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The Effect of Hospital Ownership on Quality of Care: Evidence from England

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Abstract

We investigate whether quality of care differs between public and private hospitals in England using data on 3.8 million publicly-funded patients receiving 133 planned (non-emergency) treatments in 393 public and 190 private hospital sites. Private hospitals treat patients with fewer comorbidities and past hospitalisations. Controlling for observed patient characteristics and treatment type, private hospitals have fewer emergency readmissions. But patients' choice of hospital may influenced by their unobserved morbidity. After instrumenting the choice of hospital type by the difference in distances from the patient to the nearest public and the nearest private hospital, the effect of private ownership changes sign and is statistically insignificant. Similar results are obtained with coarsened exact matching. We also find no quality differences between hospitals specialising in planned treatments and other hospitals, nor between for-profit and not-for-profit private hospitals. Our results show the importance of controlling for unobserved patient heterogeneity when comparing quality of public and private hospitals.

Keywords: ownership, hospital, quality, choice, distance, endogeneity.

JEL: C36, H44, I11, L33.

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1 Introduction

Countries differ in the mix of public and private providers treating publicly-funded patients (Barros and Siciliani, 2011). For example, in the USA 60% of hospitals are private not-for-profit, 20% are private for-profit, and 20% are public. In France 60% of hospitals are private. In Germany 30% are public, 35% are private not-for-profit and 35% are for-profit hospitals. In the Netherlands, all hospitals are private. In the United Kingdom and Norway most hospitals are public. Overall an increasing proportion of publicly-funded patients are treated in private hospitals (Siciliani *et al.,* 2017). In England the proportion of publicly-funded patients treated by private providers increased from almost zero at the start of the 2000s to 4.5% of all non-emergency treatments in 2013, and public health service expenditure on private sector providers has increased from £4bn in 2009 to £9bn in 2016.[1]

Private hospitals have strong incentives to maximise profits since they keep any financial surplus. Public hospitals are generally restricted in the use of financial surpluses, which have to be either re-invested or returned to the funder. A key policy issue is whether particular types of hospital ownership should be encouraged (Pollock, 2004; Leys and Toft, 2015). This depends in part on how ownership and the profit motive affect quality. The economic theory highlights two key mechanisms, which work in opposite directions. Driven by their financial motive, private hospitals may have a stronger incentive to increase quality in order to attract more patients, which will increases profits if the revenue from additional patients exceeds their costs of treatment. But if demand is not responsive to quality, perhaps because quality is difficult for patients to observe, private hospitals may have a stronger incentive to skimp on quality (Brekke *et al.,* 2014; Glaeser and Shleifer, 2001; Sloan, 2000). Public hospitals may also attract more altruistic workers with a stronger preference for quality (Lakdawalla and Philipson, 2006).[2]

We investigate empirically whether there are differences in quality between public and private hospitals treating publicly-funded patients in England who seek planned (non-emergency) treatment. We use data on 3.8 million publicly-funded patients receiving one of

[1] 'NHS: How much does it spend on the private sector?' http://www.bbc.co.uk/news/health-44043959 [published: 08/05/18; last accessed: 18/05/18].

[2] We provide a more formal analysis of these different mechanisms in Section 1.1.

133 types of planned treatment across 393 NHS and 190 private hospital sites between April 2013 and February 2014. (We do not examine the effects of ownership on patients admitted as emergency as publicly-funded emergency patients are treated only in public hospitals.) We measure hospital quality for patients having planned treatments as the probability that they have a subsequent *emergency readmission* (in the same hospital or any other hospital in England) within 28 days.

A key issue in the comparison of quality between public and private providers of planned care is that there may be unobserved differences in the morbidity of their patients. Patients choose their provider and their choices may be affected by their morbidity. Private providers may also have stronger incentives to avoid more severe and expensive patients and consequently may appear to provide better quality if there is no adequate adjustment for case-mix. We include an extensive range of control variables in our analysis to capture morbidity (including the Elixhauser comorbidities, and previous emergency hospitalisations in the year prior to the planned hospital admission for each patient in our sample). We deal with unobserved heterogeneity in case-mix by using the difference between the distances from the patient's residence to the nearest public and nearest private hospital as a strong instrument for choice of provider type.

We find that private providers have lower unadjusted emergency readmission rates i.e. higher quality. But they also treat patients with fewer co-morbidities and past emergency hospitalisations. Even after controlling for observed case-mix, ordinary least squares (OLS) estimates suggest that private hospitals have an emergency readmission rate which is one third smaller than the 2.3% rate of NHS hospitals. But instrumental variable (IV) estimates show that the choice of provider type is endogenous and, when this is allowed for, there is no difference in quality between public and private hospitals. We obtain similar results when we use OLS and instrumental variables models on a sample selected by coarsened exact matching. We check the plausibility of our IV results using a test, suggested by Altonji et. al. (2005) and extended by Oster (2017), which is based on the changes in the OLS coefficient as observed confounders are included. The test suggests that the OLS estimate is indeed biased in favour of private hospitals, thereby supporting the results from our IV models. Our analyses suggest that controlling for a rich set of covariates is not sufficient by itself to adequately account for differences in case-mix between public and private providers.

Private providers can be for-profit or not-for-profit and the resulting differences in incentives might affect quality. We therefore also compare quality in public providers, private for-profit and private not-for-profit providers. Using differential distances between the three types of provider to instrument for the choice of provider type we again find that patient choice of provider type is endogenous. After allowing for endogenous choice of provider there is no difference in quality across the three types of provider.

Some providers, known as treatment centres, specialise in a limited set of planned treatment types (e.g. cataract surgery, hip and knee replacements) and do not treat any emergency patients. Since such specialisation could affect quality and most treatment centres are private, we also compare quality across four types of provider: public non-treatment centres, public treatment centres, private non-treatment centres and private treatment centres. After instrumenting for choice of provider type with differential distances, we find no difference between public non-treatment centres, private non-treatment centres, and private treatment centres but public treatment centres have higher emergency readmission rates compared to public non-treatment centres. However, there are only six public treatment centres in our sample, and their quality is not statistically different from that of private treatment centres. We conclude that not only is there no overall quality difference between public and private providers there is also no difference in quality between public and private providers of the same degree of specialisation

We also examine if the effect of ownership varies by type of patient. Stratifying patients by observable morbidity makes no difference to our results: there is no difference in quality between private and public providers for high and low morbidity patients. When we split the sample by age or by deprivation, quality is higher in private providers for less deprived and younger patients. But for more deprived or older patients, quality is lower in private providers.

Finally, we estimate separate models for different type of treatment and find that private providers have lower quality for non-diagnostic treatments and higher quality for diagnostic treatments. In four of the five non-diagnostic procedures (non-trauma knee, cataract, hernia, non-trauma hip) with the highest number of private patients, there is no difference in quality between private and public providers.

Our paper makes a number of contributions to the existing literature on the effect of hospital ownership on quality. First, we use data from a period in which public and private hospitals were paid the same prospective price for a given treatment. Our results are therefore not confounded by differences in payment rules, and hence different financial incentives, for different types of hospital.

Second, most previous studies focus on quality of emergency care and use mortality as a measure of quality. We examine quality of planned care which is as important as emergency care in terms of volume, and has been understudied in the literature. Since mortality is negligible for the types of planned care provided by private hospitals in England, and in other OECD countries with relatively small private sectors, we use hospital readmission rates as the quality measure. Emergency readmissions are widely used as a quality metric, for example by the Centers for Medicare and Medicaid Services in the US (Cox *et al.,* 2016) and by the Department of Health in England.

Third, we use data on 133 different planned treatments, whereas previous studies have usually examined quality differences for a small number of specific treatments. This enables us to examine not only the *overall* effect of ownership on quality of planned hospital treatment, but also whether the effects of ownership differ across types of treatment.

Fourth, in addition to the comparisons of public and private hospitals and public versus private for-profit versus private not-for-profit, we also examine whether public and private ownership has different effects for providers specialising in planned care.

Fifth, most of the previous literature is from the US. Unlike the US, the private hospital sector in England is relatively small and within it for profit providers predominate. The institutional context is therefore quite different, and results from the US are unlikely to be applicable. Our results are relevant for other Beveridge health systems (e.g. Spain, Italy and Norway) where public purchasers have to decide the extent to which they contract out care to private providers.

In the rest of this introductory section we provide, first, a theoretical model to explain why private hospitals could have higher or lower quality than public hospitals and, second, a short account of the mixed findings in the empirical literature. Section 2 describes the institutional background and the data. Section 3 sets out the estimation strategy and Section 4 reports results. Section 5 concludes.

1.1 Theory

We provide a theory model to illustrate why the effect of ownership on quality is indeterminate. The model is a simplified version of Brekke *et al.* (2012). Since the focus is on ownership we assume that there is a single hospital choosing quality q and facing the demand function $D(q)$ ($D' > 0$), which is increasing in quality.[3] Profit is

$$\pi(q) = [p - c(q)]D(q) - K(q) \tag{1}$$

where p is the fixed tariff paid by the funder, not by the patient. $c(q)$ ($c' > 0$) is the unit cost of treating a patient and $K(q)$ ($K' > 0$) is the cost of investment in information technology, MRI scanners etc to improve quality. Hospital staff incur a non-monetary cost of effort $\phi(q)$ ($\phi' > 0$). Hospitals are altruistic and care directly about quality. Altruism is captured by $ab(q)$ where $a > 0$ denotes the degree of altruism and $b(q)$ ($b' > 0$) is patient benefit. The hospital objective function is

$$V(q) = ab(q) - \phi(q) + \delta\pi, \tag{2}$$

where δ is the weight that the hospital puts on profit.[4] We expect that not-for-profit private providers, say owned by charities, will place a lower weight on profit than for-profit private providers. Public hospitals subject to a profit constraint, even if just a requirement to break even, will also place a positive, though possibly small, weight on profit.

The hospital chooses quality q to satisfy

$$V'(q^*) = ab'(q^*) - \phi'(q^*) + \delta\pi'(q^*) = 0, \tag{3}$$

where

$$\pi'(q^*) = \left[p - c(q^*)\right]D'(q^*) - c'(q^*)D(q^*) - K'(q^*). \tag{4}$$

Quality is chosen so that the marginal monetary and non-monetary benefits, from higher revenues and patients benefits, are equal to the marginal monetary and non-monetary costs. By the use of the implicit function theorem, and substituting for the marginal profit of quality from (3), we obtain the effect of the profit weight δ on quality:

[3] The results of the theory model are qualitatively similar if hospitals instead compete on quality (see Brekke *et al.*, 2012).

[4] For example δ could be the weight on profit resulting from internal bargaining within the hospital amongst owners, managers, and medical staff or it could arise because the hospital must earn some minimum profit so that δ is the Lagrange multiplier on profit which is larger the higher is the required minimum profit.

$$\frac{\partial q^*}{\partial \delta} = -\frac{\partial V'(q^*)/\partial \delta}{V''(q^*)} = -\frac{\pi'(q^*)}{V''(q^*)} = -\frac{\phi'(q^*) - \alpha b'(q^*)}{\delta V''(q^*)}, \tag{5}$$

with $V''(q^*) < 0$ from the second order condition.

Thus the effect of a greater weight on profit (δ) on quality (q) is in general indeterminate: it will depend on the relative magnitudes of the derivatives of the provider monetary and non-monetary cost function, and patient benefit function with respect to quality. It will also depend on the degree of altruism. In the absence of altruism and non-monetary costs, a greater weight on profit has no effect on quality (Lemma 1 of Brekke *et al.,* 2012). If altruism is so high that marginal profit $\pi'(q^*)$ is negative (see (3)), a greater weight on profit reduces quality (Lemma 4 of Brekke *et al.,* 2012). If altruism is low, the marginal profit is positive (to offset the marginal effort cost) and a greater weight on profit leads the hospital to increase quality (Lemma 2 of Brekke *et al.,* 2012).[5]

In the more general model by Brekke *et al.* (2012) providers also choose cost-containment effort. In that scenario, a higher weight on profit gives stronger incentives to contain costs, which in turn reduces the marginal treatment costs and increases the price mark-up, therefore giving more profit orientated providers stronger incentives to compete on quality (Lemma 3 of Brekke *et al.,* 2012).

In summary, even in simplified theory models the effect of ownership on quality is indeterminate, which further motivates our empirical analysis.

1.2 Related Literature

A systematic review of the US literature reports mixed results: whether for-profit (FP) hospitals provide higher quality, as measured by mortality rates and other adverse events, depends on the region, the data source and the period of analysis (Eggleston *et al.,* 2008). For Australia, Jensen *et al.* (2009) control for endogenous selection by employing a sample of patients with their first heart attack (AMI) who are likely to have no or limited choice of provider. They find that private hospitals have lower unplanned readmission and mortality rates. Milcent (2005) investigates differences in AMI mortality rates between public and

[5] Notice, by contrast, that the effect of greater altruism, at given weight on profit, is always to increase quality since $\partial V'(q^*)/\partial a = b'(q^*) > 0$.

private hospitals in France when public and private not-for-profit (NFP) hospitals were subject to a global budget and private for profit (FP) hospitals were paid by fee-for-service. After controlling for differences in severity, public hospitals and private NFP hospitals have similar outcomes, but private FP hospitals have lower mortality rates. Lien *et al.* (2008) instrument the choice between Taiwanese NFP and FP hospitals with differential distance. They find that NFP hospitals have better quality and lower mortality for stroke and cardiac treatment. When endogeneity is not taken into account the estimated effect of NFP status is halved.

Picone *et al.* (2002) examine the effects of changes in ownership on quality. This approach allows for unobserved time-invariant provider effects but relies on covariates to control for casemix. Shen (2002) also uses changes in ownership and argues that restricting the analysis to AMI patients reduces endogenous selection problems. Both studies find that mortality increased in hospitals that changed status from NFP to FP.

For England, three studies compare public hospitals with private treatment centres during periods in which public and private providers faced different payment regimes. Browne *et al.* (2008) and Chard *et al.* (2011) do not allow for unobserved patient selection but do have condition specific pre and post-procedure health measures for five treatments. Browne *et al.* (2008) find that patients in private treatment centres had greater improvements in functional status and quality of life for hip replacement but smaller improvements for hernia repair. Patients in private treatment centres had fewer post-operative complications for knee replacement, hernia repair and cataracts. Chard *et al.* (2011) report that treatment centres had higher quality for hip and knee and similar quality for varicose vein and hernia surgery. Perotin *et al.* (2013) use a switching regression model to allow for endogenous choice of type of provider by patients having nine types of planned care in 2007. The effects of ownership varied across the nine treatment types and they found no overall difference in patient satisfaction between public hospitals and private treatment centres.

2 Data

2.1 Institutional Background

The English National Health Service (NHS) is tax funded. There is a gatekeeping system: patients register with a general practice and must be referred to hospital for planned care by their general practitioner (GP). Patients do not pay for healthcare other than a small charge for primary care prescriptions. Around 11% of the population have supplementary private healthcare insurance (King's Fund, 2014).

NHS patients can be treated in NHS hospitals or in the private sector, either in private general hospitals or in Independent Sector Treatment Centres (ISTCs) specialising in a limited set of procedures. Most private providers are for profit. There are also NHS treatment centres on NHS hospital sites (Bate *et al.,* 2007). After the introduction of private sector treatment centres from 2002/3 and the relaxations of constraints on NHS patients' choice of provider in 2008 (Department of Health, 2007), there was a rapid increase in the proportion of NHS planned patients treated in private providers. As Figure 1 shows the proportion of all planned patients treated in private providers has increased from about 2% in 2006 to 4.5% in 2013. There was an even greater increase for some large volume planned procedure. The proportion of NHS funded planned hip replacements carried out in private providers in increased from 3% in 2006 to 18% in 2011 (Arora *et al.,* 2013).

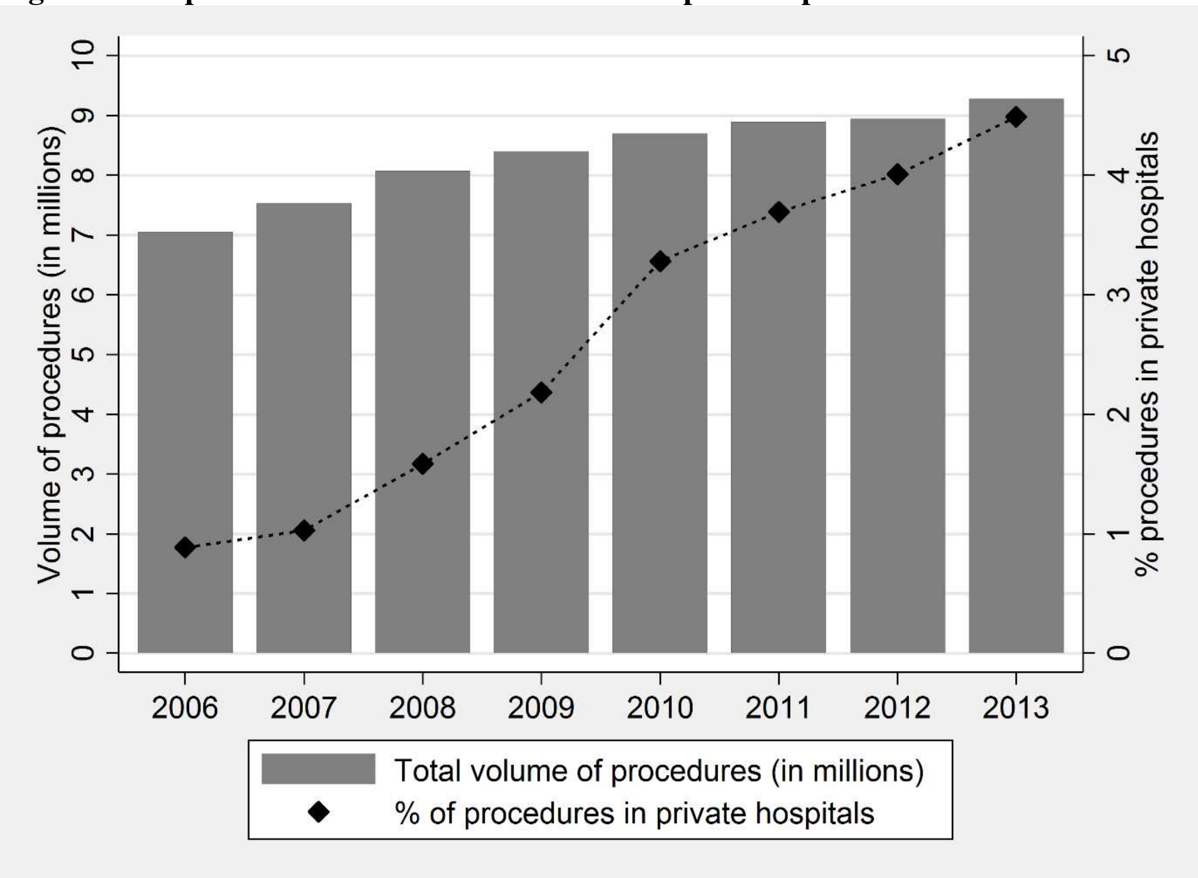
Both NHS and private sector hospitals treating NHS patients are subject to quality regulation and inspection by the Care Quality Commission which publishes reports and quality ratings. Information on hospital quality and characteristics is publicly available, for example on the NHS Choices website (www.nhs.uk).

Hospitals are paid per NHS patient treated, with the tariff based on national average costs adjusted for local input prices (Department of Health, 2002). The tariff varies by healthcare resource groups (HRGs), the English version of diagnosis related groups. From 2009/10 onwards all providers, whether public or private or general hospitals or treatment centres have been paid the same HRG tariff.[6] The HRG prospective pricing regime ensures that providers which attract more patients by increasing quality will get more revenue. All types of provider also have direct financial incentives for quality of care for NHS patients (Meacock *et al.,* 2014). In particular, if a provider's overall emergency readmission rate exceeds a benchmark agreed with the local NHS commissioning body they must bear the cost

[6] ISTCs were initially encouraged to enter the market by being offered favourable contracts. The aim was to reduce waiting times in certain planned procedures such as ophthalmology and orthopaedics (House of Commons Health Select Committee, 2006; Cooper *et al.*, 2016).

of the emergency readmissions above the threshold and are not paid for the index admissions (Department of Health, 2013).[7]

Figure 1. Hospital admissions for all NHS-funded planned procedures 2006-2013.



Notes. Authors' computations. The graph shows the number all types of NHS-funded planned hospital admission.

2.2 Data

We use administrative data from Hospital Episodes Statistics (HES) for the financial year April 2013 to March 2014. HES includes information for all publicly-funded inpatient care provided by NHS and private hospitals in England.

We measure hospital quality of planned treatment by whether the patient had a subsequent emergency readmission to hospital within 28 days of discharge from the index planned

[7] Emergency readmissions for children under 4, maternity, childbirth, cancer and patients discharging against medical advice are excluded from the total readmission rate.

procedure.[8] Emergency readmissions to hospitals are a widely used measure of quality in the clinical and health economics literatures (Ashton *et al.,* 1997; Weissman *et al.,* 1999; Balla *et al.,* 2008; Billings *et al.,* 2012; Blunt *et al.,* 2014) and are also used by as performance indicators by policy makers in the English NHS (Department of Health, 2011, 2012) and in the USA (Rosenthal, 2007). We follow NHS performance indicator methodology (HSCIC, 2013) and define emergency readmissions to exclude readmissions for repeated planned treatments such as cancer, chemotherapy, haemodialysis. We differ in including patients with an index planned day-case admission (82.5% of our sample) since, although the emergency readmission rate is less than for cases with a planned overnight stay, it is not negligible. We include a day case indicator in the readmission models to control for this (Table A4).

Most NHS and private organisations which provide hospital services are multi-site. We use the HES hospital identifier code to classify hospital sites as belonging to a public (NHS) or private organisation. We also further distinguish in some models between treatment centres and general providers using information provided by the NHS Digital Organisation Data Service.[9,10] We assigned for-profit/not-for-profit status to private providers using the Companies House register and supplementary web searches.

HRGs are assigned to admissions via the Reference Costs Grouper tool.[11] The HRG alphanumeric code has five characters, of which the first four, known as *HRG root*, define a given procedure or diagnosis (e.g. the code FZ18 is used for 'Inguinal, Umbilical or Femoral Hernia Procedures'), and the last character is a HRG-specific split used to differentiate by patient age, or by clinical severity based on complications, or by both. We use the four digit HRG root codes without the split to classify index planned admissions by procedure.[12] We only include HRGs which carry a risk of harm to the patient, whether the HRG is curative

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[8] We follow international usage and apply the term "planned" to *all* three of the admission types that HES labels as elective ("where the decision to admit could be separated in time from the actual admission"). Maternity cases are excluded.

[9] See https://digital.nhs.uk/organisation-data-service/data-downloads/other-nhs for data on NHS hospital sites and https://digital.nhs.uk/organisation-data-service/data-downloads/non-nhs for data on private hospital sites.

[10] Unlike the US, most English private hospitals are owned by for-profit organizations. Out of 25 private organizations in our sample, only 6 are not-for-profit, and they treat just 11% of the private patients in our sample (1.21% of the entire sample). We therefore do not distinguish between for-profit and not-for-profit private providers in our main analysis.

[11] http://content.digital.nhs.uk/article/6226/HRG4-201415-Reference-Cost-Grouper?tabid=3 .

[12] We do not use the 5th character of the HRG code because some of the complications covered by it may result from poorer quality hospital care, and hospitals may also upcode patients as the tariff is higher for more complex cases (Doyle *et al.*, 2017). We do not lose any useful information on morbidity contained in the 5th character as we include both age and pre-existing comorbidities in the covariates.

(e.g. hip replacments) or diagnostic. Thus we include invasive diagnostic procedures, such as colonoscopy, but not non-invasive X-rays or magnetic resonance imaging.

We further restrict the sample to NHS funded patients[13] where the index planned treatment (HRG) was carried out at least 30 times in each of four types of provider (NHS non-treatment centre, NHS treatment centre, private non-treatment centre, ISTC) in 2013. (Appendix Table A1 shows the distribution of hospital sites and patients by type of hospital, while Appendix Table A2 reports the number of public and private hospitals which offered each HRG treatment in year 2013/14). Our main estimation sample is 3,784,683 admissions for planned treatments in 133 HRGs. 9.96% of the admissions were to private providers.

To control for case-mix we include, in addition to patient age and gender, the number of Elixhauser comorbidities (Elixhauser *et al.,* 1998), and the number of emergency hospitalisations in the year before the index admission. We also control for the quality of primary care provided by the patient's general practice with a composite quality measure based on the practice's 2012 performance on 42 clinical indicators from the Quality and Outcomes Framework (Doran *et al.,* 2006).

We classify patients as living in a rural or urban area by the Office of National Statistics rurality classification of their Lower Super Output Area (LSOA)[14] of residence. We attribute a measure of LSOA income deprivation based on the 2010 Indices of Multiple Deprivation (McLennan *et al.,* 2011) to patients.

Hospital locations are derived from their postcodes. We compute straight-line distances from the centroid of each patient's LSOA of residence to all hospitals providing NHS-funded planned hospital care in 2013/14. The distances are HRG-specific, so that, for example, the distances for hernia surgery patients (HRG root FZ18) are computed only to hospital sites performing hernia surgery.

[13] There is no publicly available detailed data for privately funded patients in private providers.
[14] There were 32,482 LSOAs in England defined by 2001 Census boundaries. LSOAs have a mean population of 1,500 and are created to be homogeneous with respect to tenure and accommodation type. The rural category includes areas classified as town and fringe, village, hamlet and isolated dwellings, while the urban category consists only of urban areas. See ONS (2004) for details.

3 Methods

3.1 Model specification

Our baseline specification for the effect of private ownership on hospital quality of planned care is the linear probability model

$$y_{ij} = \alpha_j + \delta H_i + \mathbf{X}_i'\boldsymbol{\beta} + \varepsilon_i = \alpha_j + \delta H_i + \mathbf{X}_i'\boldsymbol{\beta} + \xi_i + \nu_i, \tag{6}$$

where y_{ij} is an indicator equal to one if patient i with a planned admission for treatment j is readmitted to any hospital as an emergency within 28 days of the discharge date of the index admission. H_i is an indicator equal to 1 if the index hospital is privately-owned; α_j is the fixed effect for HRG j. $\mathbf{X}_i$ is a vector of patient characteristics. ξ_i is unobserved severity and v_i is an i.i.d error. We use heteroscedasticity-robust standard errors clustered at HRG root level when estimating (6).

$\mathbf{X}_i$ includes controls for patient age (in 20-year bands), gender, number of Elixhauser co-morbidities, number of emergency hospitalizations in the previous year, whether the patient lives in a rural area, was admitted as a day case, patient LSOA income deprivation, and the patient's GP practice quality score in 2012. $\mathbf{X}_i$ also includes the distance from the centroid of i's LSOA of residence to the nearest A&E department to allow for the possibility that if i feels unwell after her discharge from the index planned treatment, her decision to visit an A&E department, and hence possibly to be admitted as an emergency patient, will depend on her distance to the A&E department.

The coefficient of interest is δ: the difference in the probability of an emergency readmission following a planned treatment in a private hospital compared to an NHS hospital. There is higher quality of care in private hospitals if $\delta < 0$.

Privately-owned hospitals in England treat NHS patients of lower observed severity for a given condition (Browne *et al.* 2008, Chard *et al.,* 2011; Mason *et al.* 2010). Selection on observed severity suggests that there may also be selection on unobserved severity (ξ_i) so that $\mathrm{Cov}(H_i,\xi_i \mid \alpha_j,\mathbf{X}_i) \neq 0$ and the OLS estimate of δ is biased. Quality affects patients' choice of provider for planned care (Beckert *et al.* 2012, Gaynor *et al.* 2016, Gutacker *et al.* 2016, Moscelli *et al.* 2016a). If patient preferences over quality vary with their unobserved morbidity and they believe that public and private providers have different quality, then there may bias due to unobserved selection.

To remove selection bias we use two stage least squares (2SLS). The first stage linear regression for provider type is

$$H_i = \lambda_j + \theta D_{ij} + \mathbf{X}_i'\boldsymbol{\gamma} + \eta_i, \tag{7}$$

where λ_j and $\mathbf{X}_i$ are respectively the HRG effects and the case-mix adjusters and η_i is a zero mean error term uncorrelated with the explanatories. The instrument D_{ij} is the *difference* between the distance from the centroid of the patient's LSOA to the nearest NHS provider of treatment j and the distance to the nearest private provider of treatment j. We use robust standard errors clustered on HRGs for the first and second stage regressions.[15]

Differential distance has been used as an instrument in the literature on the effectiveness of healthcare treatments (McClellan *et al.,* 1994; Newhouse and McClellan, 1998) and the effect of hospital ownership on quality (Sloan *et al.,* 2001; Shen, 2002; Lien, 2008). Results from our first stage model show that it is indeed a strong predictor of the type of hospital at which a patient is treated.

For our IV strategy to work, the instrument should affect the second stage outcome (emergency readmission) only indirectly through hospital type. There are good reasons to believe that this untestable assumption holds. First, differential distances are unlikely to have a direct effect on the probability of an emergency readmission. NHS patients are admitted as emergencies only to NHS hospitals. Distances to NHS hospitals may affect the probability that a patient, who is unsure if their symptoms indicate a condition requiring emergency hospital treatment, will present at the A&E department. We therefore include the distance from the patient's LSOA to the closest NHS site with an A&E department as a covariate in $\mathbf{X}_i$ in both the emergency readmission model (6), whether estimated by OLS or 2SLS, and in the first stage selection model (7). The distance to private hospitals, which do not provide emergency care to NHS patients, will not affect the probability of an emergency admission to an NHS hospital. Thus, conditional on the distance to the nearest NHS A&E department, the *difference* between the distances to the nearest NHS site and to the nearest private site, should not affect the decision to seek emergency care.

[15] The 2SLS models are estimated in Stata 13 using the *ivreg2* user written function (Baum *et al.*, 2007).

Second, it seems implausible that quality of planned care affects patients' decisions about where to live.[16] This would require prospective patients to predict the kind of planned treatments that they would require in the medium-to-long term and the future quality of care at different providers for these different treatments.[17] Quality of care varies over time and is weakly correlated across different planned treatments within hospitals (Gravelle *et al.,* 2014; Moscelli *et al.,* 2016b). Third, even if sicker patients might wish to locate near NHS hospitals with good quality emergency care (we know of no evidence for this), the qualities of emergency and planned hospital care are also weakly correlated (Gravelle *et al.,* 2014; Moscelli *et al.,* 2016b; Skellern, 2017). Fourth, we require only that the differential distance instrument is *weakly exogenous*, i.e. uncorrelated with the errors in the second stage readmission model conditional on the rich set of controls and HRG effects (λ_j and $\mathbf{X}_i$) included in the readmission model.[18]

Some unobserved selection might arise from provider choice of patient. This may be unofficial and uncontracted for or it may be explicit and agreed with local NHS commissioners of care. Some contracts for private treatment centres specify grounds on which they can refuse to treat a referred NHS patient (Cooper *et al.,* 2016; Mason *et al.* 2008).[19] The observed morbidity measures included in $\mathbf{X}_i$ will allow for some provider selection of patients but some unobserved (by the researcher) selection by providers may remain. The greater the degree of such cream skimming the weaker will be our differential distance instrument. If our first stage results show that the instrument is not weak and the

[16] The treatments in our sample do not require patients to attend hospital repeatedly. We do not include patients with conditions like cancer or renal failure who may require many planned hospital admissions and so be more likely to locate near NHS providers. Such patients are also dropped when official emergency readmissions performance indicators for NHS providers are computed: https://indicators.ic.nhs.uk/download/NCHOD/Specification/Spec_33D_533ISP4CPP1_12_V1.pdf

[17] It seems unlikely that patients getting one-off non-emergency treatments like hip and knee replacement will change their residence to be near their chosen hospital for an unanticipated planned procedure. The waits for most one-off planned procedures are shorter than the number of days to sell a house in UK (96 days on average, according to http://corporate.postoffice.co.uk/our-media-centre#/pressreleases/rate-of-sale-the-average-uk-property-takes-96-days-to-sell-2282828).

[18] We show in Appendix Tables A3 and A4 that the differential distance IV is not correlated with the main covariates measuring patient severity (number of past emergency admissions and the sum of Elixhauser comorbidities), thus suggesting that differential distance IV is unlikely to be correlated with unobserved morbidity.

[19] For example, a tender for treatments by private treatment centres of patients of five Clinical Commissioning Groups in south west England specifies that the provider can exclude patients who had a Body Mass Index of over 40 or who require a general anaesthetic and have a severe systemic disease that is a risk to life, for example unstable angina, or a recent myocardial infarction.

Durbin-Wu-Hausman test rejects the null of exogeneity of type of provider, then we know that there has been unobserved selection of providers by patients. Comparison of the OLS and 2SLS coefficients on provider type will show whether, as we expect, unobservably sicker patients are more likely to choose public hospitals. The 2SLS estimate of the effect of private ownership may still be biased by unobserved patient selection by provider. However, we know the direction of this bias: provider selection of patients leaves private providers with unobservably healthier patients, and so will lead to an over-estimate of the quality gain from private treatment compared to public treatment. Thus, if our second stage estimates show that private providers are no better than public providers, we can reasonably conclude that public providers have at least as high quality as private providers.

3.2 Matching

Regression adjustment for observable case-mix differences between private and public hospitals may not be adequate in the presence of non-linearities or interaction effects, even if there is no unobserved selection. If private providers treat observably less severe patients, the lack of common support may bias estimates of the effect of ownership even in the absence of unobserved selection (Heckman *et al.,* 1997).

We therefore use *coarsened exact matching* (CEM) (Blackwell *et al.,* 2009; Iacus *et al.,* 2011) as a robustness check. We match each patient treated by a private provider to one or more patients treated in public hospital and who have the same gender, age band, number of past year's emergency hospitalizations, number of Elixhauser comorbidities, quintile of the IMD 2010 income score, and the same HRG4 root code. We drop observations where the number of past year's emergency hospitalizations and the number of Elixhauser comorbidities exceed 4. [20] We then estimate the OLS and 2SLS models using weights provided by the CEM algorithm.

3.3 Selection on unobservables and coefficient stability

Another possible way to identify the direction of the possible omitted variables bias in our coefficient of interest δ (the effect of private ownership on emergency readmissions) is to use

[20] See https://www.bristolccg.nhs.uk/media/medialibrary/2015/10/govbody_28april2015_item10_1.pdf. These variables were much more heavily right skewed in NHS hospitals than in private hospitals, so that using a category of more than four comorbidities or previous admissions would match private patients to public patients with much higher mean counts. Using finer categories (e.g. 5 comorbidities, 6 comorbidities, etc…) would result in fewer matches.

the change in the estimate of δ when observables are added to the regression (Altonji *et al.,* 2005; Oster, 2017). Oster (2017) shows that, under certain assumptions,

$$\delta^* = \tilde{\delta} - \left[\delta^{\text{o}} - \tilde{\delta}\right] \frac{R_{\max} - \tilde{R}}{\tilde{R} - R^{\text{o}}} \tag{8}$$

converges asymptotically to the true parameter δ. Here δ^{o} is the OLS estimate of δ using only a minimal set of covariates (the HRG dummies α_j), and R^{o} is the R-squared of this regression; $\tilde{\delta}$ is the estimate of δ from the OLS regression using the full set of available explanatories (HRG dummies and the additional controls $\mathbf{X}$) and $\tilde{R}$ is the R-squared from this regression; finally, $R_{\max}$ is the assumed maximum R-squared achievable from the hypothetical OLS regression of y on the private provider indicator H, the HRG dummies, the controls $\mathbf{X}$ and on unobserved morbidity. The assumptions required for δ^* to be a consistent estimate of δ differ from those required for the IV strategy and we estimate δ^* under alternative assumptions about $R_{\max}$ to check that the direction of the omitted variable bias is consistent with our 2SLS results.

3.4 Specialist vs general and for profit vs not for profit hospitals

Treatment centres, which are mainly in the private sector, specialise in a small number of treatment types. Whereas nearly half (46.4%) of patients in private hospitals receives care in treatment centres, only 1.4% of patients in public hospitals do so. Since specialisation in planned care may affect quality we estimate models which distinguish hospitals by whether they are treatment centres as well as by ownership

$$y_{ij} = \alpha_j + \mathbf{H}_i'\boldsymbol{\delta} + \mathbf{X}_i'\boldsymbol{\beta} + \varepsilon_i \ , \tag{9}$$

where $\mathbf{H}_{\text{i}}$ is a vector of three indicators for the patient having an admission to an NHS treatment centre, a private non-treatment centre, or a private treatment centre. The reference type of hospital is an NHS general hospital (non-treatment centre). For the 2SLS specification we estimate three first stage regressions for choice of an NHS treatment centre, private non-treatment centre hospital, and private treatment centre.

The instruments in each first stage model are the three differential distances between the closest NHS general hospital and the distances to each of the three other hospital types.

Notice that, as in our main specification, the three differential distances vary by HRG and this allows for the fact that treatment centres do not offer the entire spectrum of planned care. [21]

Some of the private hospitals treating NHS patients are for profit (FP) and some are not for profit (NFP) and previous studies in other healthcare systems have found that FP hospitals have lower quality (Sloan *et al.,* 2001; Picone *et al.,* 2002; Shen, 2002; Lien *et al.,* 2008). We therefore examine whether the FP status of private hospitals affects quality for the NHS patients they treat. We estimate a model similar to (9) in which public hospitals are the reference category and the alternatives are private NFP and private FP.

3.5 Stratification by patient and procedure

We also estimate models on subsamples defined by patient characteristics. By dichotomising the sample by morbidity, for example, we can investigate whether there is more evidence of unobserved selection for high or low morbidity patients and whether the effect of ownership differs by morbidity. To investigate whether the effect of ownership is procedure specific we estimate separate models for diagnostic and non-diagnostic procedures and also estimate procedure specific models for the 15 procedures with the largest number of patients treated in private providers.

4 Results

4.1 Summary statistics

Table 1 has summary statistics by type of chosen hospital (NHS or private). *Panel A* is for the full estimation sample. Although NHS and privately treated patients have similar mean age and gender, NHS treated patients had more emergency hospitalisations (0.25 vs 0.10) in the previous year, come from slightly more income-deprived (mean IMD-income score of 0.15 vs 0.13) and less rural small areas (18% vs 21%), and are more frequently treated as a day-case. They have similar numbers of Elixhauser comorbidities and GP quality scores. NHS treated patients are on average located closer to the nearest NHS hospital site with an A&E department than patients in private hospitals, and are more likely (2.26% vs 1.38%) to undergo an emergency readmission to hospital within 28 days of discharge from the index admission. Notice that for patients in an NHS hospital the distance to the nearest NHS

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[21] We could alternatively restrict the sample to the small number of HRGs in which treatment centres specialise. This would lead to similar results since we include HRG fixed effects in Equation (9).

hospital is smaller than the distance to the nearest private provider and vice versa for patients in private providers.

Table 1. Patient descriptive statistics.

Panel A. Unmatched sample	NHS			Private		
	mean	sd	median	mean	sd	median
28-days Emergency Readmission	0.0226	0.15	0	0.0138	0.12	0
Female Patient	0.545	0.50	1	0.551	0.50	1
Age	55.96	20.28	59	56.18	16.98	57
Emergency Hospitalizations Past Year	0.25	0.76	0	0.10	0.42	0
Elixhauser comorbidities	0.68	0.97	0	0.67	0.89	0
IMD 2010 income score	0.15	0.11	0.11	0.13	0.10	0.09
GP QOF 2012	79.02	3.69	79.31	79.11	3.63	79.40
Rural patient	0.184	0.39	0	0.214	0.41	0
Daycase patient	0.854	0.35	1	0.697	0.46	1
Distance to closest NHS non-TC hospital site (km)	6.82	6.38	4.65	7.81	6.92	5.54
d_{NHS}: Distance to closest NHS site (non-TC or TC)	6.77	6.32	4.64	7.78	6.90	5.53
d_P: Distance to closest Private site (non-TC or TC)	17.37	21.73	10.22	8.60	7.85	6.31
d_{NHS} - d_P	-10.61	20.72	-3.72	-0.82	7.16	-0.15
N		3,407,820			376,863	
Panel B. Matched sample	NHS			Private		
	mean	sd	median	mean	sd	median
28-days Emergency Readmission	0.0202	0.14	0	0.0137	0.12	0
Female Patient	0.550	0.50	1	0.551	0.50	1
Age	56.39	17.15	57	56.18	16.96	57
Emergency Hospitalizations Past Year	0.10	0.45	0	0.09	0.41	0
Elixhauser comorbidities	0.67	0.89	0	0.67	0.89	0
IMD 2010 income score	0.13	0.10	0.09	0.13	0.10	0.09
GP QOF 2012	79.04	3.64	79.32	79.11	3.63	79.40
Rural patient	0.205	0.4	0	0.214	0.41	0
Daycase patient	0.776	0.42	1	0.697	0.46	1
Distance to closest NHS non-TC site	7.14	6.54	4.95	7.80	6.92	5.54
d_{NHS}: Distance to closest NHS site (non-TC or TC)	7.08	6.49	4.92	7.78	6.89	5.53
d_P: Distance to closest Private site (non-TC or TC)	15.18	18.17	9.64	8.59	7.84	6.30
d_{NHS} - d_P	-8.10	17.08	-2.79	-0.82	7.16	-0.14
N		3,105,647			375,526	

Notes. Patients in matched sample in Panel B are matched using a Coarsened Exact Matching algorithm based on the variables *in italics*, together with the 133 four digit HRG4 codes. Statistics in Panel B are computed using the CEM weights. Number of hospital sites: 148 private non-TC, 42 private TC, 387 NHS non-TC, 6 NHS TC. TC: treatment centre.

Panel B has descriptive statistics on the matched sample, after reweighting using the CEM algorithm weights.[22] Matching greatly reduces the imbalance in covariates between the two patient groups. There also is a slight reduction in the unconditional probability of emergency readmissions after treatment for NHS patients because of the exclusion of NHS-treated patients with high severity who could not be matched to private sector patients.

4.2 Estimation results

Table 2 summarises the key results for the unmatched sample from OLS and 2SLS models of the effect on the probability of an emergency readmission of being treated in a private hospital. The full results, reported in the Appendix (Table A5), have plausible effects of the covariates: emergency readmission is more likely for older patients, those with more comorbidities, with more emergency admissions in the previous year, and living in a small area with higher income deprivation. Day-case patients are less likely to have an emergency readmission, suggesting that providers do have better information than is available in the HES data and are more likely to treat a patient as a day-case rather than an overnight stay if they are unobservably (by the researcher) healthier. Patients belonging to general practices with higher quality also have lower readmission rates. Patients living further from the nearest general NHS hospital have lower emergency readmission probabilities, whether treated in a private or public provider. Patients in rural areas are also less likely to have an emergency readmission, perhaps reflecting the effects of travel costs not fully captured by the straight line distance to the nearest NHS general hospital.

In Table 2 the OLS estimate of the effect of private ownership after controlling for HRG type but not covariates is –0.0095 (column 1). Controlling for observed case-mix (column 2) reduces the estimated private ownership effect to –0.0070, which implies that patients treated in private providers have a one third lower emergency readmissions risk.

The estimates of the effect of ownership change markedly when we instrument for choice of provider type (column 3). The first stage regression results in the lower part of the table show that the probability of choosing a private provider is higher the greater the difference in distance from the patient to the closest NHS hospital site and to the closest private hospital site. The first stage F-statistic on the instrument is 48.70, which is comfortably larger than

[22] Only about 1,300 out of 295,000 patients excluded by the matching algorithm were treated in private hospitals.

the Stock and Yogo (2005) critical value of 16.38 for a type-1 error of 5% and a maximum 10% relative bias with respect to OLS. The Durbin-Wu-Hausman test (Durbin, 1954; Wu, 1973; Hausman, 1978) rejects the null hypothesis that hospital ownership is exogenous ($p<0.001$).

The second stage estimate of the effect of being treated by a private hospital on the probability of an emergency readmission is positive and statistically insignificant, whereas the OLS estimate was negative and statistically significant. Moreover, the 99% confidence interval around the 2SLS estimate of δ is [-0.0028; 0.0085], which does not include the OLS estimate.

Table 2. Effect of ownership on emergency readmissions.

	Emergency Readmission (1) OLS with HRGs only	Emergency Readmission (2) OLS	Emergency Readmission (3) 2SLS	Emergency Readmission (4) 2SLS	Emergency Readmission (5) 2SLS	Emergency Readmission (6) 2SLS
Private	-0.0095***	-0.0070***	0.0028	0.0028	0.0044	0.0030
	(-8.9607)	(-7.3660)	(1.2956)	(1.2935)	(0.8286)	(0.6589)
R^2	0.0129	0.0303	0.0299	0.0299	0.0298	0.0299
IV 1st stage choice of provider						
			Private (3)	Private (4)	Private (5)	Private (6)
$d_{NHS} - d_P$			0.0021***			
			(6.9783)			
d_{NHS}				0.0060***		
				(5.6921)		
d_P				-0.0021***		
				(-6.9979)		
$(d_{NHS} - d_P)/\min\{d_{NHS},d_P\}$					0.0009***	
					(7.3771)	
$d_{NHS}/ \min\{d_{NHS},d_P\}$						0.0029***
						(9.6772)
$d_P/ \min\{d_{NHS},d_P\}$						-0.0008***
						(-7.2841)
1st stage F-stat			48.70	29.50	54.42	61.21
Endogeneity Test Chi^2			10.95	10.96	3.84	4.07
Endogeneity Test p-value			0.0009	0.0009	0.0501	0.0436
Sargan-Hansen Overidentif. Test Chi^2				0.0058		0.2936
Sargan-Hansen Test p-value				0.9392		0.5879
Patients			3,784,683	3,784,683	3,784,683	3,784,683
HRGs			133	133	133	133

Notes. d_{NHS}: procedure specific patient distance to nearest NHS hospital, d_P: procedure specific patient distance to nearest private hospital. All models include 133 HRG effects and all except model (1) include age in bands (0-20/21-40/41-60/61-80/over 80), gender, number of Elixhauser comorbidities, number of emergency hospital admissions in the previous year, quality of patient's GP in 2012, rurality and IMD income deprivation score of LSOA of patient's residence, indicator for day-case patients, distance from the centroid of patient's residence LSOA to the closest general NHS hospital. t-stats in parenthesis based on cluster-robust standard errors at HRG level; * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

We obtain similar 2SLS results when the instruments are the distances to the nearest NHS and nearest private hospital (column 4), the proportional differential distance (column 5), and the proportional distances to the nearest NHS and nearest private hospital (column 6).[23] The 2SLS estimates of the effect of private ownership on probability of emergency admission range from 0.0028 to 0.0044 and are all statistically insignificant.

The results in **Table 3** are from models estimated on the matched sample. OLS and 2SLS results are very similar to those estimated on the unmatched sample: the OLS estimates suggest a large and statistically significant reduction in readmission risk for patients in private provides but the 2SLS estimates indicate a higher, though statistically significant risk, for patients in private providers. The first stage F-statistic on the excluded instrument (differential distance) is very large (240). The Durbin-Wu-Hausman test rejects the null of the exogeneity of hospital type (p = 0.004) and the OLS estimated effect is outside the 2SLS 99% confidence interval [–0.0038, 0.0092].

Table 3. Effect of ownership on quality, matched sample.

	Emergency Readmission (1) OLS with HRGs & no case-mix controls	Emergency Readmission (2) OLS with HRGs & case-mix controls	Emergency Readmission (3) 2SLS with HRGs & case-mix controls
Private	-0.0066***	-0.0072***	0.0027
	(-6.8278)	(-7.6404)	(1.0739)
R^2	0.0120	0.0197	0.0192
IV 1st stage choice of provider			
			Private
$d_{NHS} - d_P$			0.0030***
1st stage F-stat			239.9045
Endogeneity Test Chi^2			8.2524
Endogeneity Test p-value			0.0041
Patients	3,481,173	3,481,173	3,481,173
Number of HRGs	133	133	133

Notes. Sample selected by Coarsened Exact Matching. d_{NHS} patient distance to nearest NHS hospital. d_P distance to nearest private hospital. Controls and HRG effects as for Table 2 columns (2) and (3). t-stats in parenthesis based on cluster-robust standard errors at HRG level; * p<0.10, ** p<0.05, *** p<0.01.

Table 4 shows the effect of treatment by a private hospital estimated using the Oster (2017) procedure under different assumptions about the achievable maximum R-squared achievable

[23] With two distance-based instruments, either absolute (column (4)) or proportionate (column (6)), the Sargan-Hansen (Sargan, 1958; Hansen, 1982) over-identification test fails to reject the validity of the IVs.

if all covariates, observed and unobserved, are used (see (6)). The results are consistent with the 2SLS results in Tables 2 and 3. As $R_{\max}$ increases, the effect of private hospital treatment becomes less negative and then positive, suggesting that the OLS estimates are biased in favour of private providers.

Table 4. Selection on unobservables and coefficient stability.

	$R_{\max}= 0.05$	$R_{\max} = 0.10$	$R_{\max} = 0.15$	$R_{\max} = 0.20$
Estimated effect private (δ^*)	-0.0057	-0.0016	0.0039	0.0116
t-stat	(-22.5365)	(-4.0673)	(6.7144)	(12.0594)
95% CI Lower Bound	-0.0062	-0.0023	0.0028	0.0097
95% CI Upper Bound	-0.0052	-0.0008	0.005	0.0134

Notes. Standard errors are bootstrapped with 500 replications.

Table 5 compares private non-treatment centres, private treatment centre, and NHS treatment centres against NHS non-treatment centres. The OLS model suggests that quality is higher for patients in both types of private providers compared with NHS non-treatment centres. There is also a small reduction in readmission probability (−0.0014) in NHS treatment centres, though the coefficient is statistically significant only at 10%. The Durbin-Wu-Hausman test rejects the null of exogeneity of the hospital types at 5%.

Compared to OLS, the 2SLS coefficient on private non-treatment centre is greatly reduced (to −0.0005) and statistically insignificant. The coefficient on private treatment centre type changes sign to positive and is also statistically insignificant. The coefficient on the NHS treatment centre indicator also changes sign and suggests an increase in the emergency readmission probability of 0.018 compared with NHS non-treatment centres. Since the overall NHS mean readmission probability is 0.026, the effect of NHS non-treatment centres seems very large. However, we cannot reject at the 5% level the null hypothesis that the 2SLS estimates of the effects of NHS treatment centres and private treatment centres on readmissions are equal. Nor can we reject the null that the effects of private providers (both private ISTC and private non-TC) and NHS treatment centres are equal to zero.

As there are only six NHS TCs and they may not be properly captured in Hospital Episode Statistics, we re-ran the models after combining NHS TCs and NHS non-TCs into a single NHS type. The OLS and 2SLS results (Appendix Table A6) for private non-TCs are similar to those in Table 4. For the private TCs, the 2SLS results indicate a lower quality than NHS hospitals. However, we cannot reject at the 5% level the null that the quality of private treatment centres and private non-treatment centres are equal to each other and to the baseline NHS type.

Table 5. Effect of ownership and specialization on emergency readmission probability.

	Emergency Readmission (1) OLS	Emergency Readmission (2) 2SLS			
Private non-TC	-0.0091***	-0.0005			
	(-8.2160)	(-0.1100)			
Private TC	-0.0048***	0.0042			
	(-5.8462)	(1.5860)			
NHS TC	-0.0014*	0.0184**			
	(-1.8482)	(2.4730)			
1st stage choice of provider type					
			Private non-TC	Private TC	NHS TC
$d_{NHSnonTC} - d_{PnonTC}$			0.0011***	-0.0007***	-0.0001***
			(7.1424)	(-4.5836)	(-3.2424)
$d_{NHSnonTC} - d_{ISTC}$			-0.0002*	0.0018***	-0.0001
			(-1.9736)	(8.5846)	(-1.2166)
$d_{NHSnonTC} - d_{NHS\ TC}$			-0.0001***	-0.0002***	0.0003***
			(-6.1326)	(-4.9433)	(11.3331)
R^2	0.0303	0.0175	0.0387	0.0535	0.0300
1st stage F-stat - private non-TC			20.77		
1st stage F-stat – private TC				35.73	
1st stage F-stat - NHS TC					85.66
Endogeneity Test Chi^2 stat.		8.74			
Endogeneity Test p-value		0.0330			
Wald Test p-value: private non-TC = private TC	0.0000	0.2950			
Wald Test p-value: private non-TC = NHSTC	0.0000	0.0207			
Wald Test p-value: private TC = NHS TC	0.0000	0.0526			
Wald Test p-value: private non-TC=ISTC=NHSTC=0	0.0000	0.0516			

Notes. Covariates, HRG effects, and sample size as in Table 2, columns (2) and (3). $d_{NHSnonTC}$ patient distance to nearest NHS non TC, d_{PnonTC} patient distance to nearest private non TC, d_{NHSTC} patient distance to nearest NHS TC. All distances procedure specific. t-stats in parenthesis based on cluster-robust standard errors at HRGs level. * p<0.10, ** p<0.05, *** p<0.01.

Table 6 compares FP and NFP private providers with NHS providers.[24] The OLS estimates suggest that both types of private hospitals have higher quality than NHS providers. However, in the 2SLS model the Durbin-Wu-Hausman test rejects the null of the exogeneity of private hospital types (p = 0.0073) and the instruments are not weak according to the Stock and Yogo (2005) test based on a desired 2SLS maximal size set at 10% (the critical value with two endogenous regressors is 7.03). The 2SLS estimates of the effect of private FP and

[24] We exclude HRG root BZ04 (Lens Capsulotomy) from this analysis as it was not offered in any private NFP site. In year 2013/14 there were 25 ISP organisations in total (19 FP, 6 NFP), treating planned NHS-funded patients. The private FP and NFP organisations owned 157 and 32 hospital sites respectively.

private FP status relative to public providers are not statistically significant. Both OLS and 2SLS models also imply that there is no difference in quality between private FP and private NFP hospitals.

Table 6. Effect of ownership and for-profit status on emergency readmission probability.

	Emergency Readmission (1) OLS	Emergency Readmission (2) 2SLS		
Private Not For Profit	-0.0083***	-0.0004		
	(-4.3489)	(-0.0399)		
Private For Profit	-0.0069***	0.0034		
	(-7.7823)	(1.3862)		
1[st] stage choice of provider type				
			Private NFP	Private FP
$d_{NHS} - d_{P\_NFP}$			-0.0002***	0.0021***
			(-4.0715)	(7.2403)
$d_{NHS} - d_{P\_FP}$			0.0002***	-0.0002***
			(5.1968)	(-3.6787)
Patients	3,773,129	3,773,129	3,773,129	3,773,129
Number of HRGs	132	132	132	132
R^2	0.0303	0.0176	0.0752	0.0224
1[st] stage F-stat – private NFP			14.29	
1[st] stage F-stat – private FP				26.22
Endogeneity Test Chi^2 stat.		9.84		
Endogeneity Test p-value		0.0073		
FP=NFP F-test p-value	0.3031	0.7168		

Notes. Models include 132 HRG effects. Covariates as in Table 2 columns (2) and (3). d_{NHS} = patient distance to nearest NHS hospital site, d_{P_NFP} patient distance to nearest private not-for-profit hospital site, d_{P_FP} patient distance to nearest private for-profit hospital site. Distances are procedure specific. t-stats in parenthesis based on cluster-robust standard errors at HRG level. * p<0.10, ** p<0.05, *** p<0.01.

Table 7. Effect of ownership on quality, controlling for competition.

	Emergency Readmission (1) OLS	Emergency Readmission (2) 2SLS
Private Provider	-0.0070***	0.0026
	(-7.4502)	(1.4589)
Number of rival hospital sites within 30km	-0.0000	0.0000
	(-0.7344)	(0.2297)
1[st] stage choice of provider type		
$d_{NHS} - d_P$		0.0024***
		(7.2000)
Number of rival hospital sites within 30km		-0.0010***
		(-13.6974)
Patients	3,784,683	3,784,683
Number of HRGs	133	133
R^2	0.0303	0.0299
1[st] stage F-stat		51.84
Endogeneity Test Chi^2 stat.		15.65

Endogeneity Test Chi^2 stat. p-value	0.0001

Notes. Same sample, other controls and HRG effects as in columns (2) and (3) of Table 2. In 2013/14, NHS and private hospitals had mean (sd) numbers of rival sites within 30km of 31 (30.5) and 23.6 (22.9). t-stats in parenthesis based on cluster-robust standard errors at HRG level; * p<0.10, ** p<0.05, *** p<0.01.

In **Table 7** we report results from a robustness check in which we include a measure of market structure as a covariate to control for any potential effects of competition on quality. Including the market structure measure makes little difference: the direct effect of competition on quality is small and statistically insignificant in both the OLS and 2SLS models, and the OLS and 2SLS estimates of the effect of ownership are very similar to those in the preferred model in column (3) of Table 2.

Table 8 reports results from five pairs of models estimated on dichotomous sub-samples. The left hand model in each panel is estimated on the sub-sample which we would expect to have a lower risk of emergency readmission and the right hand part on patients likely to have higher risk.

We see that dichotomising the sample by low versus high morbidity (no versus some previous emergency admissions in *panel a*, no versus some comorbidities in *panel b*), does not change the results reported in Table 2. The OLS estimates of the effect of ownership are biased in favour of private providers but the 2SLS estimates show no significant effect. In *panel c* the subsamples are defined by the income deprivation quintile of the patient's small area of residence (least deprived quintile versus four most deprived quintiles). For patients in the least deprived quintile we can no longer reject the null that provider type is exogenous and so the OLS estimate is preferred. For patients in the more deprived quintiles the 2SLS model is preferred. *Panel c* implies that private providers have better quality relative to public providers for the least deprived patients and possibly worse quality for the most deprived. We get qualitatively similar results in *panel d* where the sample is dichotomised by age. We cannot reject endogeneity of hospital type for younger patients. The OLS estimates for younger patients and the 2SLS estimates for older patients indicate that treatment in a private provider is better for younger patients and worse for older patients.

Table 8. Heterogeneity of ownership effect of based on observable patient's characteristics.

	Emergency Readmission (1) OLS	Emergency Readmission (2) 2SLS	Emergency Readmission (3) OLS	Emergency Readmission (4) 2SLS
a. Effect of ownership by severity proxy (past emergency in the previous year)				
	Past Emergency Admission = 0		Past Emergency Admission > 0	
Private Provider	-0.0070***	0.0013	-0.0090***	0.0205
	(-7.23)	(0.64)	(-6.30)	(1.44)
IV 1st stage choice of provider				
d_{NHS} - d_{ISP}		0.0022***		0.0012***
		(7.03)		(6.22)
Patients	3,202,451	3,202,451	582,232	582,232
1st stage F-stat		49.44		38.67
Endogeneity Test p-value		0.0021		0.0341
b. Effect of ownership by comorbidies included in the Elixhauser index.				
	Elixhauser comorbidities = 0		Elixhauser comorbidities > 0	
Private Provider	-0.0055***	0.0014	-0.0087***	0.0044
	(-6.94)	(0.69)	(-7.01)	(1.35)
IV 1st stage choice of provider				
d_{NHS} - d_{ISP}		0.0021***		0.0020***
		(8.84)		(4.72)
Patients	2,161,662	2,161,662	1,623,021	1,623,021
1st stage F-stat		78.07		22.23
Endogeneity Test p-value		0.0035		0.0050
c. Effect of ownership by Income Deprivation Quintiles				
	Least deprived quintile		4 most deprived quintiles	
Private Provider	-0.0065***	-0.0027	-0.0072***	0.0043*
	(-7.24)	(-0.72)	(-7.19)	(1.80)
IV 1st stage choice of provider				
d_{NHS} - d_{ISP}		0.0030***		0.0019***
		(7.47)		(6.77)
Patients	722,061	722,061	3,062,622	3,062,622
1st stage F-stat		55.79		45.90
Endogeneity Test p-value		0.3480		0.0004
d Effect of ownership by Age				
	Age <= median age (59 years)		Age > median age (59 years)	
Private Provider	-0.0073***	-0.0034	-0.0068***	0.0095***
	(-7.96)	(-1.24)	(-5.28)	(3.08)
IV 1st stage choice of provider				
d_{NHS} - d_{ISP}		0.0021***		0.0020***
		(8.22)		(4.36)
Patients	1,876,280	1,876,280	1,908,403	1,908,403
1st stage F-stat		67.50		18.98
Endogeneity Test p-value		0.1827		0.0009
e. Effect of ownership – by HRG type (non-diagnostic vs diagnostic)				
	Diagnostic HRGs		Non-diagnostic HRGs	
Private Provider	-0.0030***	-0.0044	-0.0079***	0.0044**
	(-4.03)	(-0.71)	(-7.08)	(2.01)
IV 1st stage choice of provider				
d_{NHS} - d_{ISP}		0.0022***		0.0020***
		(14.15)		(5.89)
Patients	1,127,586	1,127,586	2,657,097	2,657,097
1st stage F-stat		200.11		34.66
Endogeneity Test p-value		0.8115		0.0003

Notes. Controls for confounding as in Table 2. Number of HRGs is 133 for panels *a* to *d*, and in panel *e* 14 HRGs are diagnostic and 119 are non-diagnostic. t-stats in parenthesis based on cluster-robust standard errors at HRGs level; *p<0.10, ** p<0.05, *** p<0.01.

Panel e dichotomises by type of HRG (diagnostic with a mean readmission rate of 1.88% vs non-diagnostic with a mean readmission rate of 2.17%). Again, like *panels c* and *d*, we cannot reject the null of exogeneity for the patients with a lower average readmission rate and private providers are better for the patients with diagnostic HRGs and worse for those with non-diagnostic HRGs.

Notice that in all five dichotomisations the F statistic on the differential distance instrument is considerable smaller, though always statistically significant, in the models estimated on the right hand subsamples which have higher emergency readmission rates, suggesting that unobserved selection by providers is greater for these patients.[25]

Table 9 reports results from a more detailed investigation of how the effect of ownership on quality differs by treatment type. We estimated separate models for each of the 15 HRGs with the largest number of patients treated in private hospitals.[26] The 15 HRGs have 2,123,479 patients, more than half of the full sample. The results fall into three groups:

(*i*) Five HRGs (Major & Intermediate Knee Procedures for Non-Trauma, Phacoemulsification Cataract Extraction and Lens Implant, Inguinal, Umbilical or Femoral Hernia Procedures, Major & Intermediate Hip Procedures for Non-Trauma and Minor Anal Procedures) for 688,872 patients have results similar to those for all procedures in Tables 2 and 3. The Durbin-Wu-Hausman tests reject the null of exogenous choice of hospital and the first stage F-statistics on the differential distance instrument are very large. All models have have negative and statistically significant OLS coefficients for treatment in a private hospital but the 2SLS coefficients are positive and not statistically significant at the conventional 5% level.

(*ii*) In four HRGs (Diagnostic Colonoscopy, Major Pain Procedures, Pain Radiofrequency Treatments, Diagnostic Flexible Cystoscopy) covering 525,297 patients the Durbin-Wu-

[25] While the results seem plausible, we cannot rule that partitioning the sample on patients' characteristics introduces selection bias. They rest on the assumption that selection into private hospital is orthogonal to the way we partition the sample based on observed patients' characteristics. This assumption is reasonable for panel *e* (diagnostic vs non-diagnostic HRGs): since the models include HRG fixed effects which will allow for any effect of unobserved morbidity on the type of treatment. It also seems plausible for panel *d* (below vs above median age) since unobserved morbidity will not affect patient age.

[26] Some HRGs for similar procedures (e.g. 'Major & Intermediate Knee Procedures for Non-Trauma' or 'Phacoemulsification Cataract Extraction and Lens Implant') are bundled together.

Hausman tests do not reject the null of exogenous hospital type. There are statistically insignificant effects of ownership in both OLS and 2SLS specifications.

(*iii*) Six HRGs (Diagnostic Endoscopic Upper Gastrointestinal Tract Procedures, Minor Hand Procedures for Non-Trauma, Major & Intermediate Shoulder or Upper Arm Procedures for Non-Trauma, Diagnostic Flexible Sigmoidoscopy, Minor Skin Procedures, Intermediate Foot Procedures for Non-Trauma) covering 909,310 patients have negative and statistically significant effects of private ownership with OLS but statistically insignificant effects with 2SLS. However, the Durbin-Wu-Hausman test does not reject the exogeneity of hospital ownership and so the OLS estimates are valid. For this set of HRGs patients treated in private hospitals have a lower probability of emergency readmissions.

Table 9. Effect of ownership on quality by procedure.

Procedures	HRG root codes	Private Providers: Patients (1)	Private Providers: 28-day Emergency Readmission Rate (2)	NHS Providers: Patients (3)	NHS Providers: 28-day Emergency Readmission Rate (4)	Effect of Private Ownership: OLS estimate (t-stat) (5)	Effect of Private Ownership: 2SLS estimate (t-stat) (6)	Effect of Private Ownership: Endogeneity test (p-value) (7)	First stage: 1st Stage F-stat (8)	First stage: Effect of IV on choice of private hospital (9)
Major & Intermediate Knee Procedures for Non-Trauma	HB21, B22, HB23	48,095	1.534%	144,892	2.989%	-0.0127*** (-17.67)	0.0043 (0.74)	8.6373*** (0.00)	6383.1	0.0065*** (79.89)
Phacoemulsification Cataract Extraction and Lens Implant	BZ02, BZ03	38,862	0.952%	274,157	1.482%	-0.0033*** (-5.55)	0.0051* (1.72)	8.2047*** (0.00)	21584.6	0.0047*** (146.92)
Inguinal, Umbilical or Femoral Hernia Procedures	FZ18	17,030	1.491%	66,286	3.581%	-0.0174*** (-14.63)	0.0084 (1.10)	11.4934*** (0.00)	4856.1	0.0065*** (69.69)
Major & Intermediate Hip Procedures for Non-Trauma	HB11, HB12, HB13	16,227	3.186%	54,097	4.475%	-0.0077*** (-4.62)	0.0154 (1.42)	4.6099*** (0.03)	2521.1	0.0061*** (50.21)
Minor Anal Procedures	FZ23	5,455	1.155%	23,771	2.238%	-0.0094*** (-5.12)	0.0187* (1.92)	8.3899*** (0.00)	1766.5	0.0071*** (42.03)
Diagnostic Colonoscopy	FZ51, FZ52	16,871	0.984%	266,114	1.385%	-0.0008 (-1.03)	0.0033 (0.40)	0.2529 (0.62)	6572.8	0.0024*** (81.07)
Major Pain Procedures	AB04	12,675	1.262%	87,246	1.474%	-0.0007 (-0.62)	0.0004 (0.04)	0.0138 (0.91)	1677.2	0.0029*** (40.95)
Pain Radiofrequency Treatments	AB08	6,007	1.415%	13,290	1.467%	-0.0006 (-0.30)	-0.0045 (-0.22)	0.0366 (0.85)	169.0	0.0029*** (13.00)
Diagnostic Flexible Cystoscopy	LB72	5,699	1.509%	117,395	2.141%	-0.0012 (-0.72)	0.0153 (0.97)	1.1217 (0.29)	3551.2	0.0017*** (59.59)
Diagnostic Endoscopic Upper Gastrointestinal Tract Procedures	FZ61, FZ60	25,476	0.993%	418,758	2.127%	-0.0041*** (-6.11)	-0.0141* (-1.87)	1.7909 (0.18)	11912.7	0.0023*** (109.15)
Minor Hand Procedures for Non-Trauma	HB55, HB56	12,988	0.554%	60,978	0.987%	-0.0035*** (-4.31)	-0.0034 (-0.66)	0.0008 (0.98)	3957.4	0.0058*** (62.91)
Major & Intermediate Shoulder or Upper Arm Procedures for Non-Trauma	HB61, HB62	11,160	0.824%	45,092	1.333%	-0.0043*** (-4.15)	-0.0068 (-0.79)	0.0820 (0.77)	2015.3	0.0060*** (44.89)
Diagnostic Flexible Sigmoidoscopy	FZ54, FZ55	10,007	1.009%	158,579	1.764%	-0.0031*** (-2.75)	-0.0025 (-0.21)	0.0027 (0.96)	5008.4	0.0020*** (70.77)
Minor Skin Procedures	JC43	9,596	0.573%	116,668	1.146%	-0.0045*** (-4.82)	0.0064 (0.61)	1.0772 (0.30)	3262.0	0.0023*** (57.11)
Intermediate Foot Procedures for Non-Trauma	HB33, HB32	8,133	0.898%	31,875	1.785%	-0.0057*** (-4.50)	-0.0144 (-1.42)	0.7416 (0.39)	2300.1	0.0053*** (47.96)

Notes. Controls for confounding as in Table 1 (excluding HRG dummies). t-stats based on heteroscedasticity-robust standard errors; IV: patient distance to nearest NHS provider minus patient distance to nearest private provider. * p<0.10, ** p<0.05, *** p<0.01. 15 procedures with highest number of NHS patients in private providers.

5 Conclusions

In the English NHS publicly funded patients have historically been treated almost entirely in public hospitals. Recently private providers have been allowed to enter the market and to treat NHS patients. We use a treatment outcome – whether the patient subsequently had an emergency readmission within 28 days of discharge from their initial planned treatment – to compare quality for publicly funded patients in public and private hospitals. We have data on 133 different planned treatments undergone by 3.8 million NHS funded patients in England between April 2013 and February 2014. We find that, on average over all treatments studied, private hospitals and public hospitals provide similar quality of care once we include case-mix and allow for unobserved selection into hospital type with an instrumental variable (difference in the distance to the nearest private and NHS hospitals). Simple case-mix adjustment based on observed patient characteristics alone provides biased estimates of quality differences that suggest that private providers have higher quality for publicly funded patients than NHS providers.

We also find no quality differences between public and private specialised and non-specialised providers. Nor does quality in private providers depend on whether they are for profit or not profit. There are however statistically and economically significant differences in quality between public and private providers for specific types of care. For example, public providers have higher quality overall for non-diagnostic treatments whilst private providers do better overall for diagnostic treatments. We find no difference in quality between public and private providers for four of the five non-diagnostic treatments with the largest number of patients in private providers.

Our analysis has two main policy implications. First, evaluating the opening of the market to private hospitals requires consideration of the effects on the quality of care for NHS patients as well as on waiting times and the cost to taxpayers who fund the NHS. Public and private providers are paid in the same way for the procedures we considered, so that there is no difference in the direct cost to the taxpayer. We find that, on average, there is no difference between public and private providers in a major measure of quality (emergency readmission rates). Hence evaluation of the policy needs to consider its effects on other aspects of quality, such as patient reported outcomes, and on patient waiting times. Second, emergency readmissions are a common quality indicator. Our analysis suggests that casemix adjustment based on observable covariates is not sufficient to make readmission rates comparable across public and private providers, so that the lack of control for unobserved patient heterogeneity may bias the comparison across providers. Our study has demonstrated it is possible to correct for this. With appropriate methods policy makers can monitor quality even in the absence of complete information to adjust for casemix differences between public and private providers.

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Appendix

Table A1. Numbers of sites and patients by hospital type.

	Sites	Patients
NHS providers	393	3,407,820
NHS non-treatment centres	387	3,359,963
NHS treatment centres	6	47,857
Private providers	190	376,863
Private non-treatment centres	148	202,152
Private treatment centres	42	174,711
Private for profit	157	335,132
Private not for profit	32	41,731

Notes. Providers are hospital sites. Ownership and for profit status is attached to the organisation that owns the sites. Numbers are from the estimation samples. One HRG was dropped from the model with FP and NFP providers as it was not carried out in any NFP provider.

Table A2. Volume and share of patients into NHS and private hospitals, by HRG4 root.

HRG 4 ROOTS	HRG 4 name	Total number of patients	Volume in NHS hospitals	Volume in ISP hospitals	% ISP of total patients	Number of NHS hospital sites	Number of ISP hospital sites
AA21	Minor Intracranial Procedures Except Trauma, with Other Diagnoses	8,006	7,775	231	2.89%	183	50
AA26	Muscular, Balance, Cranial or Peripheral Nerve Disorders, Epilepsy or Head Injury	23,572	23,395	177	0.75%	243	39
AB03	Complex Pain Procedures	20,667	17,188	3,479	16.83%	210	82
AB04	Major Pain Procedures	99,921	87,246	12,675	12.69%	241	112
AB05	Intermediate Pain Procedures	21,750	19,156	2,594	11.93%	232	100
AB06	Minor Pain Procedures	24,707	22,492	2,215	8.97%	253	140
AB08	Pain Radiofrequency Treatments	19,297	13,290	6,007	31.13%	169	83
AB09	Other Specified Pain Procedures	4,081	3,658	423	10.37%	181	56
BZ01	Enhanced Cataract Surgery	7,941	7,565	376	4.73%	169	37
BZ02	Phacoemulsification Cataract Extraction and Lens Implant	313,019	274,157	38,862	12.42%	202	101
BZ04	Lens Capsulotomy with CC Score 0	11,554	10,505	1,049	9.08%	76	11
BZ06	Intermediate Oculoplastics Procedures, 19 years and over	13,233	12,858	375	2.83%	240	47
BZ07	Minor Oculoplastics Procedures, 19 years and over	41,570	40,139	1,431	3.44%	268	66
BZ10	Minor Orbits or Lacrimal Procedures, 19 years and over	7,570	7,199	371	4.90%	192	25
BZ23	Minor Vitreous Retinal Procedures	106,361	103,852	2,509	2.36%	169	12
CA10	Septorhinoplasty, 19 years and over	4,452	4,066	386	8.67%	153	69
CA11	Septoplasty, 19 years and over	14,472	12,588	1,884	13.02%	175	98
CA14	Nasal Polypectomy	3,205	3,054	151	4.71%	158	60
CA15	Excision or Biopsy, of Lesion of Internal Nose	2,431	2,293	138	5.68%	184	61
CA16	Excision or Biopsy, of Lesion of External Nose	5,615	5,298	317	5.65%	246	45
CA21	Very Major Nose Procedures	1,701	1,373	328	19.28%	159	53
CA22	Major Nose Procedures	5,159	4,377	782	15.16%	174	85
CA24	Minor Nose Procedures, 19 years and over	2,720	2,527	193	7.10%	182	68
CA25	Minimal Nose Procedures, 19 years and over	2,281	2,124	157	6.88%	168	50
CA28	Intermediate Sinus Procedures	7,239	6,293	946	13.07%	171	90
CA32	Tympanoplasty, 19 years and over	6,725	6,425	300	4.46%	162	59
CA34	Excision or Biopsy, of Lesion of External Ear, 19 years and over	7,503	7,063	440	5.86%	255	79
CA35	Insertion of Grommets, between 2 and 18 years	21,958	21,435	523	2.38%	180	78
CA36	Clearance of External Auditory Canal, 19 years and over	4,642	3,260	1,382	29.77%	167	32
CA60	Tonsillectomy, 18 years and under	31,364	29,739	1,625	5.18%	163	95
CA66	Excision or Biopsy, of Lesion of Mouth, 19 years and over	20,351	19,820	531	2.61%	253	62
CA69	Diagnostic, Laryngoscopy or Pharyngoscopy, 19 years and over	11,113	9,349	1,764	15.87%	228	66
CD01	Major Dental Procedures, 19 years and over	21,926	19,959	1,967	8.97%	172	23
CD04	Major Surgical Removal of Tooth, 19 years and over	30,833	28,357	2,476	8.03%	173	26
CD05	Surgical Removal of Tooth, 19 years and over	26,959	23,832	3,127	11.60%	190	28
CD06	Extraction of Multiple Teeth, 18 years and under	49,742	48,728	1,014	2.04%	193	19
CD07	Minor Extraction of Tooth, 19 years and over	12,095	11,645	450	3.72%	183	16
FZ13	Minor Therapeutic or Diagnostic, General Abdominal Procedures, 19 years and over	11,111	10,583	528	4.75%	237	92
FZ17	Abdominal Hernia Procedures, 19 years and over	12,353	10,778	1,575	12.75%	248	144
FZ18	Inguinal, Umbilical or Femoral Hernia Procedures, 19 years and over	83,316	66,286	17,030	20.44%	261	155
FZ21	Major Anal Procedures, 19 years and over	7,134	6,497	637	8.93%	236	93

FZ22	Intermediate Anal Procedures, 19 years and over,	32,049	28,082	3,967	12.38%	251	114
FZ23	Minor Anal Procedures, 19 years and over	29,226	23,771	5,455	18.66%	253	115
FZ50	Intermediate Large Intestine Procedures, 19 years and over	7,533	7,246	287	3.81%	235	73
FZ51	Diagnostic Colonoscopy, 19 years and over	147,485	138,095	9,390	6.37%	240	120
FZ52	Diagnostic Colonoscopy with Biopsy, 19 years and over	135,500	128,019	7,481	5.52%	241	118
FZ53	Therapeutic Colonoscopy, 19 years and over	98,725	94,869	3,856	3.91%	235	110
FZ54	Diagnostic Flexible Sigmoidoscopy, 19 years and over	116,082	108,204	7,878	6.79%	249	115
FZ55	Diagnostic Flexible Sigmoidoscopy with Biopsy, 19 years and over	52,504	50,375	2,129	4.05%	241	104
FZ56	Therapeutic Flexible Sigmoidoscopy, 19 years and over	19,672	18,820	852	4.33%	238	91
FZ60	Diagnostic Endoscopic Upper Gastrointestinal Tract Procedures, 19 years and over	141,462	133,200	8,262	5.84%	246	113
FZ61	Diagnostic Endoscopic Upper Gastrointestinal Tract Procedures with Biopsy, 19 years and over	302,772	285,558	17,214	5.69%	245	115
FZ63	Combined Upper and Lower Gastrointestinal Tract Diagnostic Endoscopic Procedures	5,730	5,514	216	3.77%	226	60
FZ64	Combined Upper and Lower Gastrointestinal Tract Diagnostic Endoscopic Procedures with Biopsy, 19 years and over	44,902	43,711	1,191	2.65%	237	99
FZ65	Combined Upper and Lower Gastrointestinal Tract Therapeutic Endoscopic Procedures	9,335	9,155	180	1.93%	230	55
FZ70	Therapeutic Endoscopic Upper Gastrointestinal Tract Procedures, 19 years and over	12,997	12,803	194	1.49%	221	47
FZ76	Distal Colon Procedures, 19 years and over,	1,739	1,547	192	11.04%	195	46
FZ91	Non-Malignant Gastrointestinal Tract Disorders with Single Intervention,	15,724	15,550	174	1.11%	263	53
GA10	Laparoscopic Cholecystectomy, 19 years and over	57,679	52,461	5,218	9.05%	222	103
HB11	Major Hip Procedures for Non-Trauma, Category 2	13,698	11,100	2,598	18.97%	211	128
HB12	Major Hip Procedures for Non-Trauma, Category 1	54,815	41,405	13,410	24.46%	228	150
HB13	Intermediate Hip Procedures for Non-Trauma, Category 2	1,811	1,592	219	12.09%	168	61
HB14	Intermediate Hip Procedures for Non-Trauma, Category 1	6,489	5,675	814	12.54%	226	98
HB15	Minor Hip Procedures for Non-Trauma, Category 2, 19 years and over	6,431	5,724	707	10.99%	235	106
HB19	Minimal Hip Procedures for Non-Trauma	20,353	17,333	3,020	14.84%	241	142
HB21	Major Knee Procedures for Non-Trauma, Category 2	74,297	57,129	17,168	23.11%	232	153
HB22	Major Knee Procedures for Non-Trauma, Category 1	45,379	30,722	14,657	32.30%	251	165
HB23	Intermediate Knee Procedures for Non-Trauma	73,311	57,041	16,270	22.19%	257	167
HB24	Minor Knee Procedures for Non-Trauma, Category 2	13,956	12,536	1,420	10.17%	255	147
HB25	Minor Knee Procedures for Non-Trauma, Category 1, 19 years and over	7,567	7,052	515	6.81%	242	131
HB29	Minimal Knee Procedures for Non-Trauma	11,182	8,898	2,284	20.43%	226	112
HB31	Major Foot Procedures for Non-Trauma	8,705	6,966	1,739	19.98%	222	125
HB32	Intermediate Foot Procedures for Non-Trauma, Category 2, 19 years and over	19,638	15,552	4,086	20.81%	243	135
HB33	Intermediate Foot Procedures for Non-Trauma, Category 1, 19 years and over	20,370	16,323	4,047	19.87%	247	141
HB34	Minor Foot Procedures for Non-Trauma, Category 2, 18 years and under	27,822	23,855	3,967	14.26%	244	145
HB35	Minor Foot Procedures for Non-Trauma, Category 1	6,214	5,175	1,039	16.72%	244	126
HB39	Minimal Foot Procedures for Non-Trauma	12,315	10,459	1,856	15.07%	224	106
HB51	Major Hand Procedures for Non-Trauma, Category 2	8,980	7,304	1,676	18.66%	227	118
HB53	Intermediate Hand Procedures for Non-Trauma, Category 2	9,373	7,944	1,429	15.25%	236	128
HB54	Intermediate Hand Procedures for Non-Trauma, Category 1	15,143	13,110	2,033	13.43%	258	145
HB55	Minor Hand Procedures for Non-Trauma, Category 2	73,966	60,978	12,988	17.56%	269	161
HB59	Minimal Hand Procedures for Non-Trauma	9,862	8,506	1,356	13.75%	218	101
HB61	Major, Shoulder or Upper Arm Procedures for Non-Trauma	34,613	27,296	7,317	21.14%	238	142
HB62	Intermediate, Shoulder or Upper Arm Procedures for Non-Trauma	21,639	17,796	3,843	17.76%	245	139
HB63	Minor, Shoulder or Upper Arm Procedures for Non-Trauma	9,623	8,164	1,459	15.16%	252	144
HB69	Minimal, Shoulder or Upper Arm Procedures for Non-Trauma	8,185	6,414	1,771	21.64%	182	89
HB71	Major, Elbow or Lower Arm Procedures for Non-Trauma	2,050	1,858	192	9.37%	206	65
HB72	Intermediate, Elbow or Lower Arm Procedures for Non-Trauma	6,174	5,610	564	9.14%	241	112
HB73	Minor, Elbow or Lower Arm Procedures for Non-Trauma	7,287	6,254	1,033	14.18%	238	125
HB99	Other Procedures for Non-Trauma	8,560	8,013	547	6.39%	265	98
HC04	Extradural Spine Intermediate 1	16,362	13,429	2,933	17.93%	152	81
HC05	Extradural Spine Minor 2	3,519	3,050	469	13.33%	200	69
HC06	Extradural Spine Minor 1	4,908	4,041	867	17.67%	204	82
HC26	Scoliosis or Other Spinal Deformity	1,726	1,579	147	8.52%	175	48
HC27	Degenerative Spinal Conditions	34,633	29,960	4,673	13.49%	243	100
HC32	Low Back Pain	2,128	1,982	146	6.86%	178	39
HD21	Soft Tissue Disorders	8,272	7,645	627	7.58%	236	84
HR07	Orthopaedic Reconstruction with Intervention Score 43 or less, with Diagnosis Score 61 or more	13,648	12,407	1,241	9.09%	241	136
HR08	Orthopaedic Reconstruction with Intervention Score 44-65, with Diagnosis Score 23-60	11,877	9,599	2,278	19.18%	233	126
HR09	Orthopaedic Reconstruction with Intervention Score 66 or more, with Diagnosis Score 23-60	2,757	2,356	401	14.54%	208	83
JC42	Intermediate Skin Procedures, 13 years and over	28,524	27,738	786	2.76%	290	124
JC43	Minor Skin Procedures, 13 years and over	126,264	116,668	9,596	7.60%	316	161
KA09	Thyroid Procedures with CC Score 4+	8,784	8,653	131	1.49%	181	36
LB09	Intermediate Endoscopic Ureter Procedures, 19 years and over	15,401	15,049	352	2.29%	219	62
LB14	Intermediate Endoscopic Bladder Procedures	23,972	23,216	756	3.15%	237	90
LB15	Minor Bladder Procedures, 19 years and over	21,580	20,996	584	2.71%	231	82
LB17	Introduction of Therapeutic Substance into Bladder	12,473	12,103	370	2.97%	136	13
LB25	Transurethral Prostate Resection Procedures	16,829	15,642	1,187	7.05%	171	90
LB26	Intermediate Endoscopic, Prostate or Bladder Neck Procedures (Male and Female)	2,330	2,166	164	7.04%	186	49
LB27	Minor Endoscopic, Prostate or Bladder Neck Procedures (Male)	16,664	16,235	429	2.57%	184	49

LB33	Vasectomy Procedures	7,397	4,998	2,399	32.43%	187	52
LB36	Extracorporeal Lithotripsy	21,329	21,097	232	1.09%	122	9
LB51	Vaginal Tape Operations for Urinary Incontinence,	8,299	7,599	700	8.43%	197	78
LB54	Minor, Scrotum, Testis or Vas Deferens Procedures, 19 years and over	15,086	13,431	1,655	10.97%	259	116
LB55	Minor or Intermediate, Urethra Procedures, 19 years and over	16,873	15,149	1,724	10.22%	249	107
LB56	Minor Penis Procedures, between 2 and 18 years	29,092	26,304	2,788	9.58%	254	109
LB72	Diagnostic Flexible Cystoscopy, 19 years and over	123,094	117,395	5,699	4.63%	250	107
MA04	Intermediate Open Lower Genital Tract Procedures	9,755	8,427	1,328	13.61%	205	102
MA07	Major Open Upper Genital Tract Procedures	24,656	21,794	2,862	11.61%	196	110
MA08	Major, Laparoscopic or Endoscopic, Upper Genital Tract Procedures,	11,368	10,572	796	7.00%	194	98
MA10	Minor, Laparoscopic or Endoscopic, Upper Genital Tract Procedures	14,981	13,269	1,712	11.43%	213	107
MA12	Resection or Ablation Procedures for Intra-Uterine Lesions	34,700	30,982	3,718	10.71%	213	117
MA22	Minor Lower Genital Tract Procedures	9,552	8,226	1,326	13.88%	237	117
MA23	Minimal Lower Genital Tract Procedures	16,267	15,334	933	5.74%	233	100
MA30	Intermediate Female Pelvic Peritoneum Adhesion Procedures	6,505	5,384	1,121	17.23%	211	102
MA31	Diagnostic Hysteroscopy	7,587	6,788	799	10.53%	214	100
MA32	Diagnostic Hysteroscopy with Biopsy	20,410	18,490	1,920	9.41%	215	104
MA33	Diagnostic Hysteroscopy with Biopsy and Implantation of Intrauterine Device	7,834	6,669	1,165	14.87%	207	100
MA35	Implantation of Intrauterine Device	2,632	2,361	271	10.30%	198	67
YQ16	Open Treatment of Primary Unilateral Varicose Veins	7,126	6,127	999	14.02%	202	43
YR30	Percutaneous Transluminal, Laser or Radiofrequency Ablation, of Bilateral Varicose Veins	1,520	1,415	105	6.91%	105	16
YR31	Percutaneous Transluminal, Laser or Radiofrequency Ablation, of Unilateral Varicose Veins	9,527	8,929	598	6.28%	122	23
YR33	Sclerotherapy of Unilateral Varicose Veins	3,869	3,578	291	7.52%	114	17

Table A3. Correlation of differential distance IV and patient's severity covariates.

	Emergency admissions during previous year		Elixhauser Index	
	(1)	(2)	(3)	(4)
IV: d_{NHS} - d_P	0.0000	-0.0000	0.0001	0.0006
	(0.8400)	(-0.0134)	(0.4323)	(1.6093)
$(d_{NHS}$ - $d_P)$^2		-0.0000		0.0000*
		(-0.6586)		(1.8135)
distance to first NHS non TC	-0.0008***	-0.0008***	-0.0011***	-0.0013***
	(-6.9502)	(-6.4210)	(-3.4027)	(-3.6793)
GP QOF achievement score	-0.0009***	-0.0009***	0.0017***	0.0017***
	(-5.5690)	(-5.5723)	(6.1115)	(6.0647)
Rural patient	-0.0105***	-0.0107***	-0.0032	-0.0018
	(-5.5531)	(-5.7364)	(-0.7090)	(-0.3769)
Daycase patient	-0.0914***	-0.0914***	-0.1868***	-0.1865***
	(-8.9967)	(-8.9948)	(-11.3507)	(-11.3556)
Female patient	-0.0143**	-0.0143**	0.0072	0.0072
	(-2.0638)	(-2.0638)	(0.7477)	(0.7483)
Patient age	-0.0006**	-0.0006**	0.0147***	0.0147***
	(-1.9984)	(-1.9977)	(23.6303)	(23.6432)
Number of Elixhauser co-morbidities	0.0920***	0.0920***		
	(13.8702)	(13.8699)		
IMD 2010 income score	0.2687***	0.2688***	0.6761***	0.6753***
	(12.7796)	(12.7935)	(17.0780)	(17.0029)
Number of Emergency admissions previous year			0.1441***	0.1441***
			(25.5576)	(25.5588)
constant	0.3236***	0.3233***	-0.2505***	-0.2475***
	(15.5797)	(15.5015)	(-5.4950)	(-5.2486)
Patients	3784683	3784683	3784683	3784683
HRGs	133	133	133	133
R^2	0.0609	0.0609	0.1451	0.1451
AIC	8165778.2	8165777.6	9867036.	9866858.6
BIC	8165896.5	8165909.1	9867154.9	9866990.1
AIC linear - AIC quadratic	0.6		177.4	
BIC linear - BIC quadratic	-12.6		164.8	

Notes. d_{NHS}: patient distance to nearest NHS hospital. d_P: patient distance to nearest private provider. Distances computed to generate the instrumental variables are procedure specific. t-stats in parenthesis based on cluster-robust standard errors at HRG level; * p<0.10, ** p<0.05, *** p<0.01.

Table A4. Covariate-adjusted difference in means t-test for main confounders.

(A) Confounder	(B) Mean of (A) confounder if $d_{NHS,j} - d_{P,j} <= mean(d_{NHS,j} - d_{P,j})$	(C) Mean of (A) confounder if $d_{NHS,j} - d_{P,j} > mean(d_{NHS,j} - d_{P,j})$	(D = C-B) Difference: Means	(E) Difference: Covariate Adjusted Means	(F) t-statistic for column E	(G) p-value for t-statistic
Past Emergency Admissions	0.2302	0.2331	0.0029	-0.0005	-0.1559	0.8764
Elixhauser Index	0.6703	0.6859	0.0156	0.017	2.6066	0.0102
Income deprivation	0.143	0.1477	0.0047	0.0012	1.0719	0.2857
Patient Age	56.3727	55.8013	-0.5714	-0.4637	-1.8036	0.0736

Notes. The conditional means of the four confounding variables are adjusted using linear regression models with HRGs fixed effects as in Eq. (6) but having the either one of the four listed covariates as outcome variable. The regression model used to compute the adjusted means of the two subgroups is the same as the one in Table A3, except for the absence of the IV terms, which are replaced by a binary indicator for whether the differential distance $d_{NHS,j} - d_{P,j}$ for a given patient is smaller or greater than its mean (by HRG4 root). Sample sizes are 1,194,314 and 2,590,369 respectively for (B) and (C).

Table A5. Effect of ownership on emergency readmission probability: full results.

	OLS	IV First Stage	2SLS
	(1)	(2)	(3)
	Emergency Readmission	Private Provider	Emergency Readmission
Private Provider	-0.0070***		0.0028
	(-7.3660)		(1.2956)
$d_{NHS} - d_P$		0.0021***	
		(6.9783)	
$d_{NHSnonTC}$	-0.0001***	0.0011***	-0.0001***
	(-3.1627)	(5.4195)	(-3.7077)
GP QOF quality	-0.0001***	0.0004***	-0.0001***
	(-3.0940)	(3.3683)	(-3.2361)
Patient living in rural area (LSOA)	-0.0005**	0.0061***	-0.0004**
	(-2.2877)	(2.6520)	(-2.0341)
Daycase patient	-0.0102***	-0.0896***	-0.0093***
	(-9.9675)	(-5.5145)	(-8.7418)
Female patient	-0.0013***	0.0030**	-0.0013***
	(-3.3644)	(2.0061)	(-3.4212)
Patient aged 0-19 years	-0.0025	-0.0882***	-0.0017
	(-0.8906)	(-7.8309)	(-0.5977)
Patient aged 20-39 years	0.0027**	0.0214***	0.0024**
	(2.3042)	(3.2166)	(2.1408)
Patient aged 40-59 years	-0.0011**	0.0186***	-0.0012***
	(-2.3590)	(5.7898)	(-2.9206)
Patient aged over 80 years	0.0103***	-0.0186***	0.0105***
	(7.1923)	(-6.0605)	(7.2460)
N. past year emergency admissions	0.0242***	-0.0156***	0.0243***
	(35.7515)	(-10.7951)	(36.5689)
Number of Elixhauser co-morbidities	0.0042***	-0.0039	0.0043***
	(16.2827)	(-1.4704)	(16.7363)
IMD income deprivation score	0.0109***	-0.1325***	0.0122***
	(9.2000)	(-12.4959)	(9.3523)
Constant	0.0375***	0.1063***	0.0368***
	(21.5176)	(4.6885)	(22.0259)
HRGs Fixed Effects	YES	YES	YES
Statistics			
Patients	3784683	3784683	3784683
HRGs	133	133	133
R^2	0.0303	0.0819	0.0299
1st stage F-stat			48.6961
1st stage F-stat p-value			0.0000
Durbin-Wu-Hausman Endogeneity Test Chi^2			10.9500
Durbin-Wu-Hausman Endogeneity Test p-value			0.0009

Notes. All models include 133 HRGs and; $d_{NHSnonTC}$: distance from the centroid of patient's residence LSOA to the closest general NHS hospital. d_{NHS}: patient distance to nearest NHS hospital. d_P: patient distance to nearest private provider. Distances computed to generate the instrumental variables are procedure specific. t-stats in parenthesis based on cluster-robust standard errors at HRG level; * p<0.10, ** p<0.05, *** p<0.01.

Table A6. Effect of ownership and specialization on emergency readmission probability.

	Emergency Readmission (1) OLS	Emergency Readmission (2) 2SLS		
Private non-TC	-0.0091***	0.0022		
	(-8.2411)	(0.4928)		
Private TC	-0.0047***	0.0058**		
	(-5.8639)	(2.1076)		
1st stage choice of provider type				
			Private non-TC	Private TC
$d_{NHS} - d_{PnonTC}$			0.0010***	-0.0008***
			(6.7730)	(-5.2629)
$d_{NHS} - d_{ISTC}$			-0.0002***	0.0017***
			(-2.6916)	(8.8357)
Patients	3784683	3784683	3784683	3784683
Number of HRGs	133	133	133	133
R^2	0.0303	0.0374	0.0507	0.0175
1st stage F-stat – Private non-TC			30.3505	
1st stage F-stat – ISTC				53.7565
Endogeneity Test Chi^2 stat.				8.6401
Endogeneity Test p-value				0.0133
Wald Test p-value: Private non-TC = ISTC	0.0000	0.3996		
Wald Test p-value: Private non-TC = ISTC = 0	0.0000	0.0991		

Notes. Controls for confounding as in Table 4. TC: treatment centre. d_{NHS} = patient distance to nearest NHS hospital site, d_{PnonTC} = patient distance to nearest private non TC, d_{ISTC} = patient distance to nearest private TC hospital site. t-stats in parenthesis based on cluster-robust standard errors at HRG level. * p<0.10, ** p<0.05, *** p<0.01.