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Heterogeneous effects of patient choice and hospital competition on mortality

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Abstract

We examine whether the relaxation of constraints on patient choice of hospital in the English National Health Service in 2006 led to greater changes in mortality for hospitals which faced more rivals before the choice reform. We use patient level data from 2002 to 2010 for three high volume emergency conditions with high mortality risk: acute myocardial infarction (AMI) (288,279 patients), hip fracture (91,005 patients), stroke (214,103 patients). Since mortality risk varies by sub-diagnoses of AMI and stroke we include indicators for sub-diagnoses in the covariates. We also allow for the effect of covariates on mortality to differ before and after the 2006 choice reform. We find that the choice reform reduced mortality risk for hip fracture patients by 0.62% (95% CI: 1.22%, 0.01%), compared with the 2002/3-2010/11 mean of 3.5%, but had statistically insignificant negative effects for AMI and stroke. The reform also had heterogeneous effects across AMI and stroke sub-diagnoses, reducing mortality for 3% of AMI patients and 21% of stroke patients. The reduction in hip fracture mortality was greater for more deprived patients. Policies to increase competition and give patients greater choice are likely to have heterogeneous effects depending on details of patient case mix and market conditions.

Keywords: England, competition, quality, hospital, choice, mortality

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1 Introduction

Many countries are extending competition in health care (OECD, 2012). When providers face fixed prices per patient, they can only attract more patients by improving quality. It is argued that the incentive to improve quality will be greater when providers face more rivals and if patients have greater freedom to choose their health care provider (Le Grand, 2003). However, theory models of health care markets yield ambiguous predictions about the effect of competition on quality (Brekke et al., 2011). (For example, an altruistic provider may be producing such high quality that marginal cost exceeds price, and so may reduce quality to offset the increase in demand when restrictions on choice are relaxed.) The empirical evidence on hospital competition and quality in fixed price health care systems is mixed and intensely debated (Bevan and Skellern, 2011; Bloom *et al.*, 2011; Gaynor *et al.*, 2012; OHE, 2012; Pollock *et al.*, 2011).

In the English National Health Service (NHS) before 2006 patient choice of hospitals for elective hospital treatment was constrained to local NHS hospitals with contracts with the patient's health authority. In 2006 constraints on choice of hospital were relaxed, and patients had to be offered a choice of at least four providers. From 2008 patients could choose any qualified provider, wherever located. We investigate whether these relaxations of constraints on patient choice led to larger changes in quality for hospitals with more competitors.

1.1 Previous literature

The results from the literature on the effects of competition on quality vary by country, time period, and type of condition. For the US, Kessler and McClellan (2000) and Kessler and Geppert (2005) find that mortality for acute myocardial infarction (AMI) was lower in more competitive markets. Gowrisankaran and Town (2003) report that greater competition for HMO patients reduced heart attack and pneumonia mortality, but greater competition for Medicare patients increased mortality. Shen (2003) finds mixed effects of competition on AMI mortality. Mukamel *et al.* (2001) find no effect of market concentration on all-cause mortality. Mukamel *et al.* (2002) find that higher competition was associated with lower clinical expenditures, which in turn was associated with higher mortality. Colla *et al.* (2014) report that competition reduces AMI mortality rates, has no effect on 30-day emergency readmission rates for hip and knee replacement and reduces quality for dementia patients. Chou *et al.* (2014) find that report cards on the quality of providers reduced CABG mortality for more severely ill patients in more competitive areas. Berta *et al.* (2016) find that competition did not affect a quality index based on mortality and readmissions in Italy.

For the English National Health Service (NHS) during the first NHS internal market in the 1990ies when providers and local commissioners bargained over prices, Propper *et al.* (2004) report that providers facing more competition had higher AMI mortality and Propper *et al.* (2008) find that, when competition was allowed during this period, providers in more competitive areas had a slower rate of decline of AMI mortality. Papers on the post 2002 NHS internal market when hospitals faced fixed prices reach different conclusions. Using cross-sectional data and instrumenting market structure by the political marginality of nearby parliamentary constituencies Bloom *et al.* (2015) find that hospitals in more competitive areas had lower AMI mortality. Cooper *et al.* (2011) and Gaynor *et al.* (2013) use the relaxation of constraints on patient choice of provider in 2006 as a natural experiment, arguing that it would have a bigger effect for providers with more rivals. Using patient level data for 2002-2008, Cooper *et al.* (2011) find that there was an increasing negative effect of competition on in-hospital AMI mortality and that this trend became more pronounced in more competitive areas after 2006. Gaynor *et al.* (2013) use hospital level data for two financial years (April-March) 2003/4 and 2007/8. They find that hospitals facing more competition in 2003/4 had a larger decrease in AMI mortality rates between 2003/4 and 2007/8. Moscelli et al. (2016a) report that competition slightly increased emergency readmissions for elective hip and knee replacement patients, and had no effect on those for elective coronary bypass. Skellern (2017) finds that competition resulted in smaller Patient Reported Outcomes gains for hip and knee replacement patients.

Our analysis also relates to the literature investigating whether quality affects patient choice of hospital (e.g. Gaynor *et al.* (2016) for coronary bypass, Gutacker et al. (2016) and Beckert et al. (2012) for hip replacement). Although quality is a key explanatory variable in models of choice of hospital and is the dependent variable in models of the effect of competition on quality, the literatures are complementary since competition can only affect quality if choice of hospital is affected by quality.

1.2 Our contribution

We examine whether the relaxation of constraints on patient choice of hospital had different effects on mortality depending on the market structure facing the hospital. We make several contributions to the literature. First, in addition to AMI, we examine the effect of the choice reform for two other high volume and high mortality emergency conditions where better care should improve outcomes and which are also used as NHS hospital performance indicators: hip fracture and stroke. Stroke causes 10-12% of deaths in the Western world (Donnan *et al.*, 2008) and the 30 day mortality rate for stroke hospital patients aged 35-74 is 17% in our sample compared to 7% for AMI. One in five people die within one year of a hip fracture and one in four requires long-term care (Gillespie, 2000). The lifetime risk of hip fracture in industrialised countries is 18% in women and 6% in men and all age 30 day mortality is around 6%. Moreover, the main treatment for hip fracture is a hip replacement, usually carried out in the same hospital department, and often by the same staff, as elective hip replacements and there was a marked increase in competition in elective hip replacement during our study period. Mortality for AMI, hip fracture, and stroke patients is only modestly correlated across hospitals, suggesting that they could have been affected differently by market structure and the choice reforms.

Second, we use a longer panel (2002/3 to 2010/11) of patient level data than previous studies. This enables us to test if there was a change in the effect of market structure after the initial relaxation of constraints on patient choice in 2006 and whether there was a further change after 2008, when elective patients had the right to choose any qualified provider.

Third, we include sub-diagnoses of AMI, hip fracture and stroke in our case-mix controls to allow for the fact that mortality risk may differ substantially for patients with different sub-diagnoses. We also investigate whether the effects of the choice reforms differ across sub-diagnoses.

Fourth, we allow for the effect of patient casemix to differ before and after the 2006 policy change. This allows us to control for possible confounding arising from changes in the effects of patient characteristics on mortality due to trends in overall population health (manifested in changes in age and sex specific mortality rates), advances in medical care, and changes in clinical coding as prospective pricing was rolled out.

2 Institutional background

NHS hospital treatment is tax funded and there are no charges to patients. Most NHS hospital care is provided by public hospitals. From 2003 private sector providers have been able to enter the NHS market and 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). Emergency care for NHS funded patients is provided only in NHS hospitals.

During our period (2002/3-2010/11) health authorities (Primary Care Trusts – PCTs) held budgets from the Department of Health to purchase hospital care for their populations. Until 2003/4 PCTs mainly placed block contracts with local hospitals, under which the hospital agreed to treat all patients from the PCT who were referred by their primary care physicians (General Practitioners - GPs). There are over 7,600 general practices with an average of over 5 GPs and 7,500 patients (NHS Digital, 2016). 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. Prospective payment per patient was rolled out between 2003/4 and 2008/9, with the proportion of treatments covered and the financial reward increasing over time.

Until 2006 the amount of choice of hospital for elective care varied across PCTs and general practices, depending on the set of hospitals that had block contracts with PCT and on GPs' willingness to refer outside this set. In January 2006 NHS patients were given the right to be offered a choice of at least four providers. From April 2008 onwards, patients had the right to choose *any qualified provider*, wherever located and whether public or private.

To complement the choice reforms, 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). Since 2007, the NHS Choices website has provided public information on services and quality of providers. These policies led to changes in demand patterns and increased hospital elasticity of demand with respect to quality (Gaynor *et al.*, 2016; Moscelli *et al*. 2016b).

3 Data

Hospital Episodes Statistics (HES) for financial years 2002/3 to 2010/11 have information on all admissions to NHS providers and all NHS-funded hospital admissions to private providers. HES information on patients includes age, gender, dates of admission and discharge, discharge method (dead or alive), primary diagnosis and up to 13 secondary diagnoses using ICD10 (International Classification of Diseases version 10), and information on treatments. HES also records the patient's Lower Super Output Area (LSOA) - the small area (1500 mean population) in which the patient lives.

3.1 Mortality

Most NHS hospitals treat both emergency and elective (non-emergency) patients. We follow the bulk of the empirical literature on hospital competition and quality and measure quality by mortality for *emergency* patients. Mortality for these patients is well recorded, not subject to problems with small numbers, and can be reduced by appropriate treatment. Readmission rates can be subject to selection bias through mortality (Laudicella *et al.*, 2013) and patient reported outcome were not available in the pre-choice reform period.

Emergency patients do not choose their provider so that measures of emergency quality do not suffer from selection bias arising when unobservably sicker patients choose providers on the basis of quality. (See Cooper *et al.* (2011) and Gaynor *et al.* (2013) for discussions of the merits of using high volume and high mortality emergency admissions to examine the effect of competition on quality.) Since hospitals can only compete for elective patients, the use of emergency quality measures is appropriate only if emergency and elective quality are positively correlated. Such correlation may occur if quality in all specialities is influenced by the overall managerial quality of the hospital (Bloom *et al.*, 2015) or if investments in information systems or capital equipment, such as MRI scanners, raise quality across the hospital.

Our main patient level quality indicator is whether a patient aged 35 to 74 died in or outside hospital within 30 days of admission. Patients aged 35-74 have lower mortality rates than older patients but their risk of death is likely to be more responsive to good quality of care (Nolte and McKee, 2012).

3.2 Market structure

NHS Hospital Trusts can have more than one site. In our sample there are 238 sites and 165 Trusts with AMI patients, 213 sites and 160 Trusts with hip fracture patients, and 236 sites and 163 Trusts with stroke patients. We test if the competition faced by sites affects mortality for these patients.

Although we measure health outcomes for patients with one of three *emergency* conditions, our measure of market structure is based on all *elective* patients We first compute the Herfindahl-Hirschman Index (HHI) for all LSOAs as the sum of the squared shares of elective admissions at providers used by LSOA patients. It is a measure of the amount of choice they have amongst elective care providers. We then compute the HHI for each site in each year as the elective patient weighted average of the HHIs of LSOAs within 30 km of the site.

To remove possible bias arising from the effect of quality on utilisation we compute HHIs using patient shares derived from models of patient choice of provider for elective care in which choice depends on distance but is not allowed to depend on quality (Kessler and McClellan, 2000). (See Appendix A.) For a market with N firms the HHI lies between 1 (monopoly) and $1/N$. We use $1/HHI$ – the equivalent number of equal sized providers – as the measure of competition facing a provider.

3.3 Patient covariates

Patient level covariates are age, gender, up to 13 comorbidities, source of admission (home, nursing home, temporary location), day of the week and month of year admitted, and the straight-line distance from the patient's LSOA centroid to the treatment site. We measure severity of comorbidities using the Charlson index (Charlson *et al.*, 1987), which weights comorbid conditions by their impact on 10-year mortality risk. We attribute measures of income deprivation, environment deprivation, incapacity benefit claims rate, and disability claims rate to patients by their LSOA of residence.

To allow for the fact that mortality rates can vary substantially across different types of AMI, hip fracture and stroke (Appendix A) and that the mix of types can vary over time, we also include dummy variables for sub-diagnoses of AMI, hip fracture and stroke as covariates.

4 Methods

We expect the 2006 choice reform to have had different effects on quality for hospitals facing different market structures. We therefore employ a difference-in-difference (DiD) approach with a continuous treatment variable (market structure), as pioneered by Card (1992) and applied to the effect of choice policy changes on AMI mortality in NHS hospitals by Propper *et al.* (2008) and Gaynor *et al.*, (2013).

Our main specification is a linear probability model

$$q_{iht} = \beta_t + \gamma \bar{M}_{h0} P_t + \mathbf{x}'_{iht}\boldsymbol{\lambda}_0 + \mathbf{x}'_{ht}\boldsymbol{\pi}_0 + \mathbf{x}'_{iht}\boldsymbol{\lambda}_1 P_t + \mathbf{x}'_{ht}\boldsymbol{\pi}_1 P_t + \mu_h + \varepsilon_{iht} \quad (1)$$

where q_{iht} is an indicator for whether patient i aged 35-74, treated in site h in year t died in hospital or elsewhere within 30 days of admissions. The post-policy change variable P_t is an indicator for the period (2006/7-2010/11) after the initial relaxation of constraints on choice. $\bar{M}_{h0}$ is the average market structure facing site h in in the pre-choice reform years (2002/3 to 2005/6). $\mathbf{x}_{iht}$ is a vector of patient covariates, $\mathbf{x}_{ht}$ is a vector of hospital types (teaching or not, Foundation Trust or not), μ_h is a time-invariant hospital site effect and ε_{iht} is an error term. Year effects β_t control for changes in factors common to all providers. For example, the phased introduction of prospective pricing from 2003/4 to 2008/9 meant that the marginal revenue from treating additional elective patients increased over this period thereby increasing incentives to improve quality. We estimate separate models for each condition, using hospital site fixed effects, and cluster robust standard errors on sites.

The coefficient of interest is γ. If a site has no rivals then relaxation of constraints on choice can have no effect on incentives to attract more patients by raising quality. The effect of the 2006 choice reform in (1) is to pivot the linear relationship between mortality and market structure through its intercept on the mortality axis. Thus the change in mortality probability for site h due to the reform is $\gamma \bar{M}_{h0}$ and we can compute the average effect of the policy reform as $100\gamma \bar{M}_0$ where $\bar{M}_0$ is the patient weighted mean of $\bar{M}_{h0}$ over all sites and we multiply by 100 to express the effect with probability measured as a percentage.

Basing the measure of elective market structure on predicted patient flows, which do not vary with quality, avoids one source of endogeneity. But there is another potential threat to identification: endogenous entry of providers. Hospitals could choose to locate in areas where patients are healthier and easier to treat, so that there would be more competition where mortality is lower. Or hospitals could locate near existing hospitals with low quality so that there is more competition near low quality hospitals. The main source of changes in NHS market structure over the period 2002/3 to 2010/11 was the entry of private providers. Between 2002/3 and 2008/9, independent sector treatment centres (ISTCs) specialising in a small number of elective treatments were given favourable contracts and were encouraged to locate in areas where NHS patients were experiencing long waiting times (Department of Health, 2004; Department of Health, 2006). Cooper *et al.* (2016, Table A3) found that this wave of ISTC entry was more likely where existing NHS providers had longer waiting times, but it was not associated with their quality.

After 2008 NHS patients could choose any qualified provider, whether first wave ISTC, second wave ISTC, non-specialist private hospital, or NHS hospital. If pressure on management to improve quality is driven by overall elective competition (Bloom *et al.*, 2015), then the fact that the private sector accounted for only 4% of elective NHS treatments, even at the end of our period, suggests that endogenous market structure may not be a serious problem. By using time-invariant market structure ($\bar{M}_{h0}$), which is not affected by location decisions in the 2006 post-reform period, we avoid this problem.

There is a third threat to identification: differences in the effects of covariates before and after the choice reform (Meyer, 1995). If $\boldsymbol{\lambda}_1$ or $\boldsymbol{\pi}_1$ are not zero then a model without $\mathbf{x}'_{iht}\boldsymbol{\lambda}_1 P_t$ and $\mathbf{x}'_{ht}\boldsymbol{\pi}_1 P_t$ will include theses terms in the errors and the estimated $\hat{\gamma}$ will be biased if the covariates are correlated with $\bar{M}_{h0}$ in the post choice period. Epidemiological studies suggest that changes in mortality risk over time have varied by age, gender, and ethnicity (Koton, *et al.*, 2014; Rahimi, *et al.*, 2015; Wu, *et al.*, 2010). The roll out of prospective pricing over the period could also have led to changes in coding practice. Hence we allow the effect of the covariates to differ pre and post the choice reform (Abadie, 2005, p4).

5 Results

5.1 Summary statistics

There were 32,000 emergency admissions aged 35-74 per year for AMI, 10,100 for hip fracture, and 23,800 for stroke (**Table 1**). AMI and stroke admissions fell between 2002/3 and 2010/11, whilst hip fracture admissions increased. Average 30-day mortality rates were 7% for AMI, 4% for hip fracture, and 17% for stroke and declined over our period (**Figure 1**).

Table 2 reports the correlations of risk adjusted mortality amongst the three conditions. They are positive but small in the pre reform period, and increase, though are still not high, in the post reform period. The low correlations suggest that the effects of choice reform could differ across the three conditions.

The equivalent number of sites within 30km increased from 2.6 to 3.5 as did the actual number of sites with 30km (11.9 to 18.3) (**Figure 2**).

5.2 Estimation results

In **Table 3** we report the estimated coefficients on the interaction of the P_t policy break indicator, which takes the value of 1 from 2006/7 onwards, with the pre-policy mean market structure, ($\bar{M}_{h0}$) for provider *h* in the pre-choice reform period up to 2005/6 (full results are in Appendix Table B3). Models in columns (i) to (iii) do not include indicators for sub-diagnoses and covariates are not interacted with the policy break indicator. Columns (iv) to (vi) adds indicators for sub-diagnoses and columns (vii) to (ix) report results for the baseline specification in equation (1) in which we interact all covariates with the policy break indicator.

For the AMI and stroke models adding sub-diagnoses (columns (iv) and (vi)) and then also letting the effects of the covariates differ before and after 2006 (columns (vii) and (ix)) leads to marked improvement in the goodness of fit. For hip fracture, adding the sub-diagnoses (column (v) versus column (ii)) does not improve the model. Letting the effects of the covariates differ pre and post the choice reform (column (viii)) improves goodness of fit according to the R^2 and AIC but not the BIC, which imposes a heavier penalty for adding explanatory variables. Coefficients on the interactions of the post-choice reform dummy and the covariates are jointly highly statistically significant (columns (vii) to (ix)).

One explanation for the differences in the implications of adding sub-diagnoses and *covariate*post-choice policy* interactions for hip fracture compared with AMI and stroke is that that the three hip fracture sub-diagnoses have very similar mortality rates (3.5%, 3.6% and 3.5%) whereas the mortality rates for the sub-diagnoses within AMI and within stroke vary considerably, from 3.2% to 9.8% for AMI and from 9.5% to 31.4% for stroke (Appendix Table A1).

In all three hip fracture specifications the estimated change in the effect of the number of rivals ($\hat{\gamma}$) is negative and statistically significant at the 5% level. For AMI $\hat{\gamma}$ is statistically significant only at 10% for the models which constrain the effects of the covariates to be the same before and after the choice reform (columns (i) and (iv)). Allowing these effects to vary over time (column (vii)) reduces $\hat{\gamma}$ by two orders of magnitude and its t-statistic to 0.47. Estimates of $\hat{\gamma}$ for stroke are not statistically significant even at 10% in any model and its sign changes across the specifications.

The results suggest that the choice reform of 2006 reduced mortality for hip fracture, but not for AMI and stroke. At the mean pre-reform equivalent number of rivals ($\bar{M}_0$) the implied reduction in mortality risk ($100\hat{\gamma}\bar{M}_0$) for hip fracture patients is –0.62% (95% CI: –1.22%, – 0.01%), compared with the 2002/3-2010/11 mean mortality of 3.5% For AMI and stroke patients, the implied mortality reductions are –0.18% (95% CI: –0.91%, 0.56%) and –0.16% (95% CI: –1.12%, 0.79%) compared with mean mortality of 6.99% and 16.55%.

5.3 Choice reform 2008 extension

From April 2008 patients could choose any qualified provider. This could have further increased the responsiveness of hospital demand to quality compared to the 2006 reform, leading to a bigger effect of competition from 2008 onwards. **Table 4** has results from a model interacting average market structure for the pre 2006 period with indicators for the two years after the initial reform (2006/7 and 2007/8) and for the period from 2008/9. The pattern of results is similar to those for the 2006 reform in Table 3. For hip fracture the effect of the initial reform is negative and a little smaller than in the baseline model in Table 3 though not statistically significant. The effect of the 2008 reform is larger for hip fracture and the implied reduction in mortality risk ($100\hat{\gamma}\bar{M}_0$) is –0.71% (95% CI: –1.376%, –0.046%). However, the increase in the effect after 2008 is not statistically significant. For AMI and stroke, the introduction and extension of choice reform had small and statistically insignificant effects.

5.4 Robustness analyses

Table 5 examine the robustness of the baseline models (Table 3, columns (vii) to (ix)) to specifications of the casemix controls. In panel *a*, we increase the sample to include all patients aged 35 and over, rather than those aged 35 to 74. Results are not sensitive to this extension.

Patients who had an emergency admission in the previous year may be sicker than other patients. Alternatively, a patient who has survived one emergency hospitalization may be inherently resilient to severe health shocks. If rates of emergency admissions varied across hospitals and were correlated with local competition then survivorship bias could affect estimates of the effect of competition. *Panel b* excludes patients with any emergency admission in the previous year and *panel c* keeps them but adds the number of emergency admissions for any cause in the previous year as a proxy for severity. Results are substantially unchanged compared to the baseline models.

Panel *a* of **Table 6** reports results from a conditional fixed effects logistic model. The marginal effects are very similar to those from the baseline linear probability specification.

In-hospital deaths were around 88.6%, 84.6% and 97.1% of total deaths within 30 days for AMI, hip fracture and stroke patients between 35 and 74 years. Since the probability of in-hospital mortality depends on how long the patient is in hospital, as well as on clinical quality (Borzecki *et al.*, 2010), we prefer, like Gaynor *et al.* (2013) but unlike Cooper *et al*. (2012), to measure 30 day mortality in any location. Results (panel *b*) using mortality for patients dying in hospital are very similar to those in Table 3.

Next, we vary the way in which we measure competition. Using the actual number of rivals within 30km yields the same qualitative results in panel *c* as our preferred measure based on the predicted equivalent number of rivals. Allowing for the much larger magnitude of the simple count of rivals (Table 2) the implied changes in mortality ($\hat{\gamma}\bar{M}_{h0}$) are similar for the two competition measures.

Panel *d* distinguishes between competition from NHS providers and private providers. Results with the number of NHS rivals are similar in magnitude and statistical significance to those in panel *d* with the number of rivals of all types. The magnitude of the coefficient on private rivals is much larger than that on NHS rivals but this reflects the smaller number of private rivals. The implied reductions in hip fracture mortality risk due to choice reform ($100\gamma\bar{M}_0$) of −0.35% (95% CI: −0.59%, −0.10%) with NHS rivals and −0.26% (95% CI: −0.47%, −0.06%) with private rivals are not statistically different.

In panel *e* the competition measure is time varying M_{ht} rather than time invariant $\bar{M}_{h0}$. The coefficients on $P_t * M_{ht}$ are very similar to those in Table 3 for $P_t * \bar{M}_{h0}$, supporting our arguments in section 4 that endogeneity of competition is not a problem. For all three conditions the pre-reform effect of market structure (δ) was to increase mortality (though not statistically significantly) and the relaxation of the constraints on choice reduced this deleterious effect of having more rivals, though the reduction was only significant for hip fracture. More rivals post-reform were still associated with higher mortality for all conditions, though none of these associations were statistically significant.

Panels *f* and *g* uses terciles of competition measures rather than the continuous measures of competition from NHS rivals, along with the number of private rivals. Results are qualitatively similar to those in the baseline models and to those in panel *d*.

5.5 Heterogeneity within conditions

We included indicators for sub-diagnoses in our baseline models since there are marked differences in mortality rates for sub-diagnoses within AMI and stroke (see Appendix Table A1). Given these differences in mortality rates across sub-diagnoses within two of the conditions, we replaced the $P_t * \bar{M}_{h0}$ interactions in the baseline models (1) with *sub-diagnosis*$*P_t*\bar{M}_{h0}$ interactions to test if the effect of the choice reform differed across sub-diagnoses within conditions. Results for AMI (Appendix Table B4) show that there were statistically significant reductions in mortality only for two sub-diagnoses covering 3% of AMI patients. The implied reductions are large for these two sub-diagnoses: −2.6% and −3.3% compared to their mean mortalities of 6.49% and 4.93%. For stroke there was a statistically significant mortality reduction only for the 21% of stroke patients with an unspecified stroke. For hip fracture the effects of choice reform were negative for all sub-diagnoses and similar in size.

5.6 Heterogeneity with respect to deprivation

The baseline model suggested that there was income related inequity in hip fracture mortality with patients living in small areas with greater income deprivation having higher mortality, though there was no association for AMI or stroke (Appendix Table B3). We estimated models with dummies for the first four quintiles of the distribution of the deprivation measure, with the first quintile being the most deprived, including interactions of these dummies with the P_t dummy and with $P_t *(\bar{M}_{h0} - \bar{M}_0)$. We find that hip fracture patients in hospitals in more competitive areas had greater reductions in mortality post choice and this reduction was greater for patients in more deprived areas (Appendix Table B5). Thus the combination of the choice reform and more competition produced the greatest benefit for the most deprived hip fracture patients.

5.7 Comparison with other papers

Two other papers use the 2006 choice reform in a difference in differences approach to examine the effect of competition on AMI mortality. Cooper *et al.* (2011) use time varying competition, quarterly data from 2002 to 2008 on individual patients aged 35 to 100, and deaths in hospital within 30 days. Gaynor *et al.* (2013) use two years of Hospital Trust level data to examine whether 30 day mortality in or outside hospital for patients aged 35 to 74 in

2007 was smaller for Trusts facing more competition in 2003. Both papers find a statistically significant greater reduction in AMI mortality post choice for providers facing more competition.

We also find a reduction in *overall* AMI mortality but the effect is small and not statistically significant, though the negative effect on mortality is statistically significant for a subset of AMI diagnoses (Table 7) covering 3% of AMI patients. Our sensitivity tests suggest that the difference in results for overall AMI is not due to the age range of AMI patients, whether deaths were in hospital or in any location, or whether time-invariant or time-varying competition is used. The difference seems to be due (Table 3, see also Appendix Table C1) to the combination of a richer set of covariates (indicators for sub-diagnoses) and to allowing the effects of covariates to differ before and after the change in choice policy in 2006. By using time varying coefficients on covariates, we control for possible changes in the effects of patients' baseline characteristics and for changes in clinical coding practice related to patient casemix which might have been influenced by the roll out of the prospective payment system.

6 Conclusions

Increases in the responsiveness of demand to quality after the relaxation of constraints on patient choice would plausibly have bigger effects on hospital incentives to improve quality in areas where hospitals faced more competition. We indeed find that after the 2006 choice reform, there was a larger reduction in hip fracture mortality in hospitals which had faced more competition before the reform. The mean reduction in mortality was –0.62% (95% CI: –1.22%, –0.01%) compared to the mean risk of 3.5%. The change in the effect of market structure after 2006 had no effect on overall mortality for AMI patients, though it did reduce mortality for a subset of diagnoses covering 3% of AMI patients. For stroke patients the choice reforms had no overall effect though mortality was reduced for the 21% of stroke patients with the unspecified stroke sub-diagnosis. Our findings are robust to alternative measures of market structure, to using time-varying measures of competition instead of time-invariant pre-reform measures, to estimation methods, and to casemix adjustments for age and previous emergency admissions.

The initial choice reform of 2006 gave patients the right to a choice of at least four hospitals and the further relaxation of constraints on choice in 2008 let patients choose any qualified public or private hospital. Both choice reforms led to reductions in mortality for hip fracture patients, with a larger reduction after the 2008 reform.

Theory models suggest possible explanations for the difference in results across type of condition since they show that having more rivals and relaxing restrictions on patient choice could increase or reduce quality, depending on the properties of the demand and production functions, the objectives of the hospital, and the level of the regulated price (Brekke et al. 2011). Quality improved for emergency hip fracture patients in more competitive areas. The main treatment for hip fracture patients is a hip replacement carried out in orthopaedic departments and other studies (Moscelli et al. 2016a; Skellern, 2017) have found that competition did not increase and may even have reduced quality for elective hip replacement patients. A possible explanation for these contrasting results for elective and emergency hip patients is the existence of diseconomies of scope (Freeman et al, 2016; Skellern, 2017) at hospital level.

The fact that the effect of the choice reforms differed across conditions, and across sub-diagnoses within conditions, suggests that policies to increase competition and give patients greater choice are likely to have heterogeneous effects depending on details of patient case mix and market conditions.

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Table 1. Descriptive statistics (patients 35 to 74, 2002/3-2010/11)

	AMI sample				Hip Fracture sample				Stroke sample			
	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max
Providers												
N NHS sites[1]	178	9.18	165	194	169	4.92	164	179	182	9.13	171	198
N rival sites - 30 km	12.15	15.04	0	76	13.63	16.80	0	76	14.40	17.51	0	76
N rival Trusts - 30 km	5.61	6.78	0	28	6.16	7.41	0	28	6.55	7.72	0	28
1/predicted HHI 30km	2.69	1.35	1.09	8.76	2.81	1.45	1.09	9.47	2.87	1.47	1.09	8.83
N rival NHS sites - 30 km	11.34	14.45	0	66	12.62	16.08	0	66	13.43	16.81	0	66
N rival private sites - 30 km	0.81	1.58	0	12	1.01	1.79	0	12	0.97	1.79	0	12
Patients												
N patients per year	32032	4814	24921	39560	10112	601	9552	11042	23789	1533	21797	26465
Overall 30-day mortality	0.0699	0.2549	0	1	0.0350	0.1839	0	1	0.1655	0.3717	0	1
Patient age	61.18	9.38	35	74	64.84	8.74	35	74	62.74	9.52	35	74
Female Patient	0.26	0.44	0	1	0.63	0.48	0	1	0.42	0.49	0	1
N diagnoses	4.66	2.67	1	20	5.01	2.72	1	20	4.82	2.82	1	20
Charlson index	0.69	1.10	0	14	0.75	1.26	0	13	0.81	1.28	0	13
Distance to provider	12.86	30.65	0	607	13.54	32.36	0	572	12.06	27.32	0	610
IMD income deprivation	0.16	0.12	0	0.96	0.16	0.12	0	0.96	0.17	0.13	0	0.96
IMD environment deprivation	21.39	16.59	0.08	94	22.02	16.72	0.08	94	22.67	16.98	0.13	94
Incapacity claims	0.0387	0.0252	0	0.2519	0.0388	0.0263	0	0.2519	0.0391	0.0255	0	0.2519
Disability claims	0.0579	0.0305	0	0.2491	0.0571	0.0313	0	0.2491	0.0574	0.0305	0	0.2491

Notes. [1] Sites of NHS Hospital Trusts with at least 100 patients of all ages with these conditions.

Table 2. Correlation of risk adjusted mortality across hospital sites

	2002/3-2005/6	2006/7-2010/11	2002/3-2010/11
AMI & hip fracture	0.066*	0.142***	0.205***
AMI & stroke	0.090**	0.143***	0.223***
Hip fracture & stroke	0.010	0.166***	0.170***

Notes. Correlations for sites over all site by year observations where the site had at least 100 cases for both conditions. Adjusted mortality: ratio of actual to expected mortality predicted from year specific individual level logit models with age, gender, Charlson Index, number of diagnosis, day of week, admission month.
*** p<0.01, ** p<0.05, * p<0.10.

Table 3. Impact of 2006 choice reform on 30 day mortality

	No sub-diagnoses covariates			With sub-diagnoses covariates			Effects of sub-diagnoses vary pre and post 2006 choice reform		
	AMI	Hip fracture	Stroke	AMI	Hip fracture	Stroke	AMI	Hip fracture	Stroke
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)
P_t*Pre-2006 rivals (γ)	-0.0022*	-0.0026**	0.0012	-0.0026*	-0.0026**	0.0017	-0.0007	-0.0024**	-0.0006
	(-1.734)	(-2.333)	(0.650)	(-1.833)	(-2.326)	(0.986)	(-0.472)	(-1.991)	(-0.334)
R^2	0.0447	0.0520	0.0251	0.0518	0.0520	0.0889	0.0551	0.0532	0.0912
AIC	16993	-54735	178406	14848	-54733	163921	13948	-54777	163473
BIC	17447	-54330	178848	15397	-54309	164404	14953	-54014	164346
F-test: all sub-diagnoses coefs = 0				81.87	1.04	951.69	51.30	0.85	530.73
p value				0.000	0.357	0.000	0.000	0.497	0.000
F test: all P_t*covariates coefs = 0							125.9	38.49	116.53
p-value							0.000	0.000	0.000
Patients	288279	91005	214103	288279	91005	214103	288279	91005	214103
Sites	238	213	236	238	213	236	238	213	236
Sub-diagnoses in covariates?	N	N	N	Y	Y	Y	Y	Y	Y
P_t*Covariates?	N	N	N	N	N	N	Y	Y	Y

Notes. P_t: dummy for 2006/7-2010/11. Columns (vii) to (ix): specification in text equation (1). t statistics in parentheses. * p<0.1, ** p<0.05.

Table 4. Impact of introduction and extension of choice reform

	AMI	Hip Fracture	Stroke
2006 reform introduction*Pre 2006 Rivals (γ_1)	-0.0008	-0.0018	-0.0011
	(-0.472)	(-1.297)	(-0.576)
2008 reform extension*Pre 2006 Rivals (γ_2)	-0.0006	-0.0027**	-0.0003
	(-0.389)	(-2.107)	(-0.120)
R^2	0.0551	0.0532	0.0912
AIC	13950	-54775	163474
BIC	14965	-54003	164358
F-test H0: $\gamma_1=\gamma_2$	0.01	0.59	0.25
F-test p-value	0.91	0.44	0.62

Notes. 2006 reform introduction: indicator for 2006/7 and 2007/8. 2008 reform extension: indicator for 2008/9 onwards. t statistics in parentheses. Otherwise specification is text equation (1). ** p<0.05

Table 5. Impact of 2006 choice reform: robustness to case-mix

	AMI	Hip-fracture	Stroke
a. Patients aged 35 years and over			
P_t*Pre-2006 rivals (γ)	-0.0006	-0.0025**	0.0020
	(-0.311)	(-2.018)	(0.880)
R^2	0.0962	0.0734	0.1172
Patients	531210	459672	550201
b Excluding patients with any emergency admission in previous year			
P_t*Pre-2006 rivals	0.0000	-0.0029***	0.0004
	(0.001)	(-2.602)	(0.221)
R^2	0.0487	0.0481	0.0971
Patients	251649	77462	178180
c. Including number of emergency admissions in previous year			
P_t*Pre-2006 rivals (γ)	-0.0007	-0.0023*	-0.0008
	(-0.489)	(-1.934)	(-0.451)
N emerg adm prev year	0.0136***	0.0183***	0.0297***
	(8.287)	(7.188)	(12.713)
R^2	0.0560	0.0561	0.0937
Patients	288247	90998	214035
Sites	238	213	236

Notes. P_t: dummy for 2006/7-2010/11. Specification: text equation (1) plus addition of number of emergency admissions in panel *c*. *t* statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 6. Impact of 2006 choice reform: further robustness checks

	AMI	Hip-fracture	Stroke
a. Logistic regression			
P_t*Pre-2006 rivals (AME)	-0.000438	-0.00232**	-0.000990
	(-0.31)	(-1.98)	(-0.54)
Pseudo R^2	0.1026	0.1509	0.0995
b. 30 day in-hospital mortality			
P_t *Pre-2006 rivals (γ)	-0.0013	-0.0023**	0.0001
	(-0.925)	(-2.051)	(0.036)
R^2	0.0525	0.0515	0.0921
AIC	-16232	-68409	158972
BIC	-15227	-67646	159845
c. Market structure: number of rivals			
P_t*Pre-2006 Rivals (γ)	-0.0001	-0.0003**	-0.0002
	(-0.764)	(-2.564)	(-1.322)
R^2	0.0551	0.0533	0.0912
AIC	13947.2	-54779.7	163470.1
BIC	14951.6	-54016.7	164343.4
d. Market structure: number of NHS and private rivals			
P_t*pre 2006 NHS rivals	-0.0001	-0.0003***	-0.0002
	(-0.712)	(-2.791)	(-1.109)
P_t*pre 2006 private rivals	0.0027	-0.0227**	0.0203*
	(0.223)	(-2.548)	(1.713)
R^2	0.0551	0.0533	0.0912
AIC	13949	-54784	163469
BIC	14964	-54012	164352
e. Time-varying market structure			
Rivals pre reform (δ)	0.0012	0.0047*	0.0051
	(0.462)	(1.946)	(1.379)
P_t*Rivals (γ)	-0.0007	-0.0024**	-0.0013
	(-0.500)	(-2.060)	(-0.724)
Rivals post reform (δ + γ)	0.0005	0.0023	0.0038
	(0.250)	(1.226)	(1.241)
R^2	0.0551	0.0532	0.0912
AIC	13950	-54776	163471
BIC	14965	-54004	164355
f. Discretized time-invariant market structure (1/predicted HHI) in terciles			
2nd tercile of Pre-2006 Rivals	-0.0016	0.0015	0.0019
	(-0.398)	(0.374)	(0.369)
3rd tercile of Pre-2006 Rivals	-0.0006	-0.0069*	0.0018
	(-0.156)	(-1.665)	(0.335)
1 or more private hospitals pre-2006	-0.0046	-0.0382***	0.0390***
	(-0.294)	(-8.993)	(4.053)
R^2	0.0551	0.0534	0.0912
AIC	13952	-54785	163469
BIC	14977	-54004	164363
g. Discretized time-invariant market structure (Number of rivals) in terciles			
2nd tercile of Pre-2006 Rivals	0.0003	-0.0039	0.0080
	(0.073)	(-1.038)	(1.462)
3rd tercile of Pre-2006 Rivals	-0.0047	-0.0108***	-0.0002
	(-1.276)	(-2.731)	(-0.042)
1 or more private hospitals pre-2006	-0.0068	-0.0405***	0.0425***
	(-0.431)	(-9.508)	(4.410)
R^2	0.0551	0.0534	0.0912
AIC	13947	-54789	163464
BIC	14973	-54008	164358
Patients	288286	91005	214103
Sites	238	213	236

Notes. Specification: equation (1) except for changes indicated in panels. Market structure: number of sites within 30km in panels *c* and *d*, equivalent number of rivals in other panels. Panel *a* reports average marginal effects. *t*-statistics in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Figure 1. Trend in 30 day mortality rates, patients aged 35-74 years

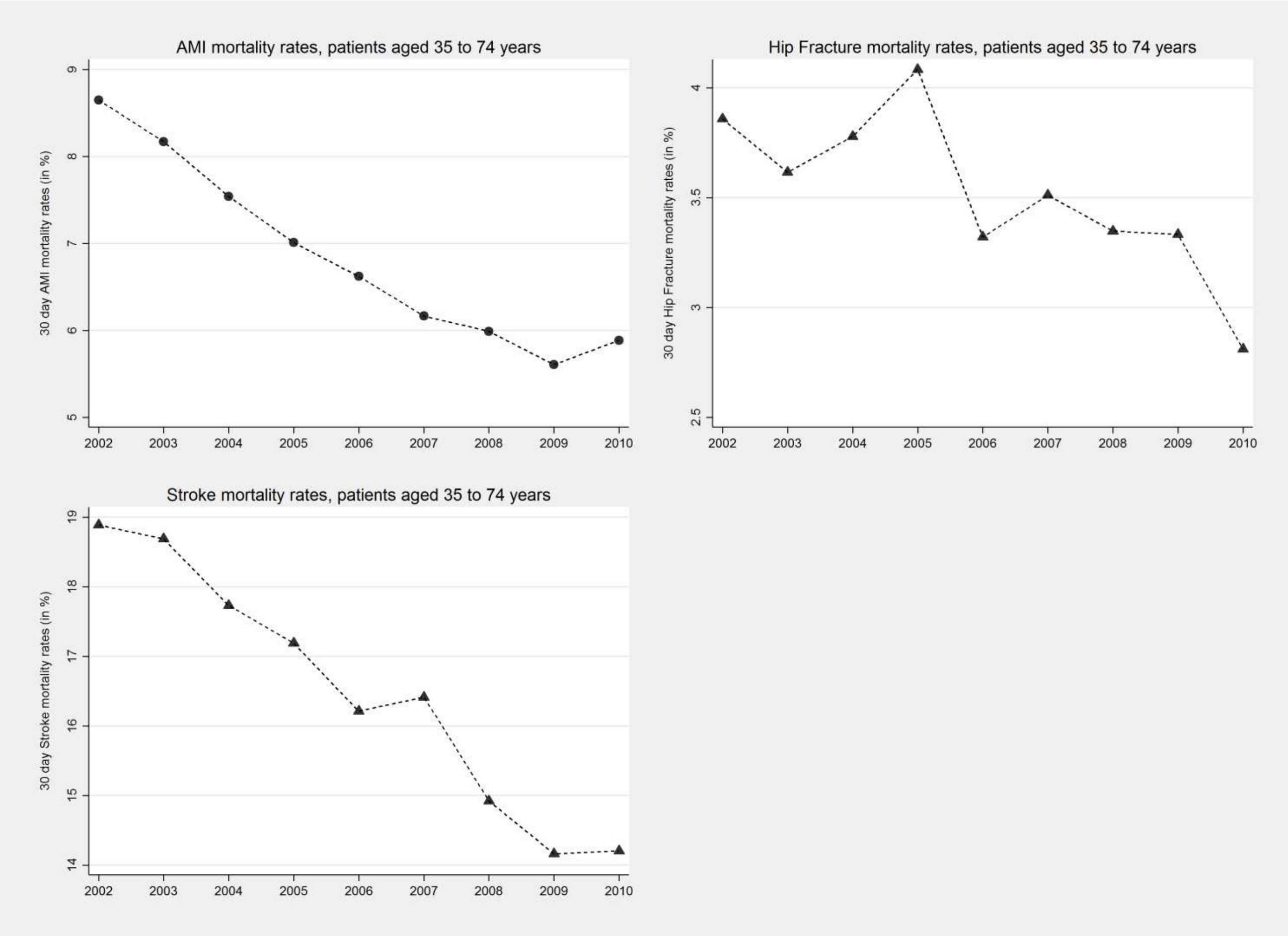
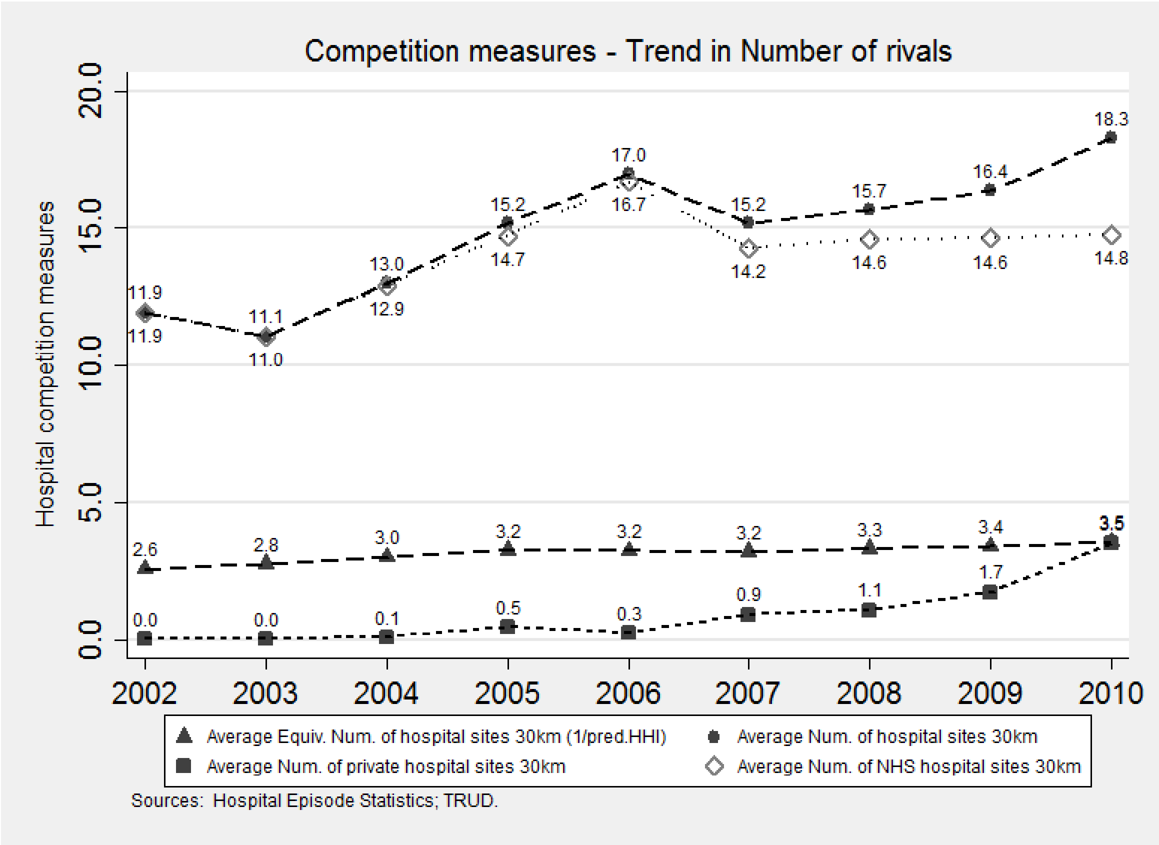


Figure 2. Competition measures: trend 2002-2010



Supplementary material

Appendix A: Data
Appendix B: Additional Tables and Figures
Appendix C. Replication of Gaynor *et al.* (2013)

Appendix A. Data

Patient sample.

Our sample is patients with an emergency admission for AMI, hip fracture and stroke at a NHS hospital site with at least 100 admissions per year for the condition. To reduce mis-coding we exclude patients with a length of stay of 2 days or less who were discharged alive. We assign patients transferred to another hospital site during their spell to the first site of their in-hospital spell, since patients are usually treated and stabilised in the Emergency Department of the first provider.

We include indicators for sub-diagnoses in the models for each condition. Table A1 summarises the ICD10 codes for the sub-diagnoses for the three conditions. Following the advice in Alexandrescu *et al*. (2013) we do not aggregate the 10 AMI sub-diagnoses into STEMI and NSTEMI.

Table A1. Definitions of conditions

Code	Definition	% of patients	30 day mortality %
AMI			
I210	Acute transmural MI of anterior wall	16.13	6.69
I211	Acute transmural MI of inferior wall	21.8	4.63
I212	Acute transmural MI of other sites	2.26	6.49
I213	Acute transmural MI of unspecified site	0.79	4.93
I214	Acute subendocardial MI: MI with non-ST elevation, Nontransmural MI NOS	11.41	3.15
I219	AMI, unspecified: MI (acute) NOS	33.44	9.30
I220	Subsequent MI of anterior wall	1.64	8.88
I221	Subsequent MI of inferior wall	2.36	6.73
I228	Subsequent MI of other sites	1.68	6.41
I229	Subsequent MI of unspecified sites	8.49	9.84
Hip fracture			
S720	Unspecified	74.63	3.47
S721	Petrochanteric	20.95	3.64
S722	Subtrochanteric	4.42	3.45
Stroke			
I60, I61, I62	Haemorrhagic	26.69	31.43
I63	Ischemic	50.89	9.46
I164	Unspecified	20.96	15.61
I166	Occlusion	0.31	7.94
G46, I672, I698, R470	Other	1.15	4.47

Note. statistics are for the main estimation sample (patients aged 35-74). MI: myocardial infarction. NOS: not otherwise specified.

Table A2. Correlations of sub-diagnosis mortality rates

(i) AMI, years 2002-2006

	I210	I211	I212	I213	I214	I219	I220	I221	I228	I1229
I210	1									
I211	0.5330***	1								
I212	0.2990**	0.0986	1							
I213	0.0397	-0.0021	-0.0397	1						
I214	-0.0064	0.0765	-0.1750	-0.1100	1					
I219	0.256*	0.1230	-0.0209	-0.1780	0.0691	1				
I220	0.0301	0.1230	-0.0427	-0.0487	-0.1490	-0.0292	1			
I221	0.0674	0.1350	0.0553	0.0394	-0.0232	-0.2430*	-0.0849	1		
I228	0.1010	0.1040	0.0355	-0.0390	0.0635	0.2290	0.1220	0.2090	1	
I229	0.0086	-0.2220	-0.1600	0.0045	-0.2320	0.1670	0.0583	0.0801	0.281*	1

(ii) AMI, years 2006-2010

	I210	I211	I212	I213	I214	I219	I220	I221	I228	I1229
I210	1									
I211	0.4500***	1								
I212	0.1060	0.4770***	1							
I213	-0.1310	-0.2510	-0.1010	1						
I214	0.3170*	0.3260**	0.2970*	-0.0532	1					
I219	0.5430***	0.2690	-0.0393	0.1770	0.2120	1				
I220	-0.1260	0.4710***	0.0268	0.1560	0.1490	-0.0591	1			
I221	0.0180	0.4590***	0.2330	-0.118	0.346**	-0.0753	0.641***	1		
I228	0.0459	0.2330	-0.0319	-0.0136	0.202	-0.256	0.3240*	0.4980***	1	
I229	0.4770***	0.4450***	0.0358	-0.0678	0.385**	0.548***	0.156	0.1100	0.0834	1

(iii) Hip fracture, years 2002-2006

	S720	S721	S722
S720	1		
S721	0.0364	1	
S722	0.1420	0.2810*	1

(iv) Hip fracture, years 2006-2010

	S720	S721	S722
S720	1		
S721	0.1410	1	
S722	0.2510	-0.0192	1

(v) Stroke, years 2002-2006

	I60,I61, I62	I63	I164	I166	G46, I672, I698, R470
I60, I61, I62	1				
I63	0.0638	1			
I164	0.0976	0.5130***	1		
I166	-0.1960	-0.2190	-0.1600	1	
G46, I672, I698, R470	-0.1900	0.1600	-0.0469	-0.0868	1

(vi) Stroke, years 2006-2010

	I60,I61, I62	I63	I164	I166	G46, I672, I698, R470
I60, I61, I62	1				
I63	0.1670	1			
I164	0.4560***	0.4470***	1		
I166	0.2530	0.4210***	0.3370**	1	
G46, I672, I698, R470	-0.0381	0.0517	-0.2100	-0.0325	1

Note. Correlations of site by year mortality rates.

Market structure: predicted equivalent number of sites

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 elective admissions at the providers they use. It is a measure of the amount of choice they have amongst elective 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:

$$HHI_h = \sum_j s_{hj} \times HHI_j = \sum_j s_{hj} \times \left[\sum_h \left(s_{jh} \right)^2 \right] \qquad \text{(A1)}$$

where $j=1,\ldots,J$ 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 on utilisation we compute *predicted HHIs* derived from models of patient choice of provider (NHS and private sites) for elective care in which choice is not allowed to depend on quality (Kessler and McClellan, 2000). We estimate Poisson choice models with the number of elective patients from LSOA j choosing provider h in year t having conditional mean

$$\mathrm{E}\left(n_{jht} \mid \xi_j, d_{jh}, X_{ht}\right) = \exp\left\{\xi_{jt} + \lambda_{1t} d_{jh} + \lambda_{2t} d_{jh}^2 + X_{ht}\lambda_t + d_{jh} X_{ht} \lambda_{1t}^X + d_{jh}^2 X_{ht} \lambda_{2t}^X\right\} \qquad \text{(A2)}$$

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 (NHS or private, belonging to a Foundation Trust, belonging to a teaching Trust, located in London). 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 elective admissions as those "where the decision to admit could be separated in time from the actual admission". We exclude elective 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. The estimates of the Poisson choice models are in Appendix Table B1. Models interacting patient characteristics with hospital site characteristics yielded very similar predicted patient flows.

The predicted $\hat{n}_{jht}$ from eq (A2) 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. (A2), 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.

The inverse predicted HHI is conceptually to be a better measure of market structure than the count of rivals which assumes that having an additional rival 1km away will have the same effect as having a rival 30km away. Nor does it take account of whether the additional rival is large or small. The inverse predicted HHI is based on patient flows predicted from a model of patient choice of provider in which providers further away from patients attract fewer patients. It thus takes account of the size and location of possible rivals.

Market structure: number of rivals
We count for each year and for each hospital site providing care for AMI, hip fracture, or stroke patients, the number of rival organisations (NHS Trusts or chains of private providers) with at least one site within 30km which has at least 100 HES elective patients in that year. We also constructed counts of rivals within 20, 40 and 50 km. Around 75% of elective patients use a provider within 30km. Competition measures using different distances and methods are highly correlated (see Appendix Table B2).

Appendix References

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Appendix B. Additional results

Figure B1. Numbers of elective care providers by year and ownership

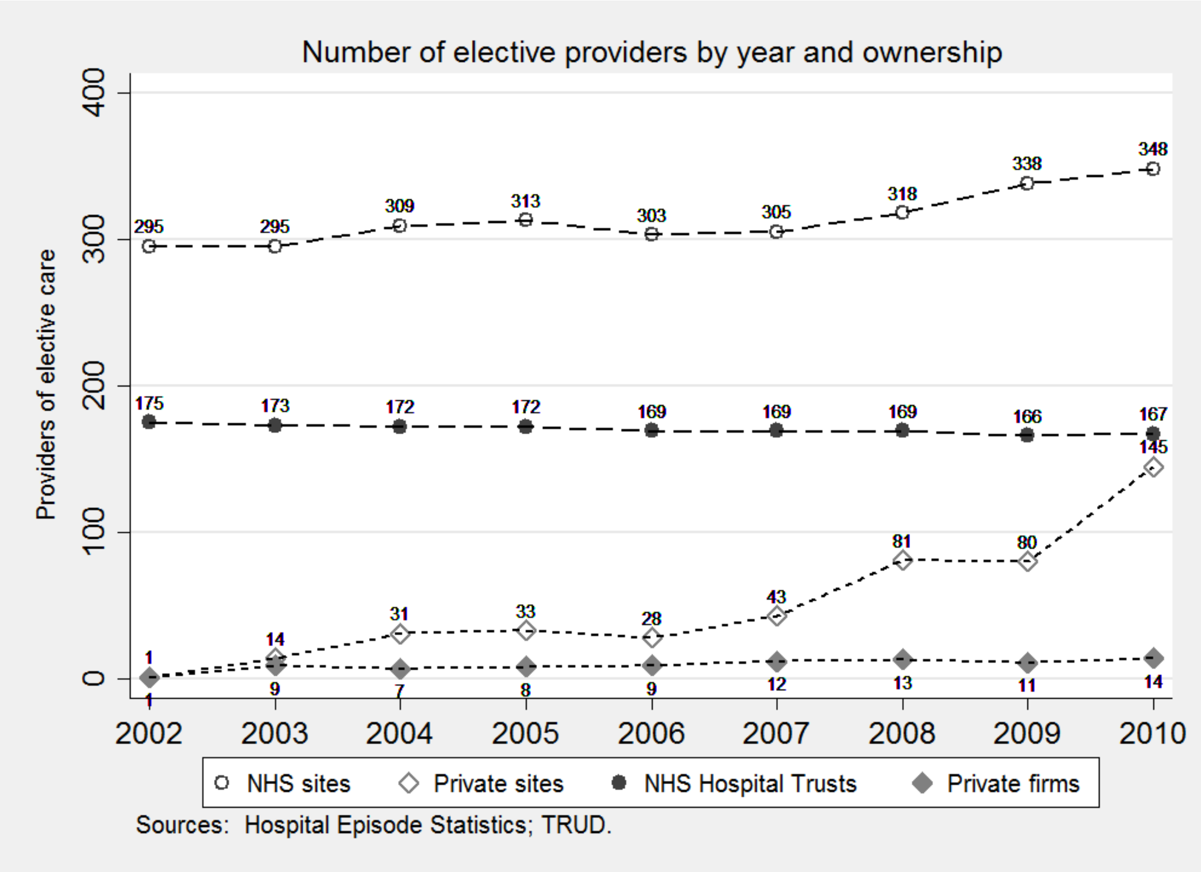

Table B1. Poisson models of patient choice of elective provider

	2002	2003	2004	2005	2006	2007	2008	2009	2010
	coef	coef	coef	coef	coef	coef	coef	coef	coef
Distance	-0.2218***	-0.2221***	-0.2213***	-0.2187***	-0.1986***	-0.1988***	-0.1656***	-0.1686***	-0.1642***
Distance^2	0.0026***	0.0028***	0.0029***	0.0029***	0.0021***	0.0021***	0.0012***	0.0013***	0.0012***
Private Hospital	-4.3093***	-4.9789***	-4.3093***	-3.6677***	-3.1165***	-3.0299***	-2.5119***	-2.1926***	-2.0811***
Teaching Trust	0.2960***	0.1450***	-0.0055	-0.0971***	-0.1062***	-0.0641***	0.1288***	0.0069	-0.0743***
Specialist Hospital	-1.8382***	-1.9368***	-1.9708***	-1.9506***	-2.1845***	-2.2383***	-2.0953***	-2.1830***	-2.2349***
Multiservice Hospital	0.2706***	0.2596***	0.2979***	0.0198*	0.2331***	0.1581***	0.1302***	-0.0876***	-0.1708***
Site in London	0.3378***	0.3198***	0.2631***	0.1836***	0.2848***	0.3952***	0.5465***	0.6193***	0.6997***
Private Hospital * Distance	0.2036***	0.3126***	0.1261***	0.0415***	0.0776***	0.0694***	0.0331***	0.0400***	0.0278***
Teaching Trust * Distance	-0.0658***	-0.0610***	-0.0266***	-0.0141***	-0.0118***	-0.0264***	-0.0315***	-0.0225***	-0.0189***
Specialist Hospital * Distance	0.0799***	0.0944***	0.1050***	0.0928***	0.1139***	0.1040***	0.1010***	0.1017***	0.1057***
Multiservice Hospital * Distance	-0.0815***	-0.0717***	-0.0592***	-0.0296***	-0.0779***	-0.0724***	-0.0901***	-0.0667***	-0.0709***
Site in London * Distance	-0.1156***	-0.1110***	-0.1264***	-0.1350***	-0.1456***	-0.1494***	-0.1939***	-0.1972***	-0.1990***
Private Hospital * Distance^2	-0.0059	-0.0079***	-0.0015***	0.0004**	-0.0003**	-0.0001	0.0004***	-0.0002***	-0.0001
Teaching Trust * Distance^2	0.0025***	0.0024***	0.0016***	0.0014***	0.0013***	0.0018***	0.0011***	0.0011***	0.0012***
Specialist Hospital * Distance^2	-0.0008***	-0.0013***	-0.0016***	-0.0010***	-0.0015***	-0.0013***	-0.0015***	-0.0014***	-0.0014***
Multiservice Hospital * Distance^2	0.0032***	0.0022***	0.0031***	0.0025***	0.0039***	0.0035***	0.0039***	0.0032***	0.0035***
Site in London * Distance^2	0.0036***	0.0034***	0.0039***	0.0041***	0.0046***	0.0046***	0.0061***	0.0061***	0.0059***
Foundation Trust			-0.1177***	0.1303***	0.5184***	0.2881***	0.4379***	0.3984***	0.4569***
Foundation Trust * Distance			0.0145***	-0.0192***	-0.0696***	-0.0395***	-0.0785***	-0.0606***	-0.0562***
Foundation Trust * Distance^2			-0.0005***	0.0001**	0.0019***	0.0011***	0.0025***	0.0019***	0.0017***
Patients Group LSOAs	175946	184324	187504	197304	201694	213538	237493	243430	267771
LSOAs	29974	29436	29614	29740	29884	30669	30915	31108	31552
Chi^2 model	2187257	2202837	2065478	2196952	2380851	2759517	3177565	3240990	3558575
Efron R^2	0.249	0.2485	0.2493	0.2629	0.2592	0.2661	0.2411	0.2447	0.2426

Notes. Specification (A2). All booked or waiting list patients treated in hospitals with at least 100 admissions per year and within 30km from LSOA of residence. Efron R^2 is the squared correlation between actual and predicted numbers choosing each site. *p<0.10, ** p<0.05, *** p<0.01

Table B2. Correlation among competition measures (all years: 2002-2010)

	1/(actual HHI 30km)	1/(predicted HHI 30km)	1/(actual HHI 100km)	1/(predicted HHI 100km)	N rival sites 30km	N rival trusts 30km
1/(predicted HHI 30km)	0.7996					
1/(actual HHI 100km)	0.9092	0.6291				
1/(predicted HHI 100km)	0.816	0.9833	0.6547			
N rival trusts 30km	0.6944	0.7936	0.5513	0.8412		
N rival trusts 30km	0.6876	0.8109	0.5338	0.8522	0.9756	
Av N rival sites 30km	0.6704	0.7604	0.5364	0.8106	0.9506	0.9268

Notes. Predicted HHIs are computed from a Poisson choice model using patient-provider distances and hospital characteristics except quality. All correlations significant at 99% confidence level. Average number of rival sites computed as the yearly average of the number of sites belonging to a same trust.

Table B3. Full results for models in columns (iv) to (vi) of Table 3.

	(1)	(2)	(5)
	AMI	Hip Fracture	Stroke
Market structure measure:	Equivalent N rival sites 30km	Equivalent N rival sites 30km	Equivalent N rival sites 30km
2002	0.0143***	0.0041	0.0107***
	(5.410)	(1.427)	(2.722)
2003	0.0105***	-0.0000	0.0099**
	(4.391)	(-0.003)	(2.543)
2004	0.0048**	-0.0002	0.0028
	(2.260)	(-0.079)	(0.853)
2006	0.0013	-0.0027	-0.0117**
	(0.299)	(-0.618)	(-2.302)
2007	-0.0108**	-0.0031	-0.0074
	(-2.376)	(-0.712)	(-1.353)
2008	-0.0193***	-0.0063	-0.0167***
	(-4.140)	(-1.395)	(-3.130)
2009	-0.0268***	-0.0102**	-0.0171***
	(-5.920)	(-2.320)	(-3.132)
2010	-0.0291***	-0.0217***	-0.0057
	(-5.751)	(-5.060)	(-1.097)
PolBk * Mkt Structure	-0.0026*	-0.0026**	0.0017
	(-1.833)	(-2.326)	(0.986)
IMD income deprivation	0.0011	0.0347***	0.0173
	(0.125)	(2.748)	(1.418)
IMD living environment deprivation	0.0001*	-0.0001	0.0000
	(1.783)	(-1.521)	(0.583)
Incapacity claims %	0.0568	-0.0028	0.0695
	(0.857)	(-0.035)	(0.752)
Disability claims %	0.0893*	-0.0210	0.0840
	(1.786)	(-0.336)	(1.116)
Female	0.0096***	-0.0119***	0.0158***
	(7.923)	(-8.590)	(9.380)
Patient age	0.0036***	0.0013***	0.0042***
	(21.581)	(5.885)	(15.640)
Num of Diagnosis	0.0017***	0.0072***	-0.0147***
	(3.298)	(17.544)	(-20.454)
Weighted Charlson Index = 1	0.0271***	0.0148***	0.0294***
	(18.316)	(9.465)	(13.509)
Weighted Charlson Index >= 2	0.0947***	0.0710***	0.0859***
	(37.547)	(22.267)	(23.845)
Teaching hospital	0.0009	0.0036	0.0051
	(0.159)	(1.131)	(0.379)
Foundation Trust	0.0023	-0.0026	0.0014
	(0.840)	(-0.952)	(0.350)
Distance to hospital	-0.0000	-0.0001***	-0.0001***
	(-0.237)	(-5.074)	(-2.758)
age 45-54 years	-0.0283***	-0.0070**	-0.0122***
	(-14.872)	(-2.128)	(-3.045)
age 55-64 years	-0.0466***	-0.0163***	-0.0282***
	(-14.346)	(-3.309)	(-4.720)
age 65-74 years	-0.0425***	-0.0195***	-0.0257***

	(-8.879)	(-2.815)	(-3.105)
Admitted from home	-0.0144***	-0.0020	-0.0012
	(-3.330)	(-0.593)	(-0.122)
Admitted from temporary location	-0.0150**	-0.0057	0.0158
	(-2.051)	(-0.752)	(0.912)
admission on Sunday	0.0020	0.0026	0.0203***
	(1.010)	(1.130)	(7.204)
admission on Tuesday	-0.0031*	0.0009	0.0034
	(-1.954)	(0.414)	(1.266)
admission on Wednesday	-0.0018	-0.0007	0.0052**
	(-1.003)	(-0.300)	(2.038)
admission on Thursday	-0.0009	-0.0020	0.0017
	(-0.504)	(-0.924)	(0.667)
admission on Friday	-0.0006	-0.0003	-0.0018
	(-0.333)	(-0.120)	(-0.771)
admission on Saturday	-0.0015	-0.0021	0.0150***
	(-0.794)	(-1.022)	(4.875)
admission in February	-0.0022	0.0004	-0.0001
	(-0.989)	(0.138)	(-0.030)
admission in March	-0.0018	-0.0011	-0.0111***
	(-0.861)	(-0.398)	(-3.124)
admission in April	0.0039*	0.0013	-0.0016
	(1.754)	(0.438)	(-0.464)
admission in May	-0.0040*	0.0018	-0.0107***
	(-1.731)	(0.617)	(-2.903)
admission in June	-0.0001	0.0029	-0.0068*
	(-0.023)	(0.972)	(-1.940)
admission in July	0.0002	0.0011	-0.0091**
	(0.099)	(0.391)	(-2.529)
admission in August	-0.0013	0.0002	-0.0151***
	(-0.612)	(0.069)	(-3.988)
admission in September	-0.0034	0.0004	-0.0102***
	(-1.501)	(0.149)	(-2.753)
admission in October	-0.0016	-0.0008	-0.0038
	(-0.696)	(-0.276)	(-1.035)
admission in November	-0.0014	0.0011	0.0020
	(-0.620)	(0.378)	(0.493)
admission in December	0.0050**	0.0033	0.0114***
	(2.075)	(1.341)	(2.837)
I211	-0.0176***		
	(-12.569)		
I212	-0.0035		
	(-0.979)		
I213	-0.0245***		
	(-4.730)		
I214	-0.0508***		
	(-24.688)		
I219	0.0222***		
	(8.083)		
I220	0.0043		
	(0.979)		
I221	-0.0145***		

	(-4.334)		
I228	-0.0404***		
	(-9.369)		
I229	0.0026		
	(0.867)		
pertrochanteric hip fracture		-0.0016	
		(-1.097)	
subtrochanteric hip fracture		-0.0032	
		(-1.096)	
Ischemic Stroke			-0.0472***
			(-12.304)
Heamorrhagic Stroke			0.1831***
			(41.268)
Occlusion Stroke			-0.0382***
			(-3.253)
Other Stroke			-0.0944***
			(-18.163)
Constant	-0.1304***	-0.0679***	-0.0686***
	(-14.563)	(-6.447)	(-4.155)
R^2	0.0518	0.0520	0.0889
AIC	14847.7	-54733.0	163920.7
BIC	15397.4	-54309.1	164403.5
Patients	288279	91005	214103
Hospital sites	238	213	236

Baseline sub-diagnoses are I210, Unspecified Hip Fracture, Occlusive Stroke.

Table B4. Impact of 2006 choice reform at sub-diagnosis level

	AMI		Hip fracture		Stroke	
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Any MI diagnosis* $P_t * \bar{M}_{h0}$	-0.0007					
	(-0.47)					
Acute transmural MI anterior wall* $P_t * \bar{M}_{h0}$		-0.0005				
		(-0.21)				
Acute transmural MI inferior wall* $P_t * \bar{M}_{h0}$		0.0001				
		(0.03)				
Acute transmural MI other sites* $P_t * \bar{M}_{h0}$		-0.0104***				
		(-2.92)				
Acute transmural MI unspec site* $P_t * \bar{M}_{h0}$		-0.0133***				
		(-3.50)				
Acute subendocardial MI* $P_t * \bar{M}_{h0}$		-0.0039*				
		(-1.92)				
AMI, unspecified* $P_t * \bar{M}_{h0}$		-0.0006				
		(-0.32)				
Subsequent MI anterior wall* $P_t * \bar{M}_{h0}$		-0.0038				
		(-0.80)				
Subsequent MI inferior wall* $P_t * \bar{M}_{h0}$		0.0024				
		(0.62)				
Subsequent MI other sites* $P_t * \bar{M}_{h0}$		0.0037				
		(0.71)				
Subsequent MI unspecified sites* $P_t * \bar{M}_{h0}$		0.0021				
		(0.90)				
Any hip fracture diagnosis* $P_t * \bar{M}_{h0}$			-0.0024**			
			(-1.991)			
Unspecified* $P_t * \bar{M}_{h0}$				-0.0023*		
				(-1.850)		
Petrochanteric* $P_t * \bar{M}_{h0}$				-0.0022		
				(-1.435)		
Subtrochanteric* $P_t * \bar{M}_{h0}$				-0.0041		
				(-1.505)		
Any stroke diagnosis* $P_t * \bar{M}_{h0}$					-0.0006	
					(-0.334)	
Ischaemic* $P_t * \bar{M}_{h0}$						-0.0007
						(-0.342)
Haemorrhagic* $P_t * \bar{M}_{h0}$						0.0025
						(0.796)
Occlusion* $P_t * \bar{M}_{h0}$						0.0178*
						(1.785)
Unspecified* $P_t * \bar{M}_{h0}$						-0.0060**
						(-2.339)
Other* $P_t * \bar{M}_{h0}$						0.0050
						(1.094)
F test: all *sub-diagnoses** $P_t * \bar{M}_{h0} = 0$		3.35		1.43		3.12
p value		0.0004		0.2363		0.0095
R^2	0.0551	0.0551	0.0532	0.0532	0.0912	0.0912
AIC	13948	13948	-54777	-54773	163473	163466
BIC	14953	15048	-54014	-53991	164346	164380
Patients	288279	288279	91005	91005	214103	214103
Sites	238	238	213	213	236	236

Notes. Specification is text equation (1) with the replacement of $P_t * \bar{M}_{h0}$ with *sub-diagnostic** *Pt* * $\bar{M}_{h0}$ in columns (ii), (iv), (vi). t statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table B5. Impact of choice reform by income deprivation quintile

	AMI	Hip fracture	Stroke
$P_t * \bar{M}_{h0}$	-0.0000	0.0002	0.0004
	(-0.023)	(0.111)	(0.126)
1st quintile deprivation* $P_t *(\bar{M}_{h0} - \bar{M}_0)$	-0.0002	-0.0045**	-0.0005
	(-0.084)	(-2.241)	(-0.186)
2nd quintile deprivation* $P_t *(\bar{M}_{h0} - \bar{M}_0)$	0.0001	-0.0017	-0.0012
	(0.065)	(-0.840)	(-0.464)
3rd quintile deprivation* $P_t *(\bar{M}_{h0} - \bar{M}_0)$	-0.0019	-0.0030	-0.0022
	(-1.038)	(-1.563)	(-0.843)
4th quintile deprivation* $P_t *(\bar{M}_{h0} - \bar{M}_0)$	-0.0020	-0.0012	-0.0020
	(-1.016)	(-0.720)	(-0.718)
1st quintile deprivation	0.0005	0.0112**	0.0063
	(0.125)	(1.996)	(1.010)
2nd quintile deprivation	0.0007	0.0088**	0.0063
	(0.238)	(2.067)	(1.215)
3rd quintile deprivation	0.0032	0.0020	0.0068
	(1.285)	(0.581)	(1.611)
4th quintile deprivation	0.0009	0.0050	0.0032
	(0.398)	(1.523)	(0.782)
1st quintile deprivation* P_t	0.0012	-0.0057	0.0068
	(0.225)	(-0.880)	(0.855)
2nd quintile deprivation* P_t	0.0022	-0.0076	0.0021
	(0.534)	(-1.524)	(0.299)
3rd quintile deprivation* P_t	-0.0018	-0.0023	0.0001
	(-0.501)	(-0.552)	(0.011)
4th quintile deprivation* P_t	-0.0020	-0.0040	0.0006
	(-0.607)	(-0.994)	(0.106)
Constant	-0.1509***	-0.0871***	-0.0490**
	(-11.228)	(-5.101)	(-1.991)
R^2	0.0551	0.0533	0.0912
AIC	13960.6	-54763.2	163484.6
BIC	15070.6	-53906.1	164460.7
F test: all deprivation quintile* $P_t *(\bar{M}_{h0} - \bar{M}_0) = 0$	0.67	1.79	0.29
p-value	0.6115	0.1310	0.8838
Patients	288279	91005	214103
Hospital sites	238	213	236

Notes. Specification is text equation (1) except for addition of interactions of deprivation quintile dummies with $P_t *(\bar{M}_0 - \bar{M}_0)$ and interactions of deprivation quintile dummies with $P_t * (\bar{M}_0 - \bar{M}_0)$, and replacement of continuous deprivation measure with deprivation quintile dummies. 1st quintile has highest deprivation. *t* statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Appendix C. Gaynor et al (2013) specification

Gaynor *et al.* (2013) use two years (2003/4 and 2007/8) to avoid possible confounding of the effect of Choice with other policy changes and estimate a form of difference in differences (DID) specification. Their unit of analysis is the Hospital Trust and they measure quality as mortality rate for the Trust, and use Trust level casemix variables. In terms of our individual level data their specification is :

$$q_{iht} = \beta_0 + \beta_1 \mathbf{1}_{(t=2007/8)} + \gamma M_{h2003} \mathbf{1}_{(t=2007/8)} + \mathbf{x}'_{iht}\boldsymbol{\lambda} + \mu_h + \varepsilon_{iht} \qquad \text{(C1)}$$

γ is change in the effect of frozen 2003 market structure between 2003/4 and 2007/8.

Column (i) of **Table C1** reports the result from this DID specification estimate with our individual patient level. Column (ii) adds dummy variables for 9 AMI sub-diagnoses, and column (iii) has all covariates interacted with the 2007 year dummy and is similar to our baseline model (equation (1) in the text).

We see that, as with text Table 3 that when the effects of the covariates and sub-diagnoses are allowed to vary before and after the change in choice policy (column (iii) the effect of relaxing the constraints becomes smaller (though it remains much larger than in the model using all the data for 2002/3 to 2010/11) and statistically insignificant.

Table C1. Market structure and choice: difference in difference specification

	(i) AMI	(ii) AMI	(iii) AMI
2007*Rivals 2003 (γ)	-0.0054**	-0.0062**	-0.0024
	(-2.166)	(-2.190)	(-0.865)
R^2	0.0523	0.0604	0.0642
AIC	6013.6	5449.1	5259.9
BIC	6360.4	5878.0	6099.4
F-test: all sub-diagnoses coefficients = 0		36.62	26.13
p value		0.0000	0.0000
F test: all P_t*covariates coefficients = 0			45.71
p-value			0.0000
Patients	67854	67854	67854
Hospitals	152	152	152
AMI sub-diagnoses?	N	Y	Y
Time varying effect of covariates?	N	N	Y

Notes. Dependent variable: patient aged 35-74 died within 30 days of admission. Column (i) model: same covariates as models in main text but not sub-diagnoses. Column (ii) model as in (i) but with sub-diagnoses dummies. Column (iii) model as in (i) but with 2007 year dummy interacted with all covariates and sub-diagnoses. Period: financial years 2003/4 and 2007/8 only. Market structure: average of Equivalent N rival sites (= 1/(predicted HHI at 30 km)) within each hospital Trust. Cluster-robust standard errors at Trust level. t-statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01.