined by the market clearing condition $D(w^k,\theta) - S^k = 0$ as $w^k(S^k,\theta)$.

The provider prioritises the different types of patient by choosing S^1 and S^2 and thus the waiting times $w^k(S^k,\theta)$ to maximise the strictly concave objective function

$$V\left(S^1, S^2; \theta\right) = p\sum_k D^k\left(w^k\left(S^k, \theta\right)\right) - C\left(S^1 + S^2\right) - \alpha\sum_k g^k\left(w^k\left(S^k, \theta\right)\right) \tag{C1}$$

The first order conditions are, using $w^k_{S^k}(S^k, \theta) = 1/D^k_{w^k}(w^k, \theta)$,

$$\begin{aligned} V_{S^k}\left(S^1, S^2; \theta\right) &= pD^k_{w^k}\left(w^k(S_k, \theta), \theta\right)w^k_{S^k}(S_k, \theta) - C_S(S_1 + S_2) - \alpha g^k_w\left(w^k(S_k, \theta)\right)w^k_{S^k}(S_k, \theta), \\ &= p - C_S(S_1 + S_2) - \alpha g^k_w\left(w^k(S_k, \theta)\right)w^k_{S^k}(S_k, \theta) = 0 \quad k = 1, 2 \end{aligned} \tag{C2}$$

The effect of competition (captured by the demand shift parameter θ) on waiting times again depends on its effects on demands and its effects on provider supply decisions. The marginal effects of competition on supply decisions ($S^k_\theta = \partial S^k(\theta)/\partial\theta$) are obtained by differentiating the first order conditions with respect to θ and solving

$$\begin{bmatrix} V_{S^1S^1} & V_{S^1S^2} \\ V_{S^2S^1} & V_{S^2S^2} \end{bmatrix} \begin{bmatrix} S^1_\theta \\ S^2_\theta \end{bmatrix} = \begin{bmatrix} -V_{S^1\theta} \\ -V_{S^2\theta} \end{bmatrix} \tag{C3}$$

to get

$$S^1_\theta = [V_{S^2\theta}V_{S^1S^2} - V_{S^1\theta}V_{S^2S^2}]\Delta^{-1} \tag{C4}$$

$$S^2_\theta = [V_{S^1\theta}V_{S^2S^1} - V_{S^2\theta}V_{S^1S^1}]\Delta^{-1} \tag{C5}$$

where $\Delta = V_{S^1S^1}V_{S^2S^2} - V_{S^1S^2}V_{S^2S^1} > 0$ because V is strictly concave in the supply variables.

One measure of the degree of prioritisation is the absolute value of the difference in waiting times: $|w^1(S^1(\theta),\theta) - w^2(S^2(\theta),\theta)|$. The effect of an increase in the competition parameter θ on this measure of prioritisation is

$$\begin{aligned}\left|\frac{dw^1}{d\theta} - \frac{dw^2}{d\theta}\right| &= \left|w^1_{S^1}S^1_\theta + w^1_\theta - w^2_{S^2}S^2_\theta - w^2_\theta\right| = \left|\frac{1}{D^1_{w^1}}\left[S^1_\theta - D^1_\theta\right] - \frac{1}{D^2_{w^2}}\left[S^2_\theta - D^2_\theta\right]\right| \\ &= \left|\frac{S^1_\theta}{D^1_{w^1}} - \frac{S^2_\theta}{D^2_{w^2}} - \left[\frac{D^1_\theta}{D^1_{w^1}} - \frac{D^2_\theta}{D^2_{w^2}}\right]\right|\end{aligned} \tag{C6}$$

Even in the model with no prioritisation in Section 3.1, it was not possible to predict the direction of the effect of the competition parameter on waiting time without extraordinarily strong assumptions about demand and cost functions and the nature of provider altruism. Even stronger assumptions are required when the provider sets different waiting times for different patient groups.

Appendix D. Distribution of log waiting time by morbidity, deprivation, age and gender

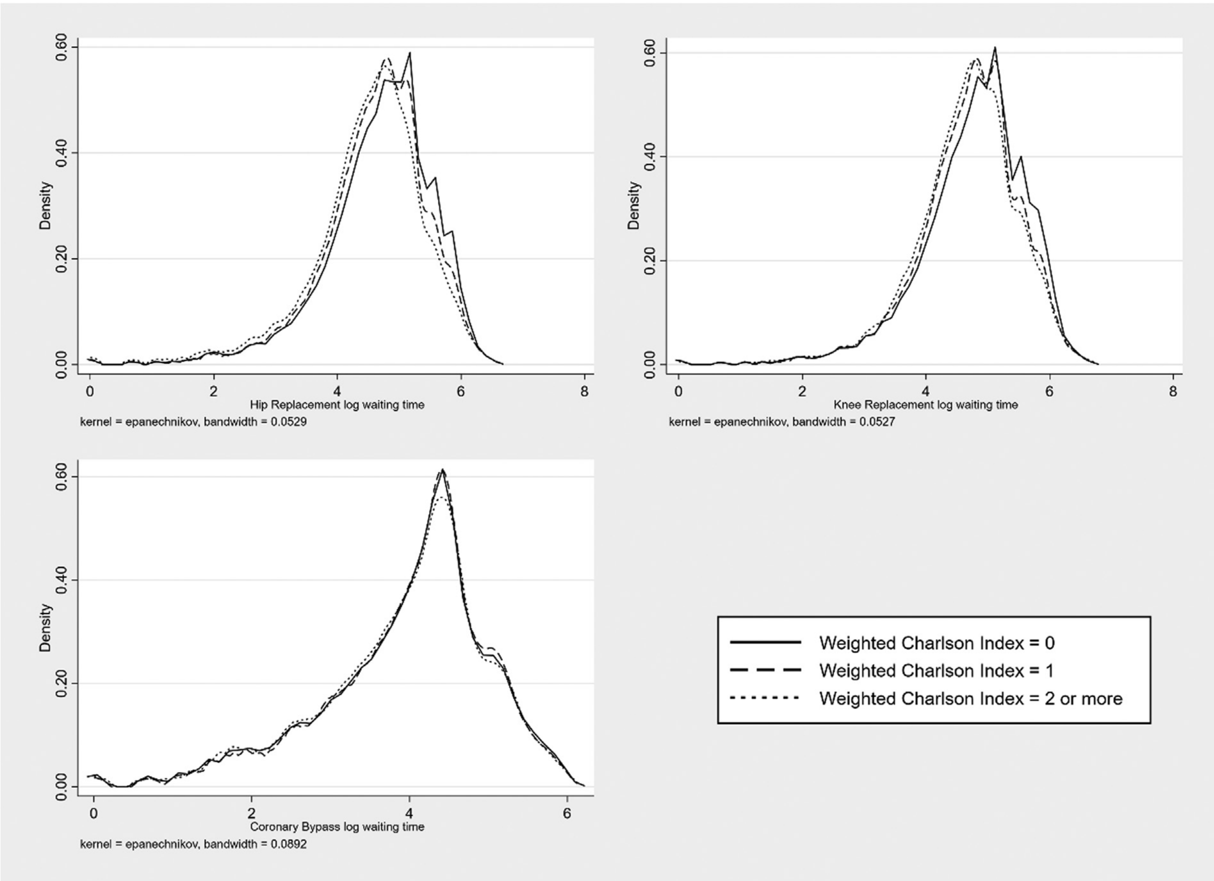

Fig. D1. Distribution of log waiting times by Charlson index co-morbidities.

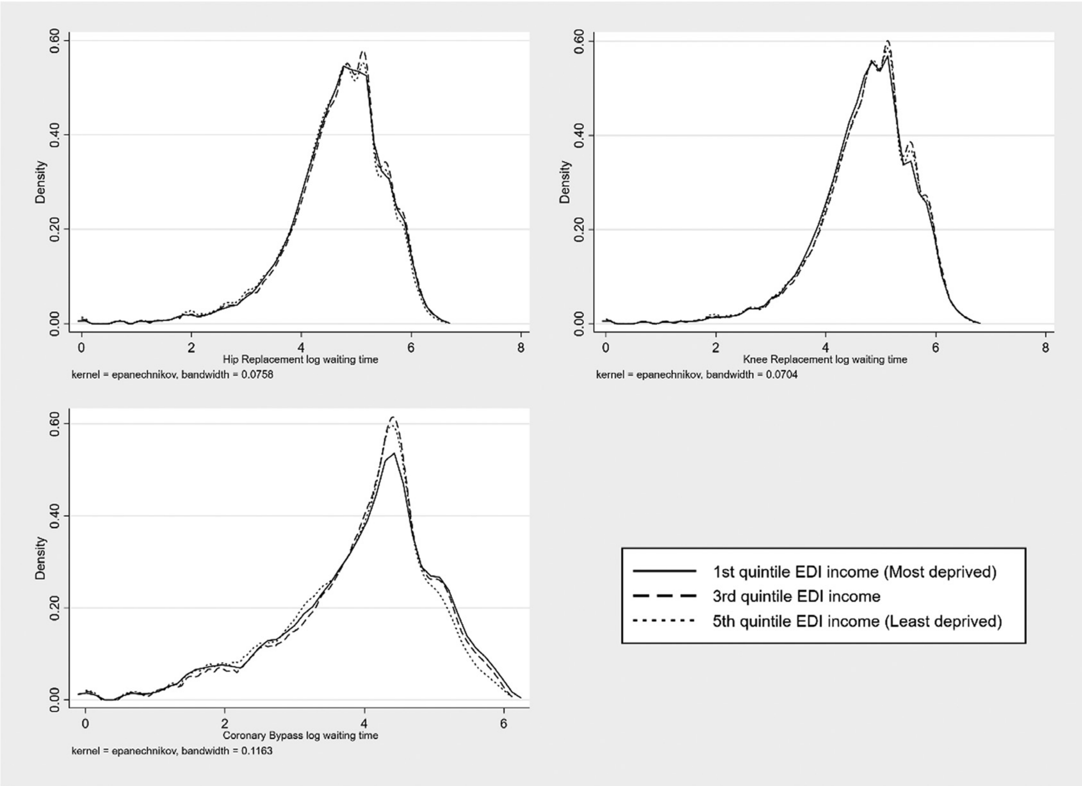

Fig. D2. Distribution of log waiting times by income deprivation.

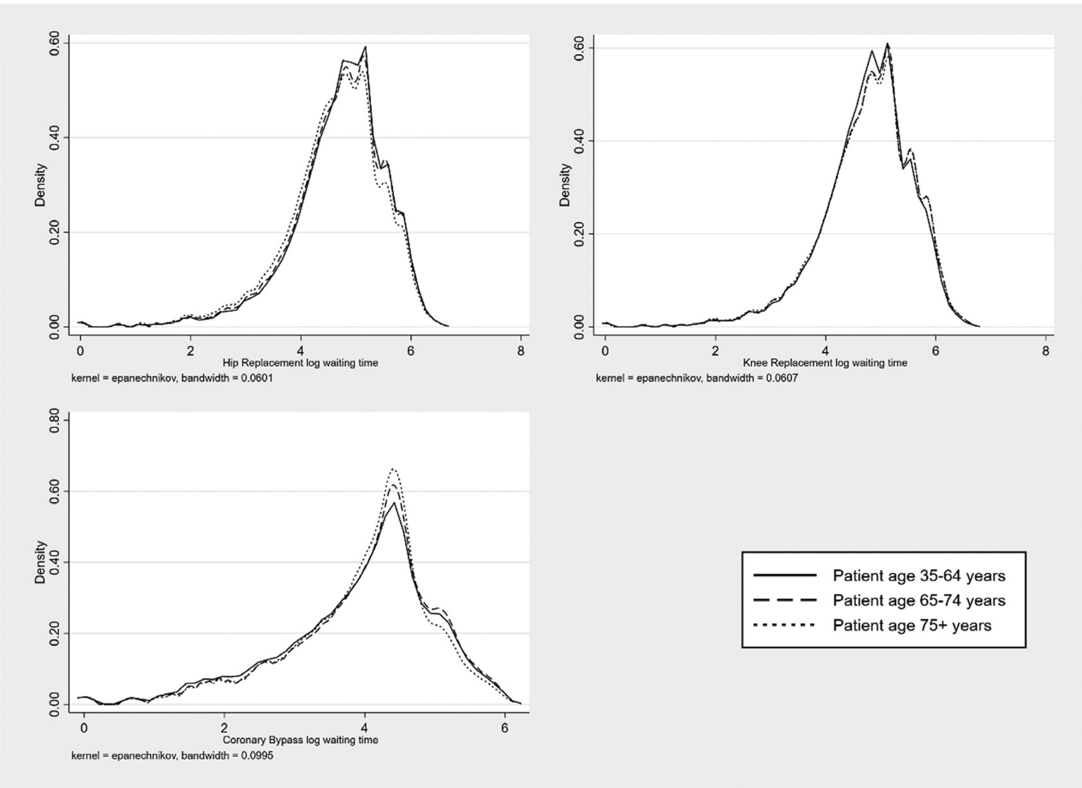

Fig. D3. Distribution of log waiting times by patient age bands.

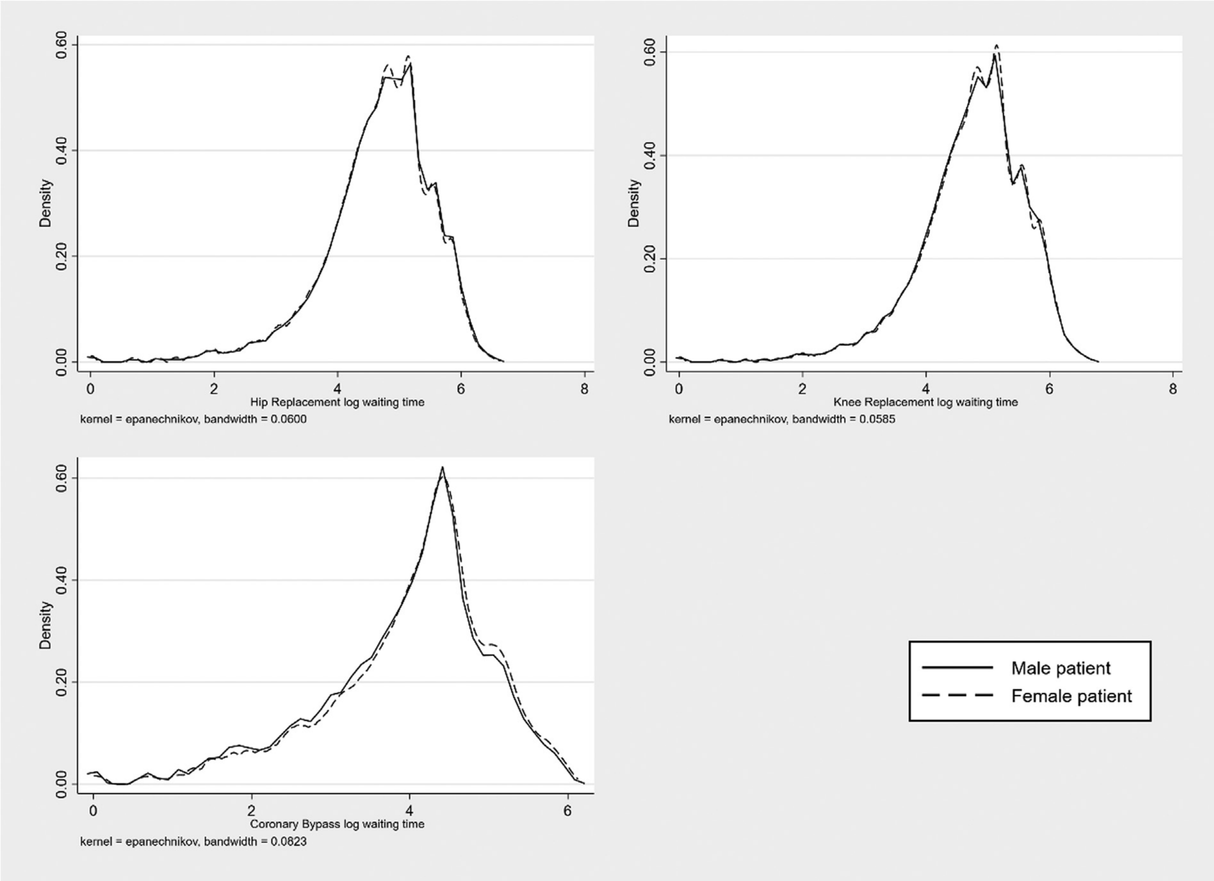

Fig. D4. Distribution of log waiting times by patient gender.

Appendix E. Waiting times over years across low and high competition hospitals

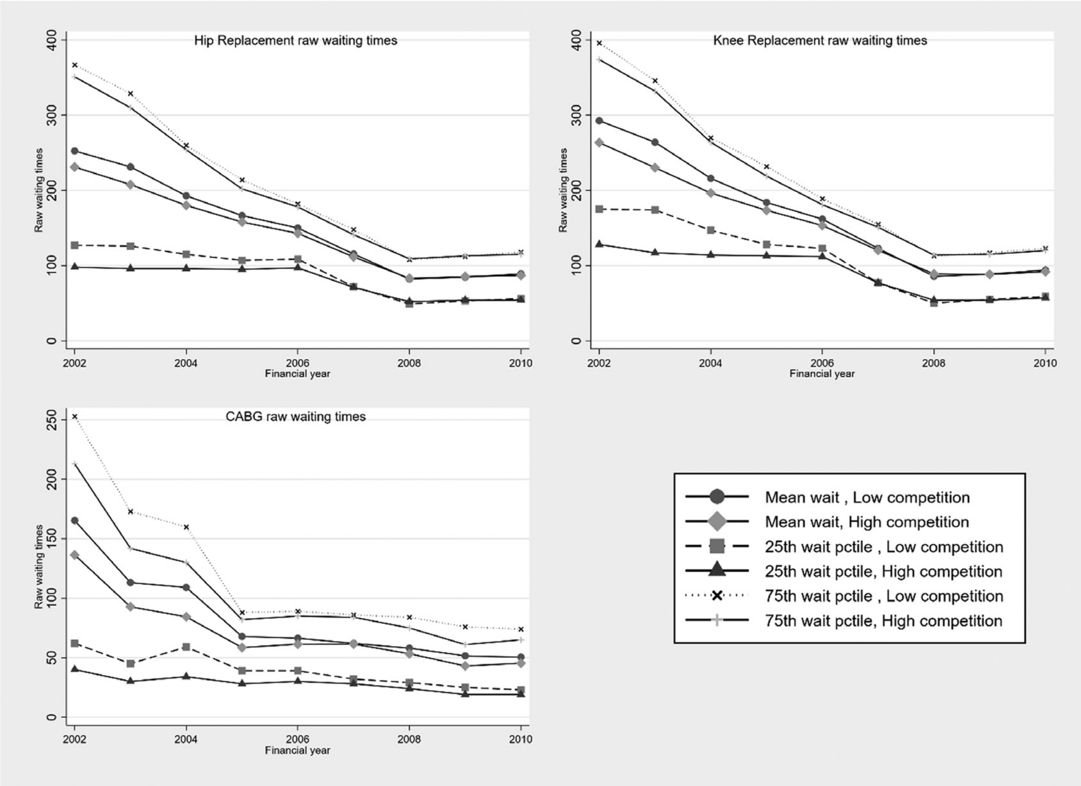

Fig. E1. Raw waiting time trends by level of competition and elective procedures.

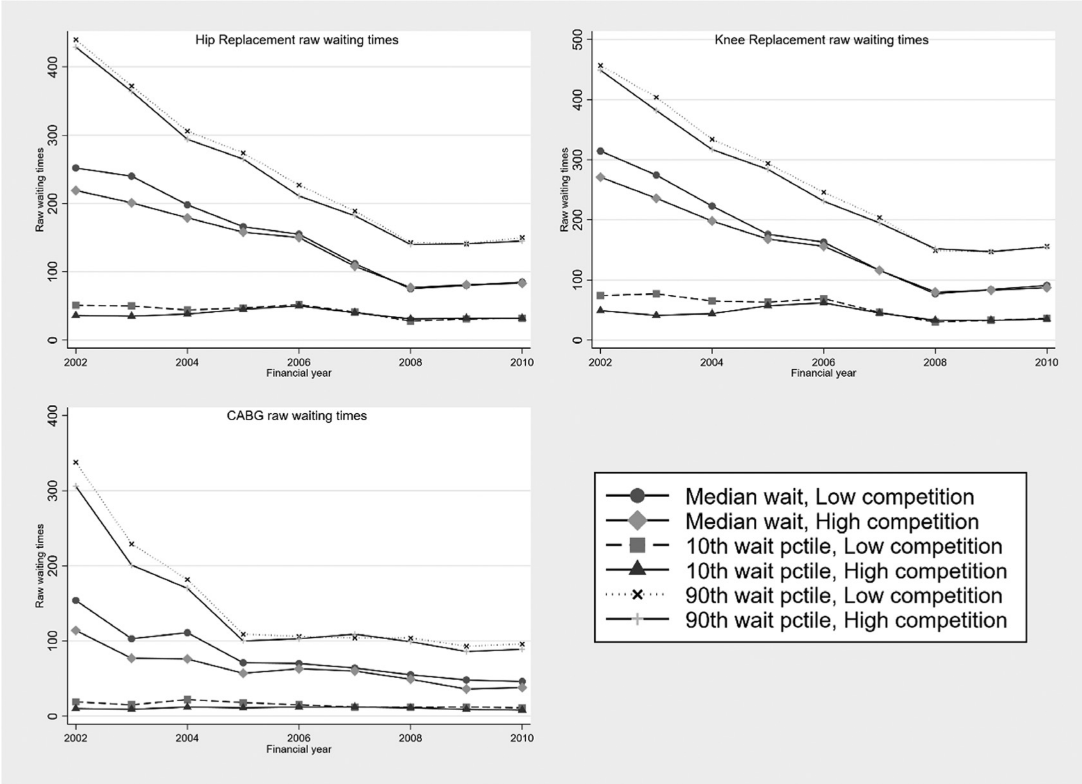

Fig. E1. Continued

Appendix F. Plausibility of parallel trend assumption: event-study estimates

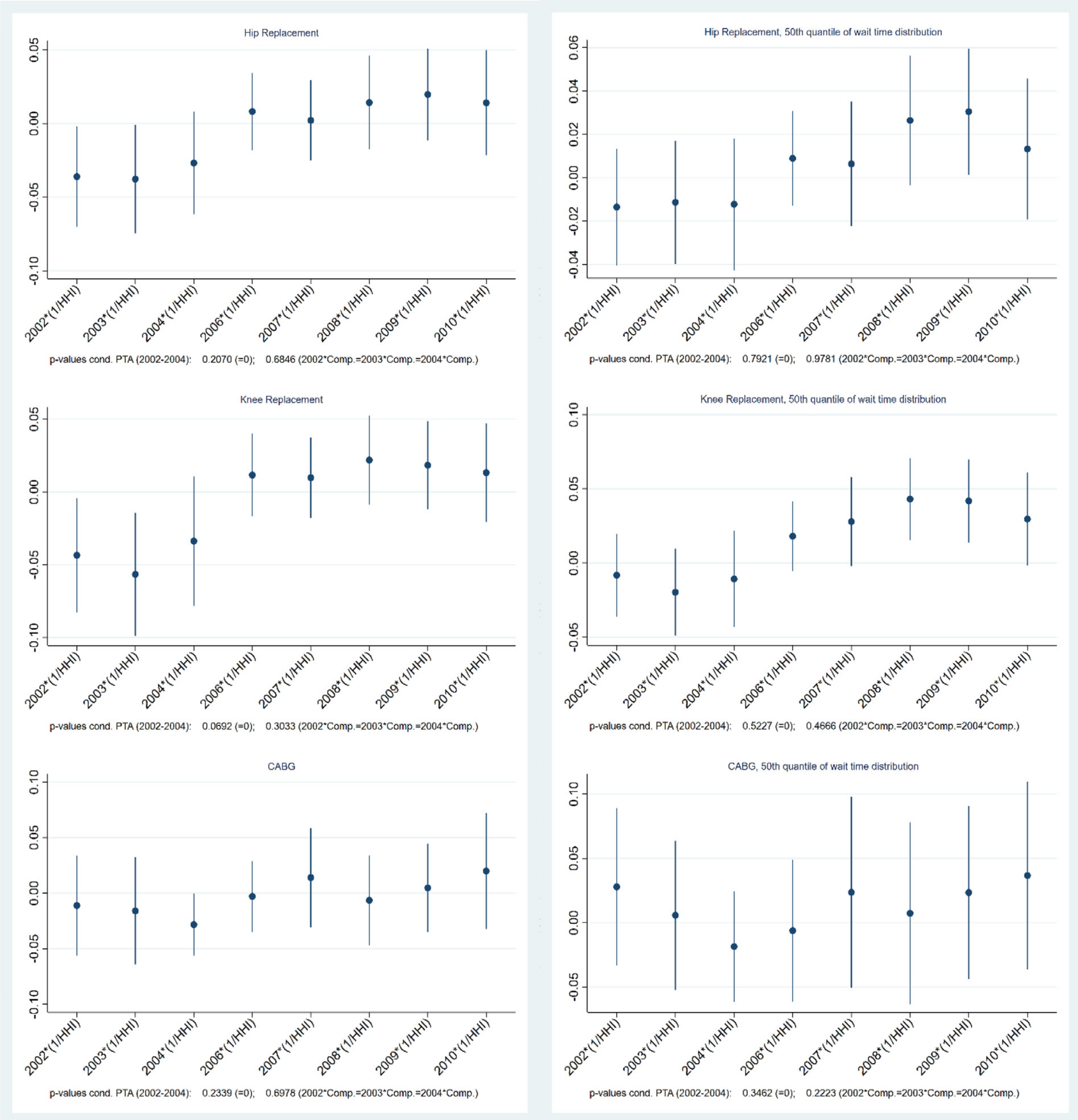

Fig. F1. Event study for change in the effect of competition on waiting times at the mean and at the 50th percentile of the wait distribution.

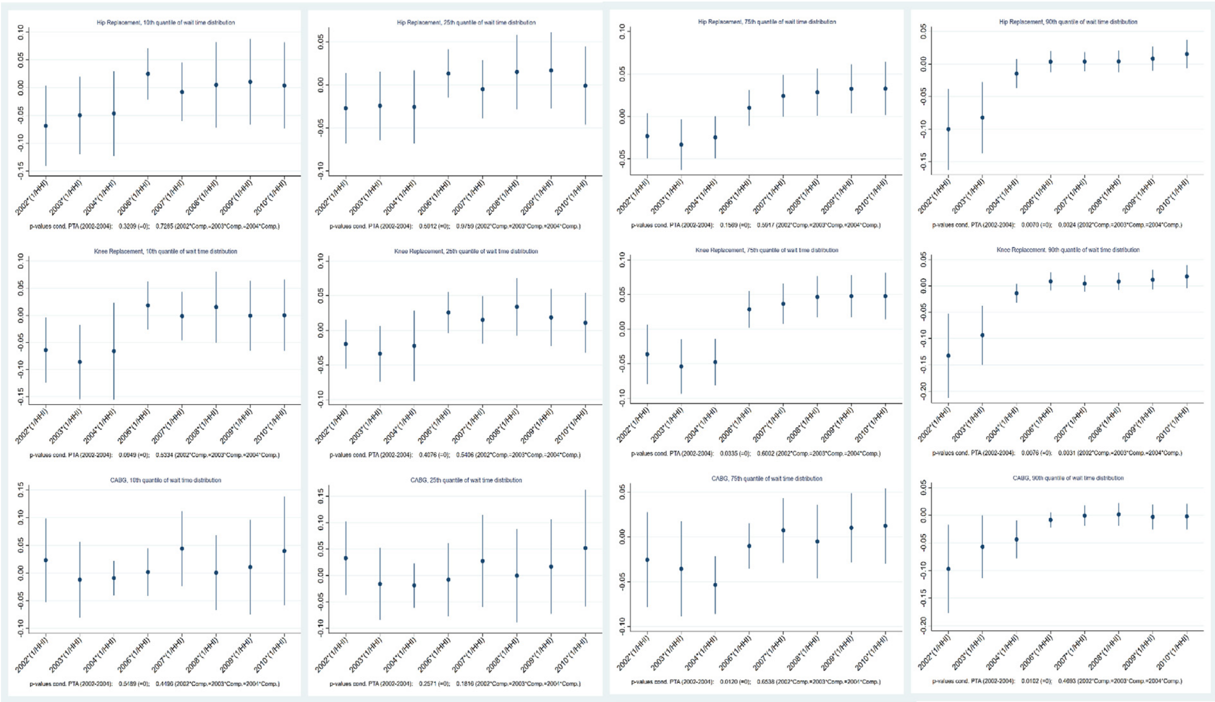

Fig. F2. Event study for change in the effect of competition on waiting times along the unconditional wait distribution (10th, 25th, 75th, 90th percentiles).

Table F1
Wald test statistics and p-values for plausibility of Parallel Trend Assumption in event-study specifications.

	Mean	$\tau=10$	$\tau=25$	$\tau=50$	$\tau=75$	$\tau=90$
	Wald test F-stat (*p-values*): $\gamma_{2002}=\gamma_{2003}=\gamma_{2004}=0$					
Hip Replacement	1.5318	1.1725	0.638	0.346	1.7536	4.1396
	0.207	*0.3209*	*0.5912*	*0.7921*	*0.1569*	*0.007*
Knee Replacement	2.3922	2.1477	0.9699	0.7511	2.9494	4.0683
	0.0692	*0.0949*	*0.4076*	*0.5227*	*0.0335*	*0.0076*
Coronary Bypass	1.4746	0.7136	1.3922	1.1316	4.0741	4.216
	0.2339	*0.5489*	*0.2571*	*0.3462*	*0.012*	*0.0102*
	Wald test F-stat (*p-values*): $\gamma_{2002}=\gamma_{2003}=\gamma_{2004}$					
Hip Replacement	0.3796	0.3172	0.0244	0.0221	0.526	6.1885
	0.6846	*0.7285*	*0.9759*	*0.9781*	*0.5917*	*0.0024*
Knee Replacement	1.1992	0.6301	0.6166	0.7648	0.5117	5.9278
	0.3033	*0.5334*	*0.5406*	*0.4666*	*0.6002*	*0.0031*
Coronary Bypass	0.3627	0.8135	1.7707	1.5542	0.4289	0.7691
	0.6978	*0.4496*	*0.1816*	*0.2223*	*0.6538*	*0.4693*

Appendix G. Robustness check regressions: private sector market shares, patients treated in private sector hospitals, patients older than 59 years, multiple hypotheses testing

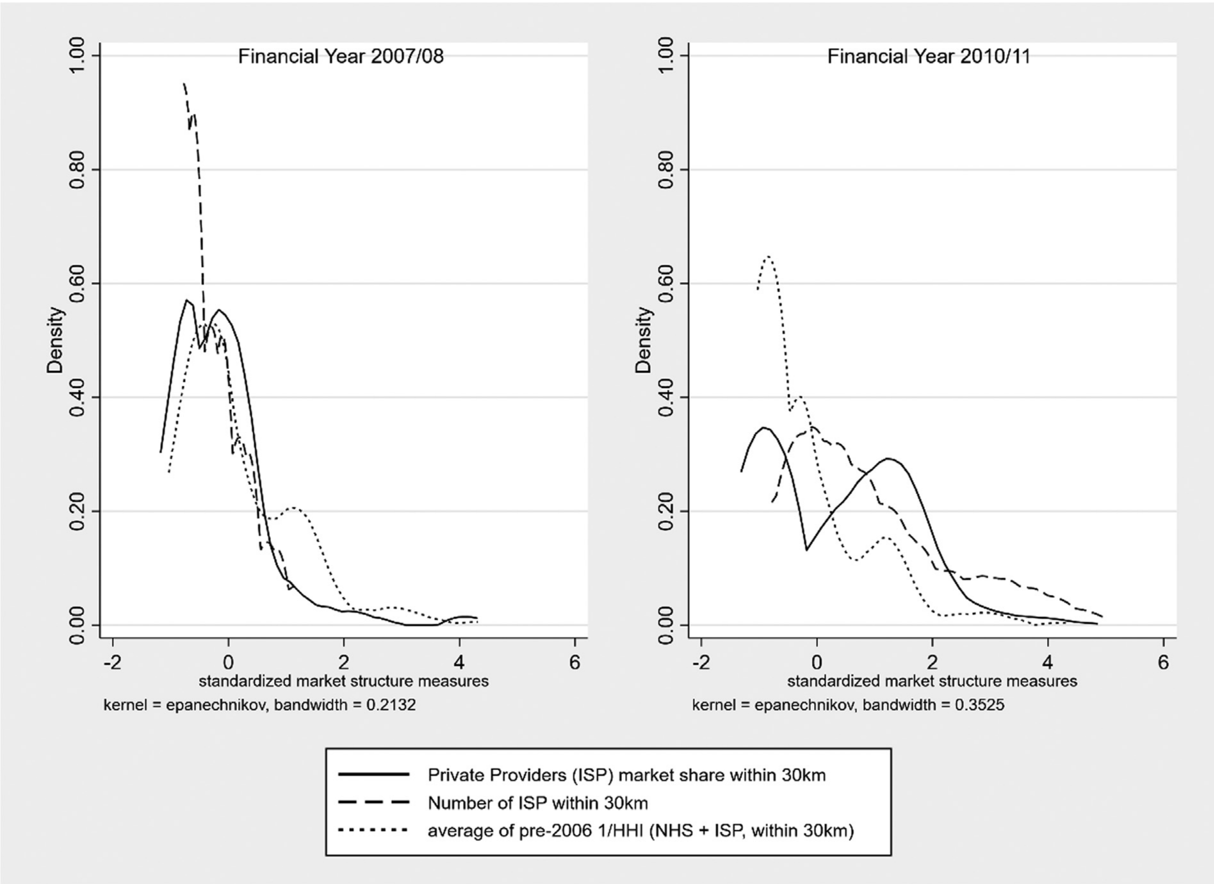

Fig. G1. Distribution of competition measures in financial years 2007/08 and 2010/11.

Table G1
Competition and waiting times: effects along the unconditional wait distribution accounting for endogenous selection into hospitals & private providers market shares.

	(1) $\tau=10$	(2) $\tau=25$	(3) $\tau=50$	(4) $\tau=75$	(5) $\tau=90$
Hip Replacement					
Choice Policy* Market Structure	0.0465**	0.0299**	0.0308***	0.0446***	0.0464***
	(1.9701)	(2.0352)	(3.1024)	(3.3616)	(2.6596)
Predicted ISP market share in 30km	0.0702	0.7711	0.7387**	-0.2033	-0.2104
	(0.0886)	(1.6026)	(2.0078)	(-0.5394)	(-0.4135)
1st quintile EDI income (Most deprived)	0.0574***	0.0227*	0.0165**	0.0050	0.0087
	(2.8373)	(1.8404)	(2.1280)	(0.6585)	(0.8437)
2nd quintile EDI income	0.0461***	0.0179*	0.0102*	0.0045	0.0097
	(2.7192)	(1.9191)	(1.6831)	(0.7833)	(1.2941)
3rd quintile EDI income	0.0417***	0.0189**	0.0117**	-0.0003	0.0037
	(3.4628)	(2.5622)	(2.4971)	(-0.0496)	(0.6356)
4th quintile EDI income	0.0298***	0.0185***	0.0082**	-0.0016	-0.0007
	(3.0070)	(2.9633)	(2.2135)	(-0.3951)	(-0.1249)
Joint test choice residuals – Chi-squared stat p-value	0.0001	0.0000	0.0000	0.0000	0.0000
Patients	400,862	400,862	400,862	400,862	400,862
Hospital Sites	232	232	232	232	232

(*continued on next page*)

Table G1 (*continued*)

	(1) τ=10	(2) τ=25	(3) τ=50	(4) τ=75	(5) τ=90
Knee Replacement					
Choice Policy* Market Structure	0.0558**	0.0438***	0.0443***	0.0705***	0.0573***
	(2.4332)	(2.9277)	(3.9955)	(3.7363)	(2.8557)
Predicted ISP market share in 30km	-0.3886	0.7732	0.4737	-0.4398	-0.1438
	(-0.4422)	(1.3487)	(1.1960)	(-0.8185)	(-0.2604)
1st quintile EDI income (Most deprived)	0.0691**	0.0239**	0.0103	0.0204*	0.0322***
	(2.5441)	(2.0080)	(1.3058)	(1.9197)	(3.1351)
2nd quintile EDI income	0.0574***	0.0197**	0.0095	0.0183**	0.0217***
	(3.1225)	(1.9660)	(1.5297)	(2.3746)	(2.7196)
3rd quintile EDI income	0.0357**	0.0150*	0.0047	0.0069	0.0044
	(2.2728)	(1.8445)	(0.9593)	(1.1103)	(0.6324)
4th quintile EDI income	0.0215*	0.0120*	-0.0004	-0.0015	0.0016
	(1.7127)	(1.6869)	(-0.0922)	(-0.2867)	(0.2694)
Joint test choice residuals – Chi-squared stat *p*-value	0.0000	0.0000	0.0000	0.0000	0.0000
Patients	447,644	447,644	447,644	447,644	447,644
Hospital Sites	239	239	239	239	239
CABG					
Choice Policy* Market Structure	0.0052	-0.0086	-0.0005	0.0284*	0.0420**
	(0.1425)	(-0.2111)	(-0.0193)	(1.7287)	(2.3432)
Predicted ISP market share in 30km	1.2028	-0.8267	-1.4358	0.0931	-0.3587
	(0.5700)	(-0.3808)	(-0.9661)	(0.0690)	(-0.2285)
1st quintile EDI income (Most deprived)	0.1622***	0.1672***	0.1070***	0.0873***	0.0921***
	(2.8259)	(4.3853)	(4.6595)	(4.8389)	(5.4960)
2nd quintile EDI income	0.1784***	0.1525***	0.0874***	0.0665***	0.0796***
	(3.8371)	(4.8900)	(5.2328)	(5.2594)	(6.0761)
3rd quintile EDI income	0.1223***	0.1342***	0.0645***	0.0479***	0.0518***
	(3.4561)	(5.3509)	(5.0096)	(4.2842)	(4.9172)
4th quintile EDI income	0.0704***	0.0703***	0.0385***	0.0212**	0.0272***
	(2.7824)	(3.3773)	(4.5625)	(2.3352)	(2.9887)
Joint test choice residuals – Chi-squared stat *p*-value	0.0002	0.0000	0.0020	0.2852	0.5736
Patients	108,328	108,328	108,328	108,328	108,328
Hospital Sites	47	47	47	47	47

Notes. ISP: independent sector providers. Models: unconditional quantile regressions for logarithm of waiting time. Models include hospital fixed effects, patient and provider characteristics. τ: τ-th quantile of the log wait distribution. t-statistics from standard errors bootstrapped with 1,000 replications and clustered at hospital site level; * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

Table G2
Competition and deprivation related inequity in waiting times accounting for private providers market shares.

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
Choice Policy* Market Structure (γ)	0.0342**	0.0475***	0.0117
	(2.560)	(3.317)	(0.463)
Effect of deprivation pre-choice reform(δ_0)	0.0736***	0.0559***	0.1833***
1st quintile EDI (Most deprived)	(4.532)	(3.491)	(6.572)
	0.0470***	0.0478***	0.1322***
2nd quintile EDI	(3.579)	(3.799)	(5.175)
	0.0400***	0.0221*	0.1130***
3rd quintile EDI	(3.312)	(1.811)	(4.995)
	0.0249***	0.0100	0.0488***
4th quintile EDI	(2.899)	(1.124)	(3.386)
Change in effect of deprivation post-choice for provider facing average competition δ_1)			
1st quintile EDI (Most deprived)* Choice Policy	-0.0751***	-0.0343*	-0.1435***
	(-3.728)	(-1.882)	(-4.125)
2nd quintile EDI* Choice Policy	-0.0428***	-0.0324**	-0.0663***
	(-2.602)	(-2.275)	(-2.716)
3rd quintile EDI* Choice Policy	-0.0351**	-0.0095	-0.0735***
	(-2.212)	(-0.656)	(-2.955)

(*continued on next page*)

Table G2 (*continued*)

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
4th quintile EDI* Choice Policy	-0.0126	-0.0010	-0.0237
	(-1.094)	(-0.092)	(-1.276)
Change in effect of deprivation post choice for provider facing more competition (δ_2)			
1st quintile EDI (Most deprived)* Choice Policy* Market Structure (demeaned)	0.0081	0.0004	-0.0014
	(1.540)	(0.096)	(-0.211)
2nd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0048	0.0066*	0.0049
	(1.089)	(1.665)	(0.939)
3rd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0045	0.0047	0.0039
	(1.128)	(1.189)	(0.625)
4th quintile EDI* Choice Policy* Market Structure (demeaned)	0.0083**	0.0051*	0.0016
	(2.451)	(1.701)	(0.403)
Predicted ISP market share in 30km	0.2773	0.1282	-0.3872
	(0.871)	(0.316)	(-0.242)
R^2	0.239	0.292	0.183
Joint test choice residuals – Chi-squared stat *p*-value	0.0000	0.0000	0.0001
Patients	400,862	447,644	108,328
Hospital Sites	232	239	47

Notes. Dependent variable: natural logarithm of patient waiting time. Models include hospital fixed effects, patient and provider characteristics. EDI: Economic Deprivation Index. t-statistics from bootstrapped (1,000 replications) standard errors clustered at hospital site level; * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

Table G3
Competition and waiting times: effects along the unconditional wait distribution accounting for endogenous selection into hospitals and including waiting times for private patients.

	(1) $\tau=10$	(2) $\tau=25$	(3) $\tau=50$	(4) $\tau=75$	(5) $\tau=90$
Hip Replacement					
Choice Policy* Market Structure	0.0385	0.0260*	0.0246**	0.0433***	0.0525***
	(1.5701)	(1.6651)	(2.2685)	(3.2573)	(2.9333)
Number of Private hospital sites in 30km	0.0203	0.0163	0.0223***	0.0087	-0.0097
	(1.1586)	(1.5199)	(3.0239)	(1.3101)	(-1.2360)
1st quintile EDI income (Most deprived)	0.0609***	0.0259**	0.0144*	0.0062	0.0105
	(2.6038)	(2.0554)	(1.6753)	(0.8754)	(1.0438)
2nd quintile EDI income	0.0535***	0.0235**	0.0096	0.0041	0.0093
	(3.0931)	(2.5147)	(1.5443)	(0.7678)	(1.2252)
3rd quintile EDI income	0.0421***	0.0199***	0.0103**	-0.0004	0.0043
	(3.1731)	(2.7603)	(2.0153)	(-0.0767)	(0.7529)
4th quintile EDI income	0.0287**	0.0196***	0.0078**	-0.0016	-0.0023
	(2.4912)	(2.9250)	(2.0397)	(-0.4506)	(-0.4162)
R^2	0.1641	0.1773	0.2741	0.3221	0.2634
Joint test choice residuals – Chi-squared stat *p*-value	0.0000	0.0000	0.0060	0.0000	0.0000
Patients	420,389	420,389	420,389	420,389	420,389
Hospital Sites	232	232	232	232	232
Knee Replacement					
Choice Policy* Market Structure	0.0510**	0.0383***	0.0402***	0.0660***	0.0638***
	(2.3015)	(2.6051)	(3.5515)	(3.9007)	(3.2247)
Number of Private hospital sites in 30km	0.0106	0.0187*	0.0167**	0.0036	-0.0102
	(0.6334)	(1.6851)	(2.3597)	(0.4739)	(-1.4821)
1st quintile EDI income (Most deprived)	0.0885***	0.0268**	0.0096	0.0177*	0.0314***
	(4.4260)	(2.2449)	(1.1729)	(1.7828)	(2.8363)
2nd quintile EDI income	0.0562***	0.0226**	0.0095	0.0178***	0.0207**
	(3.8684)	(2.4318)	(1.5365)	(2.5817)	(2.5402)
3rd quintile EDI income	0.0383***	0.0171**	0.0044	0.0058	0.0040
	(3.0948)	(2.1385)	(0.8977)	(1.0974)	(0.5706)
4th quintile EDI income	0.0230**	0.0125*	0.0004	0.0005	0.0010
	(2.1562)	(1.7403)	(0.1075)	(0.1192)	(0.1937)
R^2	0.1921	0.2084	0.3312	0.3647	0.2902
Joint test choice residuals – Chi-squared stat *p*-value	0.0000	0.0000	0.0000	0.0000	0.0000
Patients	471,036	471,036	471,036	471,036	471,036
Hospital Sites	239	239	239	239	239

Notes. ISP: independent sector providers. Models: unconditional quantile regressions for logarithm of waiting time. Models include hospital fixed effects, patient and provider characteristics. τ: τ-th quantile of the log wait distribution. t-statistics from standard errors bootstrapped with 1,000 replications and clustered at hospital site level; * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

Table G4
Competition and deprivation related inequity in waiting times, including waiting times for private patients.

	Hip Replacement (1)	Knee Replacement (2)
Choice Policy* Market Structure (γ)	0.0329**	0.0461***
	(2.5261)	(3.1746)
Effect of deprivation pre-choice reform(δ_0)		
1st quintile EDI (Most deprived)	0.0774***	0.0587***
	(4.6432)	(3.5774)
2nd quintile EDI	0.0489***	0.0494***
	(3.5567)	(3.7660)
3rd quintile EDI	0.0402***	0.0228*
	(3.2773)	(1.8599)
4th quintile EDI	0.0243***	0.0097
	(2.7098)	(1.0771)
Change in effect of deprivation post-choice for provider facing average competition δ_1)		
1st quintile EDI (Most deprived)* Choice Policy	-0.0790***	-0.0373**
	(-3.7400)	(-2.0130)
2nd quintile EDI* Choice Policy	-0.0434**	-0.0339**
	(-2.4745)	(-2.1761)
3rd quintile EDI* Choice Policy	-0.0359**	-0.0106
	(-2.2264)	(-0.6924)
4th quintile EDI* Choice Policy	-0.0131	-0.0004
	(-1.0781)	(-0.0395)
Change in effect of deprivation post choice for provider facing more competition (δ_2)		
1st quintile EDI (Most deprived)* Choice Policy* Market Structure (demeaned)	0.0065	0.0004
	(1.2948)	(0.0927)
2nd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0026	0.0050
	(0.5954)	(1.3533)
3rd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0012	0.0032
	(0.2680)	(0.8137)
4th quintile EDI* Choice Policy* Market Structure (demeaned)	0.0042	0.0033
	(1.2544)	(1.1366)
Number of Private hospital sites in 30km	0.0159**	0.0126
	(1.9959)	(1.5711)
R^2	0.308	0.361
Joint test choice residuals – Chi-squared stat *p*-value	0.0000	0.0000
Patients	420,389	471,036
Hospital Sites	232	239

Notes. Dependent variable: natural logarithm of patient waiting time. Models include hospital fixed effects, patient and provider characteristics. EDI: Economic Deprivation Index. t-statistics from bootstrapped (1,000 replications) standard errors clustered at hospital site level; * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

Table G5
Competition and deprivation related inequity in waiting times, patients age restricted to 60 years and over.

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
Choice Policy* Market Structure (γ)	0.0338**	0.0478***	0.0184
	(2.3050)	(3.2087)	(0.7048)
Effect of deprivation pre-choice reform(δ_0)	0.0833***	0.0594***	0.1587***
1st quintile EDI (Most deprived)	(4.8637)	(3.7226)	(5.7476)
	0.0532***	0.0481***	0.1092***
2nd quintile EDI	(3.8603)	(3.8910)	(4.5415)
	0.0402***	0.0229*	0.0962***
3rd quintile EDI	(3.3284)	(1.9438)	(3.9548)
	0.0249***	0.0110	0.0417***
4th quintile EDI	(2.6156)	(1.2097)	(2.6965)
Change in effect of deprivation post-choice for provider facing average competition δ_1)			
1st quintile EDI (Most deprived)* Choice Policy	-0.0903***	-0.0411**	-0.1285***
	(-4.0772)	(-2.2645)	(-4.0160)
2nd quintile EDI* Choice Policy	-0.0535***	-0.0315**	-0.0491*
	(-3.0838)	(-2.1728)	(-1.9110)
3rd quintile EDI* Choice Policy	-0.0336**	-0.0093	-0.0676**
	(-2.1580)	(-0.6485)	(-2.4109)
4th quintile EDI* Choice Policy	-0.0106	-0.0008	-0.0083
	(-0.8029)	(-0.0756)	(-0.4519)

(*continued on next page*)

Table G5 (*continued*)

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
Change in effect of deprivation post choice for provider facing more competition (δ_2)			
1st quintile EDI (Most deprived)* Choice Policy* Market Structure (demeaned)	0.0070	0.0008	-0.0006
	(1.2004)	(0.1892)	(-0.0888)
2nd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0026	0.0063	0.0028
	(0.5391)	(1.4657)	(0.5303)
3rd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0047	0.0044	0.0049
	(1.1596)	(1.0820)	(0.7868)
4th quintile EDI* Choice Policy* Market Structure (demeaned)	0.0079**	0.0057*	0.0027
	(2.0210)	(1.9275)	(0.7399)
Number of Private hospital sites in 30km	0.0083	0.0060	-0.0208
	(1.1081)	(0.8318)	(-1.0387)
R^2	0.242	0.295	0.183
Joint test choice residuals – Chi-squared stat *p*-value	0.0000	0.0000	0.0000
Patients	320,263	388,401	80,458
Hospital Sites	232	239	47

Notes. Dependent variable: natural logarithm of patient waiting time. Models include hospital fixed effects, patient and provider characteristics. EDI: Economic Deprivation Index. t-statistics from bootstrapped (1,000 replications) standard errors clustered at hospital site level; * $p<0.10$; ** $p<0.05$; *** $p<0.01$.

Table G6
Multiple Hypothesis Testing. Competition and waiting times: effects along the unconditional wait distribution accounting for endogenous selection into hospitals, with Sidak-Bonferroni p-value adjustment for 3 outcomes and 1 treatment (m=3).

	(1) $\tau=10$	(2) $\tau=25$	(3) $\tau=50$	(4) $\tau=75$	(5) $\tau=90$
Hip Replacement					
Choice Policy* Market Structure	0.0448	0.0259	0.0246**	0.0421***	0.0502**
	0.0544	0.0717	0.0141	0.0018	0.0041
Number of Private hospital sites in 30km	0.0046	0.0125	0.0179**	0.0060	-0.0098
	0.7687	0.2287	0.0132	0.3899	0.2349
1st quintile EDI income (Most deprived)	0.0568**	0.0223	0.0157	0.0047	0.0073
	0.0107	0.0810	0.0520	0.5265	0.4766
2nd quintile EDI income	0.0457**	0.0177	0.0098	0.0044	0.0084
	0.0083	0.0664	0.1068	0.4373	0.2592
3rd quintile EDI income	0.0413***	0.0186**	0.0113**	-0.0003	0.0034
	0.0011	0.0116	0.0162	0.9482	0.5682
4th quintile EDI income	0.0295**	0.0183**	0.0079	-0.0017	-0.0012
	0.0075	0.0064	0.0451	0.6685	0.8256
Knee Replacement					
Choice Policy* Market Structure	0.0557*	0.0395**	0.0396***	0.0710***	0.0618***
	0.0185	0.0084	0.0003	0.0002	0.0019
Number of Private hospital sites in 30km	-0.0002	0.0132	0.0141	0.0022	-0.0108
	0.9901	0.2171	0.0374	0.7929	0.1663
1st quintile EDI income (Most deprived)	0.0689**	0.0236	0.0099	0.0211	0.0334***
	0.0078	0.0451	0.2331	0.0606	0.0025
2nd quintile EDI income	0.0573***	0.0194	0.0091	0.0188*	0.0224**
	0.0013	0.0369	0.1372	0.0194	0.0051
3rd quintile EDI income	0.0356*	0.0147	0.0044	0.0071	0.0047
	0.0172	0.0611	0.3671	0.2388	0.5028
4th quintile EDI income	0.0215	0.0119	-0.0006	-0.0014	0.0019
	0.0839	0.0762	0.8841	0.7938	0.7379
CABG					
Choice Policy* Market Structure	0.0137	0.0085	0.0057	0.0265	0.0385*
	0.6915	0.8230	0.8365	0.1431	0.0291
Number of Private hospital sites in 30km	-0.0493	-0.0698	-0.0151	0.0099	0.0147
	0.1203	0.0727	0.5423	0.5680	0.1907
1st quintile EDI income (Most deprived)	0.1619**	0.1711***	0.1083***	0.0885***	0.0897***
	0.0047	0.0000	0.0000	0.0000	0.0000
2nd quintile EDI income	0.1765***	0.1551***	0.0888***	0.0675***	0.0780***
	0.0001	0.0000	0.0000	0.0000	0.0000
3rd quintile EDI income	0.1215***	0.1369***	0.0656***	0.0485***	0.0506***
	0.0010	0.0000	0.0000	0.0001	0.0000
4th quintile EDI income	0.0702**	0.0719***	0.0390***	0.0215*	0.0265**
	0.0071	0.0005	0.0000	0.0321	0.0060

Notes. Models: unconditional quantile regressions for logarithm of waiting time. Models include hospital fixed effects, patient and provider characteristics. τ: τ-th quantile of the log wait distribution. *p*-values with Sidak-Bonferroni adjustment for 3 outcomes and 1 treatment, from bootstrapped (1,000 replications) standard errors clustered at hospital site level: * $p<0.0345$; ** $p<0.0169$; *** $p<0.0033$.

Table G7
Multiple Hypothesis Testing. Competition and deprivation related inequity in waiting times, with Sidak-Bonferroni p-value adjustment for 3 outcomes and 1 treatment (m=3).

	Hip Replacement (1)	Knee Replacement (2)	CABG (3)
Choice Policy* Market Structure (γ)	0.0311*	0.0454***	0.0166
	0.0199	0.0017	0.5086
Effect of deprivation pre-choice reform(δ_0)	0.0739***	0.0559***	0.1822***
1st quintile EDI (Most deprived)	0.0000	0.0005	0.0000
	0.0471***	0.0478***	0.1326***
2nd quintile EDI	0.0003	0.0002	0.0000
	0.0395***	0.0218	0.1135***
3rd quintile EDI	0.0011	0.0744	0.0000
	0.0245**	0.0095	0.0491***
4th quintile EDI	0.0043	0.2824	0.0009
Change in effect of deprivation post-choice for provider facing average competition δ_1)			
1st quintile EDI (Most deprived)* Choice Policy	-0.0761***	-0.0344	-0.1403***
	0.0002	0.0593	0.0000
2nd quintile EDI* Choice Policy	-0.0429**	-0.0325*	-0.0664**
	0.0093	0.0233	0.0071
3rd quintile EDI* Choice Policy	-0.0345*	-0.0092	-0.0740**
	0.0295	0.5279	0.0039
4th quintile EDI* Choice Policy	-0.0122	-0.0005	-0.0238
	0.2861	0.9642	0.2087
Change in effect of deprivation post choice for provider facing more competition (δ_2)			
1st quintile EDI (Most deprived)* Choice Policy* Market Structure (demeaned)	0.0080	0.0005	-0.0013
	0.1277	0.9082	0.8415
2nd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0047	0.0066	0.0049
	0.2862	0.0922	0.3493
3rd quintile EDI* Choice Policy* Market Structure (demeaned)	0.0043	0.0047	0.0040
	0.2756	0.2347	0.5278
4th quintile EDI* Choice Policy* Market Structure (demeaned)	0.0081**	0.0051	0.0017
	0.0162	0.0933	0.6659
Number of Private hospital sites in 30km	0.0097	0.0066	-0.0188
	0.1644	0.3490	0.3514

Notes. Dependent variable: natural logarithm of patient waiting time. Models include hospital fixed effects, patient and provider characteristics. EDI: Economic Deprivation Index. p-values with Sidak-Bonferroni adjustment for 3 outcomes and 1 treatment, from bootstrapped (1,000 replications) standard errors clustered at hospital site level: * $p<0.0345$; ** $p<0.0169$; *** $p<0.0033$.

References

Aakvik, A., Holmås, T., Kjerstad, E., 2015. Prioritization and the elusive effect on welfare – A Norwegian health care reform revisited. Social Science and Medicine 128, 290–300.
Angrist, J., Pischke, J., 2009. Mostly Harmless Econometrics. Princeton University Press.
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.
Borgen, N.T., 2016. Fixed effects in unconditional quantile regression. Stata Journal 16 (2), 403–415.
Brekke, K.R., Siciliani, L., Straume, O.R., 2011. Hospital competition and quality with regulated prices. Scandinavian Journal of Economics 113, 444–469.
Brekke, K.R., Siciliani, L., Straume, O.R., 2008. Competition and waiting times in health care markets. Journal of Public Economics 92, 1607–1628.
Brekke, K.R., Holmås, T.H., Monstad, K., Straume, O.R., 2018. Socio-economic status and physicians' treatment decisions. Health economics 27 (3), e77–e89.
Card, D., 1992. Using regional variation in wages to measure the effects of the federal minimum wage. Industrial and Labor Relations Review 46 (1), 22–37.
Charlson, M.E., Pompei, P., Ales, K.L., MacKenzie, C.R., 1987. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. Journal of Chronic Diseases 40 (5), 373–383.
Colla, C., Bynum, J., Austin, A., Skinner, J., 2016. Hospital competition, quality, and expenditures in the US Medicare population (No. w22826). National Bureau of Economic Research.
Cookson, R., Laudicella, M., Donni, P.L., 2013. Does hospital competition harm equity? Evidence from the English National Health Service. Journal of Health Economics 32 (2), 410–422.
Cooper, Z.N., McGuire, A., Jones, S., Le Grand, J., 2009. Equity, waiting times, and NHS reforms: retrospective study. BMJ: British Medical Journal 339.
Cooper, Z., Gibbons, S., Jones, S., McGuire, A., 2011. Does hospital competition save lives? evidence from the English NHS patient choice reforms. The Economic Journal 121 (554), F228–F260.
Dawson, D., Gravelle, H., Jacobs, R., Martin, S., Smith, P.C., 2007. The effects of expanding patient choice of provider on waiting times: evidence from a policy experiment. Health Economics 16, 113–128.
Department of Health (2002). Delivering the NHS Plan. Stationery Office, London.
Department of Health, 2015. Handbook to the NHS Constitution. The StationaryOffice, London.
Dusheiko, M., Gravelle, H., 2018. Choosing and booking-and attending? Impact of an electronic booking system on outpatient referrals and non-attendances. Health economics 27 (2), 357–371.
Firpo, S., Fortin, N.M., Lemieux, T., 2009. Unconditional quantile regressions. Econometrica 77 (3), 953–973.
Gaynor, M., 2006. What do we know about competition and quality in health care markets? National Bureau of Economic Research Working paper w12301.
Gaynor, M., Town, R.J., 2011. Competition in health care markets. Handbook of health economics 2, 499–637.
Gaynor, M., Moreno-Serra, R., Propper, C., 2013. Death by Market Power: Reform, Competition, and Patient Outcomes in the National Health Service. American Economic Journal: Economic Policy 5 (4), 134–166.
Gaynor, M., Propper, C., Seiler, S., 2016. Free to choose? Reform, choice, and consideration sets in the English National Health Service. American Economic Review 106 (11), 3521–3557.

Gill, B., 2012. Tracking economic and child income deprivation at neighbourhood level in England, 1999–2009.
Gowrisankaran, G., Town, R.J., 1999. Estimating the quality of care in hospitals using instrumental variables. Journal of Health Economics 18 (6), 747–767.
Gravelle, H., Siciliani, L., 2008. Is waiting-time prioritisation welfare improving? Health Economics 17 (2), 167–184.
Guimaraes, P., Figueirdo, O., Woodward, D., 2003. A tractable approach to the firm location decision problem. Review of Economics and Statistics 85 (1), 201–204.
Guimaraes, P., 2004. Understanding the multinomial-Poisson transformation. The Stata Journal 4 (3), 265–273.
Hawkes, N., 2012. Private Hospitals Look to NHS for Elective Operations as Private Medical Insurance Falls. BMJ: British Medical Journal (Online) 345.
Healthcare Commission. (2008). Independent sector treatment centres: the evidence so far. London. July
Heckley, G., Gerdtham, U., Kjellsson, G., 2016. A general method for decomposing the causes of socioeconomic inequality in health. Journal of Health Economics 48, 89–106.
Iacobucci, G., 2017. Pressure on NHS finances drives new wave of postcode rationing. British Medical Journal 358. doi:10.1136/bmj.j3190, 4 July.
Johar, M., Jones, G., Keane, M., Savage, E., Stavrunova, O., 2013. Differences in waiting times for elective admissions in NSW public hospitals: A decomposition analysis by nonclinical factors. J Health Econ 32, 181–194.
Kaarboe, O., Carlsen, F., 2014. Waiting times and socioeconomic status. Evidence from Norway. Health economics 23 (1), 93–107.
Kessler, D.P., McClellan, M.B., 2000. Is hospital competition socially wasteful? The Quarterly Journal of Economics 115 (2), 577–615.
Kessler, D.P., Geppert, J.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.
Laudicella, M., Siciliani, L., Cookson, R., 2012. Waiting times and socioeconomic status: evidence from England. Social science & medicine 74 (9), 1331–1341.
Lindsay, C., Feigenbaum, B., 1984. Rationing by waiting lists. Amercian Economic Review 74, 404–417.
Manning, W., 1998. The logged dependent variable, heteroscedasticity, and the retransformation problem. Journal of Health Economics 17, 283–295.
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.
Monstad, K., Engesæter, L.B., Espehaug, B., 2014. Waiting time and socioeconomic status—An individual-level analysis. Health Economics 23 (4), 446–461.
Moran, M., 1999. Governing the health care state: a comparative study of the United Kingdom, the United States, and Germany. Manchester University Press.
Moscelli, G., Gravelle, H., Siciliani, L., 2018a. Effects of Market Structure and Patient Choice on Hospital Quality for Planned Patients (No. 1118). School of Economics. University of Surrey.
Moscelli, G., Siciliani, L., Gutacker, N., Cookson, R., 2018b. Socioeconomic inequality of access to healthcare: Does choice explain the gradient? Journal of Health Economics 57, 290–314.
Moscelli, G., Gravelle, H., Santos, R., Siciliani, L., 2021. Hospital competition and quality for non-emergency patients in the English NHS. Rand Journal of Economics 52, 382–414.
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, 2020. Waiting Times for Health Services. Next in Line. OECD Health Policy Studies.
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., Windmeijer, F., 2010. Incentives and targets in hospital care: evidence from a natural experiment. Journal of Public Economics 94 (3-4), 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.
Sharma, A., Siciliani, L., Harris, A., 2013. Waiting times and socioeconomic status: does sample selection matter? Economic Modelling 33, 659–667.
Siciliani, L., 2005. Does more choice reduce waiting times? Health Economics 14 (1), 17–23.
Siciliani, L., Martin, S., 2007. An empirical analysis of the impact of choice on waiting times. Health Economics 16 (8), 763–779.
Siciliani, L., Borowitz, M., Moran, V., 2013. A review of waiting times policies in 13 OECD countries. In: Siciliani, L., Borowitz, M., Moran (Eds.), Waiting Time Policies in the Health Sector. What works?. OECD Report, Paris, France DOI doi:10.1787/9789264179080-en.
Siciliani, L., 2016. Waiting times: evidence of social inequalities in access for care. In: Levy, A., Goring, S. (Eds.), Data and Measures in Health Services Research. Springer Science+Business Media, New York DOI doi:10.1007/978-1-4899-7673-4_17-1.
Siciliani, L., Straume, O.R., 2019. Competition and Equity in Health Care Markets. Journal of Health Economics 64, 1–14.
Tornqvist, L., Vartia, P., Vartia, Y., 1985. How should relative changes be measured? The American Statistician 39 (1), 43–46.
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.
Wagstaff, A., Paci, P., Van Doorslaer, E., 1991. On the measurement of inequalities in health. Social Science and Medicine 33, 545–557.
Wagstaff, A., 2002. Inequality Aversion, Health Inequalities and Health Achievement. Journal of Health Economics 21 (4), 627–641.
Wooldridge, J., 2015. Control Function Methods in Applied Econometrics. Journal of Human Resources 50 (2), 420–445.