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# Choice of hospital: which type of quality matters?

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## Abstract

The implications of hospital quality competition depend on what type of quality affects choice of hospital. Previous studies of quality and choice of hospitals have used crude measures of quality such as mortality and readmission rates rather than measures of the health gain from specific treatments. We estimate multinomial logit models of hospital choice by patients undergoing hip replacement surgery in the English NHS to test whether hospital demand responds to quality as measured by detailed patient reports of health before and after hip replacement. We find that a one standard deviation increase in average health gain increases demand by up to 10%. The more traditional measures of hospital quality are less important in determining hospital choice.

**JEL:** I11, I18

**Key words:** Quality, demand, healthcare, hospitals, competition, patient reported outcomes

## 1 Introduction

Many European healthcare systems have recently extended patients' right to choose their provider of elective hospital care (Vrangbaek et al. 2012). One of the aims is to encourage hospitals to compete for patients by improving quality (Besley and Ghatak 2003). A prerequisite for this is that patients' choice of hospital is influenced by quality (Marshall et al. 2004; Faber et al. 2009). But quality is multi-dimensional and the implications of increased incentives to compete on quality depend on which aspects of hospital quality affect demand: if demand responds to a limited set of quality dimensions then hospital attempts to attract patients may be misdirected.

Studies of quality and choice of hospital have measured quality by mortality rates, either at hospital level or for specific conditions (e.g. Sivey 2008; Beckert et al. 2012; Moscone et al. 2012; Gaynor et al. 2012; McConnell et al. forthcoming), readmission rates (Varkevisser et al. 2012; Moscone et al. 2012; McConnell et al. forthcoming), or hospital reputation and composite scores (Pope 2009; Bundorf et al. 2009; Varkevisser et al. 2010; Varkevisser et al. 2012; Ruwaard and Douven 2014).<sup>1</sup> See Brekke et al. (2014) for an overview. The studies typically report a positive association between quality measures and hospital demand.

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<sup>1</sup>Early studies from the US include Folland (1983), Luft et al. (1990), Burns and Wholey (1992), Hodgkin (1996), Tay (2003), Howard (2005) and Ho (2006).

1 But these quality measures, even those that are condition-specific, are incomplete, revealing  
2 little about the changes in health and functioning that patients will experience as the result of  
3 treatment (Appleby and Devlin 2004). In this paper we use newly available data to examine whether  
4 choice of hospital is also influenced by quality measures based on detailed patient reports of health  
5 and functioning before and after treatment.  
6

7 Since April 2009, all hospitals in England have been required to collect patient-reported outcome  
8 measures (PROMs) for National Health Service (NHS)-funded patients undergoing hip and knee  
9 replacement, varicose vein surgery or groin hernia repair (Department of Health 2008).<sup>2</sup> PROMs  
10 are detailed validated questionnaires used to measure patients' health status, functioning, and  
11 health-related quality of life before and after treatment. Hospital quality measures derived from  
12 PROMs improve over 'failure' measures such as mortality or emergency readmission rates in several  
13 ways. First, they capture more dimensions of health and more sensitively (Appleby and Devlin  
14 2004; Gutacker et al. 2013). Second, they embody much better adjustment for case-mix, because  
15 they incorporate the rich pre-operative PROMs data. Finally, PROMs reflect the patients' views  
16 on their health and health improvement. Hospital-specific average risk-adjusted changes in patient  
17 health status have been produced and disseminated online to support the Department of Health's  
18 ambition that they would be used "*by patients and [general practitioners (GPs)] exercising choice*"  
19 (Department of Health 2008, p.6).<sup>3 4</sup>

26 We use newly available PROMs-based quality data to estimate a multinomial logit model of  
27 patient choice of hospital for hip replacement surgery to test whether hospital demand responds  
28 to the aspects of quality captured by PROMs, as well as to more conventional measures such as  
29 mortality and readmission rates.<sup>5</sup> Our main empirical strategy relies on the use of lagged hospital  
30 quality variables to identify the effect of quality on hospital choice: patients are assumed to use  
31 quality information that is made publicly available with a one-year lag and that can therefore not  
32 be affected by current choices. We test the robustness of our results by estimating models with  
33 hospital fixed effects, and by using closely matched emergency hip replacement patients as a control  
34 group.  
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39 We find that patients are more likely to choose providers producing greater health gains. In  
40 our baseline specification, the elasticity of hospital demand with respect to the average health gain  
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42 <sup>2</sup>Similar initiatives are underway or being considered in other health systems, including Sweden (Rolfson et al.  
43 2011), Australia (Arthroplasty Clinical Outcomes Registry 2015), Canada (McGrail et al. 2012), the Netherlands  
44 (Landelijke Registratie Orthopedische Implantaten 2013) and the US (Basch et al. 2013).

45 <sup>3</sup>The English NHS is funded by general taxation and there are no charges to patients (except for a small charge for  
46 dispensed medicines). Providers receive a nationally set prospective price for hip replacement paid for by the patient's  
47 Primary Care Trust from its capitated budget. There is a list system in general practice and patients wishing to  
48 access elective care must be referred to a hospital by their GP. If a hospital specialist decides the patient should  
49 be treated she is placed on a waiting list. Patients have the right to be treated at any qualified provider (NHS or  
50 private). Providers must accept all clinically appropriate referrals from GPs and cannot close their waiting lists to  
51 new patients.

52 <sup>4</sup>Some patients might access this information directly, whereas others might rely on their GPs, who act as their  
53 agent, to retrieve, interpret and communicate this information. In some instances, patients may not even be willing  
54 or able to make a choice and their referring GP may choose the most appropriate hospital for them, i.e. the GP acts  
55 as an agent to the patient. It is generally not possible to distinguish between decision makers using administrative  
56 data. For simplicity, we will henceforward denote the decision-maker as the patient.

57 <sup>5</sup>Information on the average change in PROM scores by hospital, including the change in the Oxford Hip Score as  
58 used in our analysis, is reported to the general public through the NHS Choices website (<http://www.nhs.uk/>) and  
59 the Health & Social Care Information Centre website (<http://www.hscic.gov.uk/proms>). The same public sources  
60 also provide information on procedure-specific mortality, emergency readmission and revision rates.  
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1 (measured in terms of the Oxford Hip Score) is 1.4, whereas the demand elasticities with respect to  
2 the readmission rate and the mortality rate are -0.02 and -0.004. A one standard deviation increase  
3 in the health gain increases demand by up to 9.8% whereas one standard deviation increases in  
4 readmission and mortality rates reduce demand by 6.8% and 0.7%, respectively. This suggests that  
5 hospitals' abilities to improve their patients' health reflect an important dimension of quality that  
6 is valued by patients and not captured by other quality measures. Our robustness analyses, both  
7 with emergency patients as a control group and using hospital fixed effects, also find statistically  
8 significant, though smaller, marginal willingness to travel for higher PROM quality and lower  
9 elasticities of demand. For example, using emergency patients as a control group we find the  
10 demand elasticity to PROM quality to be 0.6 and a one standard deviation increase in health gain  
11 is estimated to increase demand by 4.4%.  
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16 Our study makes a number of contributions. It is the first to explore whether hospital demand  
17 responds to quality as measured by average health gains derived from patient self-reported outcome  
18 measures. Second, we make novel use of pre-operative individual level PROMs data to explore  
19 whether sicker patients travel farther and choose hospitals with higher quality of care. Such  
20 self-selection can bias performance assessments ('*distance bias*') and create perverse incentives in  
21 the context of e.g. pay-for-performance schemes (Gowrisankaran and Town 1999; Etzioni et al.  
22 2013). Previous studies have either relied on instrumental variable approaches to allow for the effect  
23 of unobserved pre-operative health status on demand (Gowrisankaran and Town 1999; Geweke  
24 et al. 2003) or have used simple measures of comorbidity and past utilisation. Our data has rich  
25 information on pre-operative health, which allows us to address this question directly. Third, our  
26 paper contributes to the small literature on hospital choice in publicly funded health systems where  
27 prices are regulated and demand is rationed by waiting time (Sivey 2012; Beckert et al. 2012;  
28 Moscone et al. 2012; Gaynor et al. 2012). Our analysis differs from Beckert et al. (2012), who also  
29 study choice of provider for hip replacement surgery in England, in that we use provider quality  
30 measures that are procedure-specific and more directly related to the quality of care provided<sup>6</sup>,  
31 explore the role of pre-operative health status, and model the entire NHS market, including private  
32 providers of NHS-funded care.  
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40 More broadly, the analysis relates to the literature on hospital report cards, which has mostly  
41 focused on the publication of coronary artery bypass graft (CABG) surgery quality scores in a  
42 number of US states. For example, Chou et al. (2014) investigate whether information on quality  
43 gives stronger incentives to improve care for hospitals that face more competition. They find that  
44 after the online publication of CABG report cards in Pennsylvania, hospitals in more competitive  
45 areas used more resources per patient and had lower mortality for more severe patients than  
46 those in less competitive areas. Wang et al. (2011) find that the probability of patients receiving  
47 CABG surgery from low-performing surgeons was significantly reduced following the publication  
48 of report cards. In contrast, Epstein (2010) failed to detect changes in referrals following the  
49 introduction of report cards in Pennsylvania compared to the counterfactual state Florida, and  
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55 <sup>6</sup>Beckert et al. (2012) model hospital quality using hospital-wide mortality and MRSA infection rates. Aggregate  
56 hospital level quality indicators, such as the summary hospital mortality indicator (SHMI) used in the English NHS,  
57 do not correlate well with procedure-specific outcome measures (Gravelle et al. 2014). In 2010/11, the Pearson  
58 correlation coefficients between SHMI and the quality measures used in this study were -0.09 (change in OHS), -0.07  
59 (emergency readmission rate), -0.005 (revision rate) and 0.08 (mortality rate), respectively.  
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1 this may be due to referring physicians already having expectations about the relative performance  
2 of cardiac surgeons. The result is consistent with Dranove and Sfekas (2008) who find that the  
3 introduction of report cards in New York State was less effective when the ratings confirmed prior  
4 beliefs about quality. Dranove et al. (2003) found that the introduction of report cards led to a  
5 reduction in average severity with doctors trying to avoid high-risk patients. Cutler et al. (2004)  
6 observed improvements in quality for New York State hospitals that received a negative report  
7 card, suggesting that healthcare providers are responsive to quality reporting. This literature  
8 analyses either aggregate demand patterns or individual choice behaviour using discrete choice  
9 models (similar to the approach adopted in this study) and takes quasi-experimental approaches or  
10 panel data techniques to establish causality.

11 In the next section we describe the data and in Section 3 we set out the econometric model and  
12 our strategy to mitigate potential endogeneity bias. In Section 4 we present the estimated marginal  
13 utilities of different aspects of quality and other hospital characteristics and show how these vary  
14 with observed patient characteristics. Section 5 reports estimates of the effect of providers' quality  
15 on their own demand and on demand of their competitors. In Section 6 we discuss the key results.

## 23 2 Data

24 We use patient-level data from Hospital Episode Statistics (HES) for all elective admissions for  
25 patients aged 18 or over who underwent NHS-funded primary (i.e. non-revision) hip replacement  
26 surgery between April 2010 and March 2013 in NHS or private providers.<sup>7</sup> HES contains rich  
27 information on patients' demographic and medical characteristics, small area of residence and on  
28 the hospital stay. Privately funded patients are excluded from our analysis.<sup>8</sup> We also exclude  
29 patients attending providers with less than 30 patients in that year.

30 We derive four patient variables from HES: age, gender, the number of emergency admissions  
31 during the 365 days prior to their hip replacement admission, and the number of Elixhauser  
32 comorbid conditions recorded in admissions in the previous year (Elixhauser et al. 1998; Gutacker,  
33 Bloor et al. 2015). These are available for all patients. As a measure of income deprivation we use  
34 the 2010 Index of Multiple Deprivation (McLennan et al. 2011) to attribute to each patient the  
35 proportion of residents in households claiming means-tested benefits in their Lower Super Output  
36 Area (LSOA).<sup>9</sup> We measure a patient's distance from a hospital as the straight-line distance from  
37 the centroid of their LSOA.<sup>10</sup>

38 All NHS-funded hip replacement patients are invited to report their health status and health-

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39 <sup>7</sup>See Department of Health (2008) for procedure codes. We exclude patients who had revision surgery. This  
40 ensures a more homogeneous sample and they are likely to return to the hospital providing the initial hip replacement.

41 <sup>8</sup>Approximately 16% of hip replacement surgeries are funded privately, either out-of-pocket or through private  
42 insurance (Hunt et al. 2013). Privately funded patients treated in the private sector are not included in HES and we  
43 do not have information on them. We also exclude the small number (<2%) of patients treated in NHS hospitals who  
44 are privately funded.

45 <sup>9</sup>LSOAs have a mean population of 1,500 and are constructed to be homogeneous with respect to tenure and  
46 accommodation type.

47 <sup>10</sup>Some NHS trusts perform hip replacement surgery across multiple sites, but the site codes for NHS hospitals  
48 are often poorly recorded in HES. Also, quality information for NHS providers is only recorded at trust level. We  
49 therefore locate hospitals using the postcode of the trust headquarter (for NHS), which is consistently recorded, or  
50 the hospital site (for ISTCs). Analysis of complete data reveals that multi-site operations are rare: approximately  
51 80% of NHS trusts perform more than 80% of their surgery in a single site.

1 related quality of life before, and six months after, surgery using a paper-based questionnaire.  
2 The pre-operative PROM questionnaire is administered by the hospital either as part of the  
3 admission process or during the last outpatient appointment preceding admission. The post-  
4 operative questionnaire is administered by a central agency and posted to the patient. Participation  
5 in the PROM survey is compulsory for providers but optional for patients. Approximately 60% of  
6 patients provide complete pre- and postoperative PROM questionnaires that can be linked to their  
7 HES record (Gutacker, Street et al. 2015).  
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10 Each PROM questionnaire contains three instruments: the Oxford Hip Score (OHS), the  
11 EuroQoL-5D (EQ-5D) descriptive system, and the EuroQol Visual Analogue Scale (EQ-VAS). The  
12 OHS is a condition-specific instrument with 12 questionnaire items regarding hip-related functioning  
13 and pain (Dawson et al. 1996). Each item is scored on a five-point scale, with four indicating no  
14 problems and zero indicating severe problems. The overall score is calculated as the sum of all  
15 items and ranges from zero (worst) to 48 (best). Both EuroQol instruments are generic PROMs,  
16 i.e. they can be applied to different health conditions (Brooks 1996). Previous analysis showed  
17 substantial correlation between the EQ-5D and OHS (Neuburger et al. 2013). We focus on analysis  
18 with the OHS since it is a condition-specific measure and hence plausibly more likely to affect  
19 hospital choice for hip replacements. We report a choice model using the EQ-5D quality measures  
20 as sensitivity check.  
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26 We use PROMs data in two ways. First, we use the risk-adjusted hospital-specific OHS change  
27 scores computed and published by the Health & Social Care Information Centre (HSCIC) as a  
28 measure of hospital quality (Health & Social Care Information Centre 2013b). Data are reported by  
29 financial years (April to March). The HSCIC case-mix adjustment methodology takes into account  
30 a range of patient characteristics including age, sex, pre-operative PROM score, socio-economic  
31 status, comorbidity burden, whether the patient lives alone as well as other indicators of disability  
32 (Department of Health 2012). The hospital-specific mean scores have been found to be robust to  
33 missing data (Gomes et al. 2015). They are also unlikely to be affected by survivorship bias since  
34 less than 0.1% of patients die during the six-month follow-up. Second, in some of our models, we  
35 use the information in the individual patients' pre-operative PROMs questionnaires to investigate  
36 whether their choice of provider is affected by pre-operative morbidity.  
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42 We also calculate risk-adjusted hospital-specific annual 28-day emergency readmission, 28-day  
43 mortality rates and 1-year revision rates after primary hip replacement surgery as additional quality  
44 measures. We link our HES data to Office of National Statistics death records and apply the  
45 HSCIC case-mix adjustment as set out in the readmission outcome indicator specification (Health &  
46 Social Care Information Centre 2013a).<sup>11</sup> <sup>12</sup> Quality metrics are not calculated for hospitals that  
47 treat less than 30 elective hip replacement patients in that year because they are considered too  
48 noisy for analysis.  
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52 We group providers into seven categories used by the National Patient Safety Agency (n.d.):  
53 NHS small / medium / large non-teaching trust, NHS teaching trust, NHS specialised orthopaedic  
54 provider, NHS multi-service provider, and NHS Primary Care Trusts (PCTs).<sup>13</sup> We also distinguish  
55  
56

57 <sup>11</sup>This adjustment takes into account age (in 5-yr bands), sex, socio-economic status, comorbidity burden as  
58 captured by the Charlson index and the number of emergency admissions in the last year.

59 <sup>12</sup>One hospital-year observation was dropped from the analysis because information on discharge date was missing  
60 for all patients.

61 <sup>13</sup>During our study period, PCTs were responsible for purchasing care for their resident population and, with the  
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1 NHS hospitals from privately operated Independent Sector Treatment Centres (ISTCs) that treat  
2 NHS patients. The size categorisation of NHS providers is based on the overall number of beds  
3 available and providers' annual revenue. Teaching trusts receive additional funding from the English  
4 Department of Health to train doctors and are more research active. Multi-service providers  
5 offer acute services as well as mental health and/or community services.<sup>14</sup> Orthopaedic specialist  
6 hospitals only treat musculoskeletal conditions, and, like ISTCs, do not provide emergency care.

7  
8 Finally, we derive from HES the proportion of patients in each hospital who waited longer than  
9 120 days between the specialist's decision to add the patient to the waiting list and admission  
10 to hospital for treatment (the inpatient wait). Patients dislike waiting since health benefits from  
11 treatment are postponed and they are in pain and less mobile while waiting. Waiting times have  
12 been shown to reduce the overall demand for NHS elective care (Martin and Smith 1999; Gravelle  
13 et al. 2002; Martin and Smith 2003) and to influence choice of provider (Sivey 2012; Beckert et al.  
14 2012; Moscone et al. 2012; Gaynor et al. 2012). We focus on long waits because this is how waiting  
15 time targets for NHS providers are defined and thus reported in the press if hospitals miss targets.  
16 We also conduct sensitivity analysis using the median waiting time (in months) at each provider.  
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### 23 3 Methods

#### 24 3.1 Model specification

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26 We use a random utility choice model (McFadden 1974). In our baseline specification utility of  
27 patient  $i = 1, \dots, N$  at provider  $j = 1, \dots, J$  at time  $t = 1, \dots, T$  is

$$28 \quad U_{ijt} = V_{ijt} + \nu_{ijt} = D'_{ij}\beta_{d,i} + D'^2_{ij}\beta_{d^2,i} + D'^3_{ij}\beta_{d^3,i} + Q'_{jt-1}\beta_{q,i} + W'_{jt-1}\beta_{w,i} + Z'_j\beta_{z,i} + \nu_{ijt} \quad (1)$$

29  
30 where  $V_{ijt}$  depends on the distance from the patient's residence to the hospital  $D_{ij}$ , hospital quality  
31 metrics  $Q_{jt-1}$ , waiting time  $W_{jt-1}$ , and a vector of time-invariant hospital characteristics  $Z_j$ . The  
32 error term  $\nu_{ijt}$  subsumes unobserved hospital characteristics and random utility. Patients choose  
33 from a set of hospitals  $M_{it}$ . Assuming  $\nu_{ijt}$  is iid extreme value yields the *multinomial logit* (MNL)  
34 model in which the probability that patient  $i$  chooses hospital  $j$  is

$$35 \quad P_{ijt} = \frac{\exp(V_{ijt})}{\sum_{j' \in M_{it}} \exp(V_{ij't})} \quad (2)$$

36  
37 We allow a non-linear effect of distance on utility by modelling linear, squared and cubic  
38 distance terms.<sup>15</sup> We assume that anticipated utility at a provider is based on its previous period's  
39 quality and waiting time because relevant information are available only with a lag (see section 3.2).  
40 Varkevisser et al. (2012) make a similar assumption. In sensitivity checks, we also estimate models  
41 with contemporaneous waiting time and quality scores.  
42

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43 exception of the Isle of Wight PCT, did not provide care themselves.

44 <sup>14</sup>Such sites must provide at least two differing service functions, each with gross internal floor area representing  
45 more than 20% of the total gross internal site floor area for the whole site (Health & Social Care Information Centre  
46 n.d.).

47 <sup>15</sup>The results are noticeably different from a model including distance and distance<sup>2</sup> only, but are very similar to  
48 one that also included the fourth power.  
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We allow preferences to vary across patients according to their observed characteristics. Thus the marginal utility of quality for patient  $i$  is

$$\beta_{q,i} = \beta_q + X_i' \delta_q \quad (3)$$

and similar for distance, waiting time, and other hospital characteristics. All continuous covariates in  $X_i$  are mean centred and base categories for categorical characteristics are set to their mode. Thus, the vectors of coefficients  $\beta_d, \beta_{d^2}, \beta_{d^3}, \beta_q, \beta_w, \beta_z$  reflect the preferences of the *reference patient*.

We also estimate models which allow for unobserved patient heterogeneity in tastes over quality, with

$$\beta_{q,i} = \beta_q + X_i' \delta_q + \sigma_q \alpha_i \quad (4)$$

where  $\sigma_q$  is the standard deviation of a zero mean normal variable and  $\alpha_i$  is an unobserved patient effect. The latter may capture, for example, differences in the ability to access and interpret quality information. This *random coefficient multinomial logit* (RCMNL) or mixed logit model (Hensher and Greene 2003; Train 2003), unlike the MNL model, allows for unrestricted substitution patterns, thereby relaxing the assumption of independence of irrelevant alternatives (IIA). If  $\sigma_q = 0$  then the RCMNL model reduces to the MNL model in (1).

While the MNL model has a closed form solution that can be estimated via maximum likelihood, the RCMNL needs to be approximated through simulation. To reduce the computational burden<sup>16</sup> we assume uncorrelated normally distributed random coefficients for the quality metrics in  $Q_{jt-1}$  and no random coefficients for other covariates. The RCMNL model is estimated with maximum simulated likelihood using 50 Halton draws.

All models are estimated in Stata 13 with *clogit* and the user-written command *mixlogit* (Hole 2007b). Standard errors are clustered at the GP practice level to allow for GP-induced correlation across choices by patients in a practice.

### 3.2 Endogeneity

A necessary condition for  $\beta_q$  to be an unbiased estimate of the marginal utility of hospital quality (up to a linear transformation) is that the error term  $\nu_{ijt}$  is uncorrelated with any of the independent variables, i.e. all observed variables are exogenous. This condition may not hold for four reasons (Varkevisser et al. 2012; Gaynor et al. 2012; Brekke et al. 2014).

First, hospitals may learn by doing so that higher volume providers have higher quality (Luft et al. 1987; Gaynor et al. 2005). Thus changes in demand could affect quality and induce simultaneity bias. A pre-PROM study with English 1997-2002 hip replacement data found that 30-day in-hospital mortality was higher in low volume hospitals that treated less than 100 patients per year but found no volume effect above this threshold (Judge et al. 2006). The average NHS hospital in our sample treated over 361 NHS patients per year and the average ISTC treated 155 NHS patients per year as well as an unknown number of private patients. A more recent study using the OHS reported no relationship between hospital volume and quality (Varaganam et al. 2015). Furthermore, since

<sup>16</sup>Even after imposing those constraints the RCMNL model with our baseline specification still took over 3 weeks to compute on a high-performance computing system.



1 demand is likely to respond to past, rather than current, quality, our modelling strategy prevents  
2 such bias: demand changes in period  $t$  cannot affect quality in  $t - 1$ . We therefore believe that  
3 simultaneity arising from the effect of volume on quality is not a problem with our data and  
4 modelling approach.

5  
6 Second, because of short run capacity constraints, changes in demand will also affect waiting  
7 time in the same period (Gaynor et al. 2012).<sup>17</sup> While our primary interest is not in the effect of  
8 waiting time on demand, we are concerned that any bias introduced through endogenous variables  
9 will filter through to our estimate of  $\beta_q$  (Wooldridge 2002). Again, the use of lagged waiting time  
10 measures guards against this type of bias.

11  
12 Third, sicker patients may choose higher quality hospitals or hospitals may turn away or  
13 discourage patients with characteristics that make them less likely to achieve a large improvement  
14 in health status. If such systematic selection occurs and is not controlled for in the calculation  
15 of hospital quality scores then those scores would in part be determined by patients' choices or  
16 provider selection. However, provider quality scores are adjusted for a rich set of demographic,  
17 socio-economic, and morbidity patient characteristics, including, in the case of PROMs, the patients'  
18 self-reported pre-operative health status. Hence, we do not believe that unobserved patient selection  
19 is likely to bias the quality scores significantly.

20  
21 Finally, the error term in (1) may be the sum of unobserved hospital characteristics  $\xi_{jt}$  and iid  
22 random patient utility, i.e.  $\nu_{ijt} = \xi_{jt} + \epsilon_{ijt}$  where  $\xi_{jt}$  affect demand and are correlated with observed  
23 covariates (Ho 2006; Jung et al. 2011). For example, hospitals in areas with better amenities  
24 may attract better staff thereby ensuring higher observed clinical quality but also unobserved  
25 interpersonal aspects of quality. Our assumption that patients use information on previous period  
26 quality and waiting times when choosing hospitals does not remove omitted variable bias operating  
27 through unobserved non-transitory hospital characteristics. We therefore undertake two types of  
28 sensitivity analyses to explore the size of the potential omitted variable bias. Our first approach is to  
29 estimate the choice model in (1) with alternative-specific time-invariant fixed effects (FEs) (Hodgkin  
30 1996; Ho 2006; Monstad et al. 2006; Sivey 2012). These hospital FEs capture the utility of non-  
31 transitory unobserved hospital characteristics. The coefficients on observed hospital characteristics  
32 are now identified solely through variation within providers over time, thereby removing any  
33 endogeneity bias operating through unobserved time-invariant characteristics. However, since  
34 hospital quality varies little over time (see Section 4.1) and we only observe providers over three  
35 years this approach may yield imprecise estimates of the marginal utility of quality. Also, because  
36 the market structure changes over time, due to the opening of new independent sector treatment  
37 centres, the FEs do not correspond to observed market shares in each time period. This may bias  
38 estimates if incumbent providers differ systematically from new entries. We therefore also estimate  
39 a model based on NHS trusts only, whose numbers are relatively stable over time.

40  
41 Our second approach is to follow Pope (2009) (see also Moscone et al. (2012) and Gaynor et al.  
42 (2012)) and gauge the possible impact of unobserved hospital heterogeneity by using a control group  
43 of emergency hip replacement patients whose choice of provider is less responsive to quality and  
44 waiting time. The majority of emergency hip replacement patients suffer from a fractured neck of

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<sup>17</sup>It may also be that supply and demand are determined simultaneously, i.e. hospitals react to demand shocks by adjusting their supply, e.g. by performing more surgeries on weekends. We do not consider this in our model explicitly, although the use of lagged waiting time circumvents this problem as well.

1 the femur as a result of a fall. The key idea is that in an emergency patients do not have time to  
 2 compare the quality of hospitals (or at least not as easily as for a planned procedure). The official  
 3 recommendations are that hip fracture patients should be treated within 48 hours because further  
 4 delays are linked to worse outcomes (NICE 2011; Moja et al. 2012).<sup>18</sup> Conversely, elective patients  
 5 have time to gather information, consult websites, family doctors, etc. We therefore expect elective  
 6 patients to respond more to quality than emergency patients, whose scope to choose providers  
 7 based on quality is clearly limited given the time-sensitive nature of their condition.

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 10 Emergency hip replacement surgery is undertaken by the same orthopaedic departments that  
 11 provide elective surgery and so measures of the quality of elective care also apply. However,  
 12 given the relatively urgent nature of their condition, we expect provider choice by emergency  
 13 hip replacement patients to be largely unaffected by publicly reported information on quality.  
 14 To the extent that they exercise choice they are likely to be influenced by distance to providers  
 15 and time-invariant unobserved factors that also matter to elective patients, such as long-standing  
 16 reputation or dimensions of accessibility not captured by our distance measure (e.g. parking charges  
 17 or connection to the public transport system).

18  
 19 If we assume that emergency patients' demand is entirely inelastic to observed quality and that  
 20 they do not wait,<sup>19</sup> but value the same unobserved hospital characteristics as elective patients, then  
 21 their true utility is given by

$$22 \quad U_{ijt}^{Emer} = D'_{ij}\beta_{d,i}^{Emer} + D_{ij}^{2'}\beta_{d^2,i}^{Emer} + D_{ij}^{3'}\beta_{d^3,i}^{Emer} + \nu_{ijt} \quad (5)$$

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 30 If we estimate the model specified in (1) for emergency patients and find  $\widehat{\beta}_q^{Emer} \neq 0$ , we conclude  
 31 that  $cov(Q_{jt-1}, \xi_{jt}) \neq 0$ . If we also assume that elective and emergency patients have the same  
 32 preferences for unobserved hospital characteristics, then the effect of quality on elective demand,  
 33 purged of omitted variable bias, is  $\beta_q^\Delta = \beta_q^{Elec} - \beta_q^{Emer}$ . Hence, if these assumptions are valid, the  
 34 strategy is similar to a control group design. Since coefficients in separate MNL models may be  
 35 scaled differently, we estimate a pooled model for elective and emergency patients by interacting all  
 36 covariates with an indicator variable for emergency. This forces the scaling to be the same. The  
 37 coefficients on the interaction terms are estimates of  $\beta_k^\Delta$  for  $k \in [d, d^2, d^3, q, w, z]$ .

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 42 If emergency patients choose using information on the same type of quality as elective patients<sup>20</sup>,  
 43 or care about emergency quality that correlates with it, or if unobserved hospital characteristics  
 44 have different effects on choices by emergency and elective patients and are correlated with observed  
 45 quality, then  $\beta_q^\Delta$  can no longer be interpreted as an unbiased estimate of the effect of quality on  
 46 elective demand. If unobserved hospital factors are not correlated with quality, then  $\beta_k^\Delta$  reflects the  
 47 differences in preferences between elective and emergency patients. In this case, we expect that  
 48  $\beta_q^\Delta > 0$ : elective patients will be more sensitive to quality than emergency patients, at least in part  
 49 because they have more time and can exert more effort to identify high quality care providers.

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 54 <sup>18</sup>The NHS choices website suggests that “if you think you’ve fractured your hip, you will need to go to the hospital  
 55 as soon as possible. Dial 999 to request an ambulance. Try not to move while you’re waiting for the ambulance and  
 56 make sure you keep warm”. The text gives an idea of the criticality of the condition.

57 <sup>19</sup>Emergency patients are usually treated within hours of their hip fracture, not weeks or months. Analysis of our  
 58 data revealed that elective waiting time is only weakly correlated with the volume of emergency patients, suggesting  
 59 that there is separate supply for those two types of patients.

60 <sup>20</sup>As with elective patients, we do not observe who chooses the hospital for emergency hip replacement. This may  
 61 be the patient, a family member, GP, or the ambulance crew.

Finally, we note that our findings may be of interest even without a strict causal interpretation since they reveal whether patient demand patterns tend to favour high-quality hospitals (e.g. hospitals with a good reputation may invest more in quality because of intrinsic motivation).

### 3.3 Elasticities, changes in demand and willingness to travel

The estimated coefficients on hospital characteristics are estimates of the marginal utilities. Since the utility function is unique only up to a linear transformation, the coefficients only convey information about the sign of marginal utility of hospital characteristics and hence about the sign of the effect of quality on demand. The ratio of marginal utilities (the negative of the marginal rate of substitution) is unaffected by linear transformations and so provides quantitative information about patient preferences. We estimate the reference patient's willingness to travel (WTT) for a one standard deviation (SD) increase in quality as

$$WTT = \frac{\partial D_{ij}}{\partial Q_j} \Big|_{U_{ij}} SD(Q) = -\frac{\partial U_{ij}}{\partial Q_j} / \frac{\partial U_{ij}}{\partial D_{ij}} SD(Q) = \frac{-\beta_q}{\beta_d + 2\beta_{d^2}D + 3\beta_{d^3}D^2} SD(Q) \quad (6)$$

where  $D$  is the average distance to elective patients' chosen hospitals. WTT is the extra distance in kilometres that the reference patient located the average distance away from a provider would be willing to travel to that provider if its quality was increased by  $SD(Q)$ , where  $SD(Q)$  is averaged across hospitals and years. To allow comparisons of WTTs across models based on different sample definitions we evaluate all WTT at the values of  $D$  and  $SD(Q)$  for the sample used to estimate our baseline specification (see Table 2). We estimate standard errors by the delta method (Hole 2007a).

We are also interested in whether providers could attract more patients by improving their quality. Expected demand at provider  $j$  is  $Y_{jt} = \sum_{i \in S_{jt}} P_{ijt}$ , where  $S_{jt}$  is the set of patients whose choice set includes provider  $j$ , i.e. for whom  $j \in M_{it}$ . Following Santos et al. (2015) we calculate the average partial effect of a one SD increase in quality on provider  $j$ 's demand, i.e. demand responsiveness to quality, as

$$\frac{\partial Y_{jt}}{\partial Q_{jt-1}} SD(Q) = SD(Q) \sum_{i \in S_{jt}} \frac{\partial P_{ijt}}{\partial Q_{jt-1}} = SD(Q) \sum_{i \in S_{jt}} \beta_q P_{ijt} (1 - P_{ijt}) \quad (7)$$

We report the mean of (7) over all providers and years.

We calculate the elasticity of demand of provider  $j$  with respect to own quality as

$$E_{jt}^{Q_{jt-1}} = \sum_{i \in S_{jt}} \frac{\partial P_{ijt}}{\partial Q_{jt-1}} \frac{Q_{jt-1}}{\sum_{i \in S_{jt}} P_{ijt}} = \sum_{i \in S_{jt}} \beta_q P_{ijt} (1 - P_{ijt}) \frac{Q_{jt-1}}{\sum_{i \in S_{jt}} P_{ijt}} \quad (8)$$

We report the mean of (8), weighted by providers' predicted demand  $\sum_{i \in S_{jt}} P_{ijt}$ .

Finally, we compute the cross-elasticity of demand for provider  $j$  with respect to the quality of provider  $j'$  as

$$E_{jt}^{Q_{j't-1}} = \sum_{i \in S_{jt} \cap S_{j't}} \frac{\partial P_{ijt}}{\partial Q_{j't-1}} \frac{Q_{j't-1}}{\sum_{i \in S_{jt}} P_{ijt}} = - \sum_{i \in S_{jt} \cap S_{j't}} \beta_q P_{ijt} P_{ij't} \frac{Q_{j't-1}}{\sum_{i \in S_{jt}} P_{ijt}} \quad (9)$$

with  $j \neq j'$ . Note that for some combinations of  $j$  and  $j'$  the cross-elasticity is zero because no

patients have both providers in their choice sets.

## 4 Results

### 4.1 Descriptive statistics

Our main sample is 171,472 elective hip replacement patients treated in 228 providers during the period April 2010 to March 2013.<sup>21</sup> Their average age is 68 years and 40% are male (Table 1). The average pre-operative OHS is 17.4 and 9.5% of patients have been admitted to hospital as an emergency at least once during the preceding 365 days (average number of admissions = 0.13). Self-reported pre-operative OHS is only weakly correlated with past emergency utilisation ( $\rho = -0.10$ ) and the number of comorbidities ( $\rho = -0.14$ ). This suggests that past emergency utilisation and comorbidity burden are poor proxies for current health status<sup>22</sup> as experienced by the patient.

Table 1: Descriptive statistics - elective sample

Variable	Obs	Mean	SD	ICC
<b><i>Patient characteristics</i></b>				
Distance travelled (in km)	171,472	14.6	17.4	
Distance travelled past closest provider (in km)	171,472	5.0	14.4	
Number of providers within 10km radius	171,472	1.3	1.5	
Number of providers within 30km radius	171,472	6.7	5.7	
Age	171,472	68.0	11.5	
Male	171,472	0.40	0.49	
Past utilisation	171,472	0.13	0.49	
Number of Elixhauser conditions	171,472	0.43	0.94	
Income deprivation	171,472	0.12	0.09	
Pre-operative Oxford Hip Score	114,187	17.4	8.2	
<b><i>Provider characteristics</i></b>				
Observed volume	568	305.4	209.1	94.7%
Waiting time (proportion waiting >120 days)	568	0.2	0.2	59.5%
Change in Oxford Hip Score	568	19.8	1.4	57.2%
28-day emergency readmission rate (%)	568	5.67	2.40	36.8%
1-year revision rate (%)	568	0.94	0.82	17.8%
28-day mortality rate (%)	568	0.17	0.36	3.5%

Obs = Observations; SD = Standard deviation; ICC = Intraclass correlation coefficient.

Notes: Patient characteristics for patients choosing provider between April 2010 and March 2013. Waiting time and quality metrics are for financial years 2009/10 to 2011/12. Provider characteristics are unweighted. The intraclass correlation coefficient (ICC) measures the proportion of variation that occurs between providers, rather than over time.

On average, patients have a choice of 7 providers within 30km, with over 75% of patients having access to at least two different providers. Within 10km there are on average 1.3 hospitals and over 14% of patients can choose between two or more providers. Conversely, 36% of patients have no

<sup>21</sup>The number of providers varied over this period because of mergers, changes in coding and market entry, especially with respect to private facilities. There were 155 providers in 2010/11, 202 in 2011/12, and 211 in 2012/13, of which 16 (11.5%) in 2010/11, 62 (30.7%) in 2011/12, and 77 (36.5%) in 2012/13 were privately operated.

<sup>22</sup>The correlations between these measures and the EQ-5D utility score are similar:  $\rho = -0.10$  for past utilisation, and  $\rho = -0.13$  for comorbidity burden.

options within a 10km radius. To reduce computational burden we restrict patient choice sets to the 50 nearest providers. The 556 patients (0.3% of the sample) who chose a provider outside this set were dropped from the analysis.

Patients live on average 14.6km from their chosen hospital. Figure 1 shows that just under half (44.2%) of patients bypassed the local hospital and nearly a tenth (9.9%) bypassed the nearest three hospitals. On average, patients travel 5.0km beyond their nearest hospital to be treated.

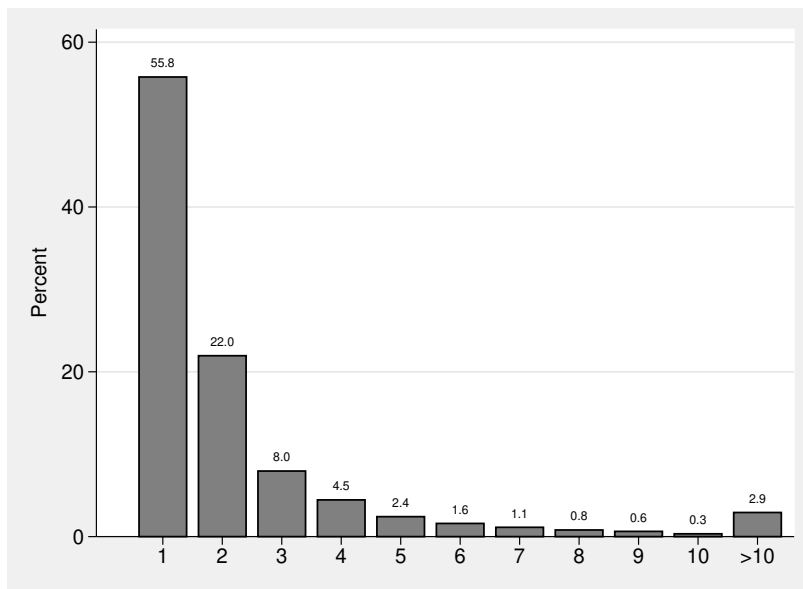


Figure 1: Percentage of elective patients who went to their Nth nearest hospital

The hospital waiting time and quality scores are lagged by one year and are for financial years 2009/10 to 2011/12. There are much larger coefficients of variation for hospital emergency re-admission, revision and mortality rates than for OHS change scores. The provider OHS change scores are only weakly correlated with our waiting time measure ( $\rho=-0.23$ ), readmission rates ( $\rho=-0.28$ ), revision rates ( $\rho=-0.07$ ) and mortality rates ( $\rho=-0.05$ ). This suggests that choice models that are restricted to failure rates may not even indirectly pick up the effect of PROM measures on demand.

The intra-class correlation coefficient (ICC) shows that just over half of the observed variation in OHS (ICC=57%) and our waiting time measure (ICC=59%) is between providers rather than over time. This is less pronounced for readmission, revision and mortality rates (all ICC<40%). The limited within (i.e. over time) variation in provider characteristics impedes the identification of associated coefficients in the fixed effects model.

## 4.2 Regression results

### 4.2.1 Main effects

The results for the RCMNL model (see Appendix Table A1) are very similar to the MNL model and the Hausman tests also did not reject the IIA assumption. We therefore concentrate on the MNL models reported in Tables 2 to 6.

Table 2 is our baseline specification with distance, lagged waiting time, the four lagged quality metrics, and indicators for the type of provider as well as interactions with patient age, gender,

1 past utilisation, comorbidity, and local area income deprivation (we explore interactions with  
2 pre-operative OHS in section 4.2.2). The main effects are the estimated marginal utilities for the  
3 reference patient with mean or modal characteristics. The reference patient prefers shorter distances  
4 with the marginal disutility from distance declining with distance. She prefers providers with lower  
5 proportions of long-waits and specialised providers to non-specialised providers. She is also more  
6 likely to choose a public provider over a private provider after accounting for distance, waiting time  
7 and quality.<sup>23</sup>

10  
11 Table 2: Estimated marginal utilities

12 Variable	13 Est	14 SE
15 <b>Main effects</b>		
16 Change in Oxford Hip Score	0.130	0.008***
17 28-day emergency readmission rate (%)	-0.053	0.004***
18 1-year revision rate (%)	-0.017	0.010
19 28-day mortality rate (%)	-0.038	0.028
20 Distance (in km)	-0.270	0.007***
21 Distance <sup>2</sup>	0.002	0.000***
22 Distance <sup>3</sup>	-0.00001	0.000***
23 NHS trust - medium	-0.572	0.031***
24 NHS trust - multi-service	-0.663	0.096***
25 NHS trust - small	-0.832	0.039***
26 NHS trust - specialist	1.016	0.075***
27 NHS trust - teaching	-0.444	0.034***
28 Independent sector treatment centre	-1.564	0.039***
29 Primary care trust	-1.256	0.206***
30 Waiting time (proportion waiting >120 days)	-0.157	0.077*
31 <b>Interaction with distance</b>		
32 x Patient age	-0.002	0.000***
33 x Male	0.015	0.012
34 x Past utilisation	-0.018	0.005***
35 x Comorbidity count	0.0002	0.001
36 x Income deprivation	-0.261	0.046***
37 <b>Interaction with waiting time</b>		
38 x Patient age	0.008	0.003**
39 x Male	-0.076	0.055
40 x Past utilisation	0.022	0.063
41 x Comorbidity count	-0.046	0.033
42 x Income deprivation	1.126	0.469*
43 <b>Interaction with change in Oxford Hip Score</b>		
44 x Patient age	0.001	0.000*
45 x Male	-0.007	0.006
46 x Past utilisation	-0.007	0.007
47 x Comorbidity count	-0.008	0.003*
48 x Income deprivation	-0.420	0.050***
49 <b>Interaction with 28-day emergency readmission rate</b>		
50 x Patient age	-0.0004	0.000*
51 x Male	-0.001	0.004
52 x Past utilisation	0.012	0.004**

53 *continued*

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57 <sup>23</sup>During our study period ISTC were funded through block contracts and paid to provide care to a pre-specified  
58 number of NHS patients. However, most ISTCs did not fulfil their quotas although they generally had low waiting  
59 times (Naylor and Gregory 2009). Our results are consistent with this observation and suggest a positive preference  
60 for public providers by NHS-funded hip replacement patients. Brown et al. (2015) also found evidence of a pro-public  
61 preference in the stated preferences of the general public in New Zealand.

Table 2: Estimated marginal utilities

Variable	Est	SE
x Comorbidity count	0.001	0.002
x Income deprivation	0.122	0.027***
<i>Interaction with 1-year revision rate</i>		
x Patient age	0.001	0.000
x Male	0.012	0.009
x Past utilisation	-0.002	0.011
x Comorbidity count	0.000	0.005
x Income deprivation	-0.045	0.068
<i>Interaction with 28-day mortality rate</i>		
x Patient age	-0.001	0.001
x Male	-0.058	0.023*
x Past utilisation	0.046	0.028
x Comorbidity count	-0.008	0.016
x Income deprivation	-0.111	0.179
WTT(OHS change)	0.899	0.056***
WTT(Readmission rate)	-0.625	0.050***
WTT(Revision rate)	-0.067	0.041
WTT(Mortality rate)	-0.068	0.049
Number of patients	170,916	
Number of providers	228	
BIC	442,722	
Pseudo R <sup>2</sup>	0.659	

\*\*\* p<0.001; \*\* p<0.01; \* p<0.05

Notes: Conditional logit model of choice of hospital for elective hip replacement patients treated between April 2010 and March 2013. Waiting time and quality metrics are lagged by one year. Coefficients are marginal utilities. Interactions of patient characteristics with distance<sup>2</sup>, distance<sup>3</sup> and provider type are not reported (available on request). WTT (OHS) is the ratio of the coefficient on the quality variable to the marginal utility of distance ( $\beta_d + 2\beta_{d^2} + 3\beta_{d^3}$ ) evaluated at the average distance to the chosen provider.

Reference patient demand is increasing with the OHS change score and decreasing with emergency readmission rates. The estimated WTT for a one SD increase in OHS is 0.9km or 6% of the average distance travelled to the chosen provider. The WTT for a SD decrease in emergency readmission rates is 0.6km. There is no statistically significant effect of procedure-specific mortality or revision rates on demand.

Using contemporaneous, rather than lagged, waiting time and quality measures, we find that the sign of all coefficients remain the same, but the coefficients on revision and mortality rates are now statistically significant (Appendix Table A2, model 1), possibly because of endogeneity in the contemporaneous quality measures. When we use the lagged median waiting time as a waiting time measure its coefficient is positive but not statistically significant (Appendix Table A2, model 2) and the other coefficients are unaffected. This lack of an effect of median waiting time may be explained by its historically low level, with patients being more concerned about excessive rather than average waits.<sup>24</sup> The HSCIC also produces hospital quality scores based on the case-mix adjusted change in the EQ-5D utility score. This is highly correlated with the OHS change score (Neuburger et al. 2013) and when we estimate the baseline specification with EQ-5D substituted for OHS we find similar WTT of 0.9km for a one SD increase in the PROM measure (Appendix Table A2, model

<sup>24</sup>The average waiting time at provider level is 2.5 months, compared with around 8 months at the beginning of the century (Siciliani et al. 2014).

3). We also test for a non-linear relationship between marginal utility and PROM quality by re-estimating the model with indicators for quartile groups of the OHS change score. We find a positive dose-response relationship: marginal utility increases proportionally between the first and second quartile, and between the second and third quartile, with no further increase between the third and fourth quartiles (available on request). Excluding independent sector treatment centres from patient choice sets (Appendix Table A2, model 4) has little impact, though the coefficient on revision rates becomes negative and statistically significant. Finally, results are robust to differing definitions of choice sets (i.e. 30 or 100 closest providers) (Appendix Table A3).

Very few healthcare systems collect and report information on health gains from surgery disaggregated by hospital. It is therefore important to understand whether studies of healthcare market structures that rely solely on traditional measures of quality are likely to be biased. Results (available on request) from a model without OHS change scores suggest that this is not the case: there is little change in the coefficients on the other quality variables. This is consistent with the low observed correlation between PROM change scores and the other quality metrics and suggests that the former pick up an additional different dimension of hospital quality that is valued by patients.

#### 4.2.2 Patient heterogeneity

The coefficients on the interaction terms in Table 2 suggest that preferences vary across types of patient. We find, like other studies (Propper et al. 2007; Beckert et al. 2012), that older patients dislike distance more. They care less about waiting time and get greater marginal utility from improvements in the OHS change score and reductions in emergency readmissions. There is little difference between the preferences of male and female patients except that male patients have a greater dislike for providers with higher mortality. Preferences vary little by morbidity as measured by past emergency admissions or comorbidity count, except that more morbid patients have a greater dislike of distance and care less about OHS change rates. Finally, patients from neighbourhoods with greater income deprivation care more about distance and less about quality, although the estimated marginal utility of PROM quality is positive for all but the 1,644 most deprived patients ( $\leq 1\%$  of sample).

We use the detailed patient reported pre-operative OHS measures in our dataset to explore in more detail how patients in worse health status differ from their healthier counterparts in their sensitive to quality and willingness to travel for higher quality, as commonly assumed in the literature on hospital quality (Gowrisankaran and Town 1999; Geweke et al. 2003). Sicker patients may have greater marginal disutility from distance but greater marginal utility from quality, so that they may be more or less willing to travel to a provider than health patients. The correlations between patients' pre-operative OHS and the routinely available morbidity measures are low, suggesting that they measure different aspects of the patient's condition at the time of admission.

The first model in Table 3 is the same as our baseline specification but with additional patient pre-operative OHS interactions. Interaction terms with other patient characteristics are omitted and available from the authors. We find that healthier patients are more willing to travel. Although the marginal utility from higher quality is unaffected by pre-operative OHS, healthier patients



1 have a smaller disutility from distance and so are more willing to travel for higher quality.<sup>25</sup>  
2 Healthier patients are also more likely to choose a private provider, which is consistent with  
3 observed differences in patient mix across provider types (Browne et al. 2008).

4 The fact that pre-operative OHS data are available for only about 60% of patients raises concerns  
5 about response bias if unobserved factors affect propensity to respond and utility from providers.<sup>26</sup>  
6 To investigate if responders to the pre-operative PROM questionnaire have different preferences to  
7 non-responders we re-estimate the baseline specification of Table 2 for our full sample (responders  
8 and non-responders) but interact a dummy variable for responder status with all the main and  
9 interacted explanatory variables; pre-operative health status is not modelled. However, because  
10 the pre-operative PROM questionnaire is administered *after* the patient has chosen the provider,  
11 it is unclear whether an observed response indicates differences in patient preferences or whether  
12 the choice determines the likelihood to observe a response. For example, private providers have  
13 higher response rates than NHS hospitals (Gomes et al. 2015; Gutacker, Street et al. 2015) and  
14 also tend to have higher observed quality and shorter waiting times. We address this concern  
15 by including the observed provider pre-operative response rate as a provider characteristic when  
16 modelling the choices of responders and non-responders. This variable is informative about the  
17 individual's propensity to fill in a pre-operative PROM questionnaire given the chosen provider<sup>27</sup>.  
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25 In model 2 in Table 3 we add the provider response rate to the responder only model. Its  
26 coefficient is positive, which is to be expected since patients responding to the pre-operative  
27 questionnaire are more likely to have been treated at a provider with a higher response rate.  
28 Two effects are worth noting. The inclusion of the response rate reduces WTT for an increase  
29 in the OHS change score by about 8% relative to model 1, suggesting that providers' ability  
30 to administer the pre-operative questionnaire may be correlated with desirable, but unobserved,  
31 provider characteristics. More importantly, the estimated WTTs with or without adjusting (Table 2)  
32 for pre-operative health differ in a magnitude of only 100 meters. This suggests that the estimates  
33 from our baseline specification without adjustment for pre-operative health are robust to potential  
34 response bias.  
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39 Model 3 in Table 3 shows that responders and non-responders have generally similar revealed  
40 preferences, with the exception of preferences for waiting times (non-responders prefer lower  
41 proportions of long-waits), distance (non-responders are less willing to travel), revision rates (non-  
42 responders dislike providers with higher rates, whereas responders do not) and PROM quality  
43 (non-responders derive less utility from health gains and are thus less willing to travel for it). There  
44 is no difference with respect to the disutility from readmission rates or mortality.  
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48 <sup>25</sup>In additional analyses we explored whether patients' past experience of care quality as measured by their individual  
49 change in OHS predicts their future willingness to return to the same provider for planned hip replacement of their  
50 other hip joint. We use data on 3,195 patients that were treated in 2010/11, had pre- and post-operative OHS  
51 recorded and received a second primary hip replacement before the end of our dataset (31st March 2013). Of these,  
52 2,923 (91.4%) attended their initial provider for further surgery. Estimates from logit regression models show no  
53 association between the probability to re-attend and the experienced change in OHS from the initial surgery.

54 <sup>26</sup>We are not concerned about the implications of response rates for the hospital level case-mix adjusted OHS  
55 change scores as these have been shown to be robust to variations in response rate (Gomes et al. 2015)

56 <sup>27</sup>As a check, we first re-estimate the responder only model with the addition of provider pre-operative response  
57 rates but without interactions with pre-operative health. The results are robust to this sensitivity analysis, with  
58 the WTT of 0.9km (SE=0.056) for a standard deviation increase in PROM quality being similar to our baseline  
59 specification (full results available on request).  
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Table 3: Choice models allowing for patient pre-operative Oxford Hip Score

Variable	Patients with pre-op OHS (1)		Patients with pre-op OHS (2)		All patients (3)					
	Est	SE	Est	SE	Responders (3a)		Non-responders (3b)		Difference (3c)	
					Est	SE	Est	SE	Est	SE
<b>Main effects</b>										
Change in Oxford Hip Score	0.153	0.009***	0.141	0.009***	0.139	0.009***	0.113	0.009***	0.026	0.009**
28-day emergency readmission rate (%)	-0.058	0.005***	-0.051	0.005***	-0.051	0.005***	-0.048	0.006***	-0.003	0.005
1-year revision rate (%)	-0.028	0.011*	-0.002	0.011	-0.003	0.011	-0.036	0.014**	0.032	0.013*
28-day mortality rate (%)	-0.137	0.033***	-0.052	0.030	-0.052	0.030	-0.021	0.034	-0.031	0.033
Distance (in km)	-0.265	0.008***	-0.264	0.008***	-0.265	0.009***	-0.281	0.006***	0.017	0.008*
Distance <sup>2</sup>	0.002	0.000***	0.002	0.000***	0.002	0.000***	0.003	0.000***	0.000	0.000
Distance <sup>3</sup>	-0.00001	0.000***	0.000	0.000***	0.000	0.000***	0.000	0.000***	0.000	0.000
NHS trust - medium	-0.517	0.035***	-0.591	0.034***	-0.583	0.034***	-0.565	0.036***	-0.018	0.031
NHS trust - multi-service	-0.948	0.125***	-0.961	0.124***	-0.951	0.123***	-0.625	0.107***	-0.325	0.126**
NHS trust - small	-0.799	0.043***	-0.854	0.043***	-0.849	0.042***	-0.885	0.046***	0.036	0.039
NHS trust - specialist	1.184	0.074***	0.961	0.076***	0.954	0.076***	0.979	0.100***	-0.025	0.068
NHS trust - teaching	-0.383	0.037***	-0.425	0.037***	-0.414	0.037***	-0.539	0.039***	0.125	0.034***
Independent sector treatment centre	-1.520	0.043***	-1.548	0.042***	-1.556	0.042***	-1.698	0.046***	0.141	0.042***
Primary care trust	-1.031	0.219***	-1.404	0.221***	-1.400	0.221***	-1.263	0.254***	-0.137	0.251
Waiting time (proportion waiting >120 days)	-0.343	0.088***	-0.026	0.086	-0.024	0.085	-0.399	0.092***	0.375	0.088***
Response rate (%)			0.019	0.001***	0.019	0.001***	-0.027	0.001***	0.046	0.001***
<b>Interaction with pre-operative Oxford Hip Score</b>										
x Change in Oxford Hip Score	0.000	0.000	0.000	0.000						
x 28-day emergency readmission rate (%)	0.000	0.000	0.000	0.000						
x 1-year revision rate (%)	0.000	0.001	0.001	0.001						
x 28-day mortality rate (%)	0.002	0.002	0.003	0.002						
x Distance (in km)	0.001	0.000***	0.001	0.000***						
x Distance <sup>2</sup>	0.000	0.000**	0.000	0.000**						
x Distance <sup>3</sup>	0.000	0.000**	0.000	0.000**						
x NHS trust - medium	-0.002	0.002	-0.004	0.002*						
x NHS trust - multi-service	-0.007	0.007	-0.008	0.007						
x NHS trust - small	-0.002	0.002	-0.003	0.002						
x NHS trust - specialist	0.014	0.003***	0.011	0.003***						
x NHS trust - teaching	-0.007	0.002***	-0.008	0.002***						
x Independent sector treatment centre	0.029	0.002***	0.027	0.002***						
x Primary care trust	0.000	0.008	-0.004	0.008						
x Waiting time (proportion waiting >120 days)	-0.001	0.005	0.002	0.005						
x Response rate (%)			0.000	0.000***						
WTT(OHS change)	1.075	0.062***	0.991	0.064***	0.974	0.063***	0.756	0.064***	0.218	0.062***
WTT(Readmission rate)	-0.689	0.057***	-0.612	0.056***	-0.604	0.056***	-0.544	0.063***	-0.060	0.060
WTT(Revision rate)	-0.116	0.046*	-0.006	0.045	-0.013	0.045	-0.139	0.053**	0.126	0.051*
WTT(Mortality rate)	-0.243	0.060***	-0.092	0.054	-0.093	0.054	-0.036	0.058	-0.057	0.057
Number of patients	113,846		113,846		170,916					
Number of providers	228		228		228					
BIC	296,526		292,634		432,899					
Pseudo R <sup>2</sup>	0.658		0.662		0.667					

\*\*\* p<0.001; \*\* p<0.01; \* p<0.05

Notes: Conditional logit model of choice of hospital for elective hip replacement patients treated between April 2010 and March 2012. Waiting time and quality metrics are lagged by one year. Coefficients are marginal utilities. WTT is the ratio of the coefficient on the quality variable to the marginal utility of distance evaluated at the average distance to the chosen provider. Models in (1) and (2) are for patients reporting a pre-operation OHS. Model in (3) is for all patients and interacts a dummy variable for reporting a pre-operation OHS. Interaction effects are reported in (3c). All models also contain a full set of interactions of age, gender, past utilisation, Elixhauser comorbidities, and deprivation with hospital characteristics and distance (not reported). Standard errors are clustered at GP practice level.

### 4.3 Testing for unobserved provider characteristics

We also explore the possible impact of omitted hospital characteristics on our estimates of marginal utility for quality and other hospital characteristics. We first compare preferences of elective and emergency patients estimated from pooled choice models with a full set of emergency patient dummy variables interacted with all explanatory variables (see Section 3.2 for the detailed rationale). There are 73,496 emergency patients in our sample. Only 19.5% of emergency patients bypassed the nearest provider (see Appendix Figure A1). Descriptive statistics for this patient group are reported in Appendix Table A4. Emergency patients' choice sets are the 50 closest providers who carried out hip replacement surgery on at least 30 emergency patients in the current and previous year. This rules out private and specialised providers who only treat elective hip replacement patients. 694 (0.9%) emergency patients were dropped because they attended a provider not in their choice set. All main effects are for patients with mean or modal elective patient characteristics.

We report results for two different specifications. The first model in Table 4 compares emergency patients with elective patients who choose NHS or independent providers (same as Table 2). However, there are some marked differences in observed characteristics between those two groups. For example, emergency patients are on average 12 years older than elective patients and have over twice as many recorded comorbidities. Hence in the second model reported in Table 5 we compare a set of elective and emergency patients matched exactly on age, gender, past emergency admissions, number of comorbidities, income deprivation and year of treatment. Additionally, we restrict the elective patient sample to those who used an NHS provider that treated at least 30 elective and emergency patients in that year, so that the choice sets are identical for elective and emergency conditional on location.

Table 4: Comparison of marginal utilities for elective and emergency patients

Variable	Elective patients		Emergency patients		Difference	
	Est	SE	Est	SE	Est	SE
Change in Oxford Hip Score	0.130	0.008***	0.071	0.015***	0.058	0.014***
28-day emergency readmission rate (%)	-0.053	0.004***	-0.043	0.008***	-0.010	0.008
1-year revision rate (%)	-0.017	0.010	-0.063	0.022**	0.046	0.021*
28-day mortality rate (%)	-0.038	0.028	-0.011	0.057	-0.027	0.059
Distance (in km)	-0.270	0.007***	-0.324	0.011***	0.054	0.013***
Distance <sup>2</sup>	0.002	0.000***	0.003	0.000***	0.000	0.000
Distance <sup>3</sup>	0.000	0.000***	0.000	0.000***	0.000	0.000
NHS trust - medium	-0.572	0.031***	-0.660	0.051***	0.088	0.045*
NHS trust - multi-service	-0.663	0.096***	-1.021	0.167***	0.358	0.150*
NHS trust - small	-0.832	0.039***	-0.872	0.053***	0.040	0.048
NHS trust - specialist	1.016	0.075***	n/a		n/a	
NHS trust - teaching	-0.444	0.034***	-0.641	0.050***	0.197	0.047***
Independent sector treatment centre	-1.564	0.039***	n/a		n/a	
Primary care trust	-1.256	0.206***	-1.353	0.275***	0.097	0.183
Waiting time (proportion waiting >120 days)	-0.157	0.077*	-0.054	0.114	-0.103	0.107
WTT(OHS change)	0.899	0.056***	0.398	0.085***	0.501	0.076***
WTT(Readmission rate)	-0.625	0.050***	-0.405	0.080***	-0.219	0.075**
WTT(Revision rate)	-0.067	0.041	-0.203	0.072**	0.137	0.068*
WTT(Mortality rate)	-0.068	0.049	-0.016	0.081	-0.052	0.086
Number of patients	170,916		72,802			
Number of providers	228		137			
BIC	542,130					
Pseudo R <sup>2</sup>	0.709					

\*\*\* p<0.001; \*\* p<0.01; \* p<0.05

Notes: Conditional logit model of choice of hospital for elective and emergency hip replacement patients treated between April 2010 and March 2013. Waiting time and quality metrics are lagged by one year. Coefficients are marginal utilities for the 'reference patient'. Elective and emergency patients are not matched on observed characteristics but the 'reference patient' in both patient populations is defined according to the average characteristics of the elective patient sample. WTT is the ratio of the coefficient on the quality variable to the marginal utility of distance evaluated at the median distance (in km). Model is estimated with a full set of dummy variables interacted with hospital characteristics and other interaction terms. All models also contain a full set of interactions of age, gender, past utilisation, Elixhauser comorbidities, and deprivation with hospital characteristics and distance (not reported). Standard errors are clustered at GP practice level.

Table 5: Comparison of marginal utilities for elective and emergency patients - matched sample

Variable	Elective patients		Emergency patients		Difference	
	Est	SE	Est	SE	Est	SE
Change in Oxford Hip Score	0.110	0.017***	0.058	0.016***	0.052	0.018**
28-day emergency readmission rate (%)	-0.060	0.010***	-0.041	0.009***	-0.019	0.011
1-year revision rate (%)	-0.099	0.025***	-0.078	0.025**	-0.021	0.030
28-day mortality rate (%)	-0.035	0.067	0.006	0.066	-0.041	0.087
Distance (in km)	-0.379	0.010***	-0.324	0.015***	-0.055	0.017**
Distance <sup>2</sup>	0.005	0.000***	0.003	0.000***	0.002	0.000***
Distance <sup>3</sup>	0.000	0.000***	0.000	0.000***	0.000	0.000***
NHS trust - medium	-0.817	0.054***	-0.642	0.055***	-0.176	0.061**
NHS trust - multi-service	-0.784	0.174***	-1.027	0.189***	0.242	0.220
NHS trust - small	-0.958	0.063***	-0.834	0.059***	-0.123	0.071
NHS trust - teaching	-0.489	0.058***	-0.622	0.054***	0.133	0.066*
Primary care trust	-1.419	0.324***	-1.509	0.366***	0.090	0.353
Waiting time (proportion waiting >120 days)	-0.546	0.137***	-0.200	0.131	-0.347	0.162*
WTT(OHS change)	0.617	0.094***	0.324	0.091***	-0.292	0.103**
WTT(Readmission rate)	-0.573	0.091***	-0.389	0.087***	0.184	0.106
WTT(Revision rate)	-0.323	0.081***	-0.254	0.082**	0.069	0.099
WTT(Mortality rate)	-0.049	0.095	0.008	0.094	0.058	0.123
Number of patients	31,631		31,631			
Number of providers	137		137			
BIC	97,740					
Pseudo R <sup>2</sup>	0.794					

\*\*\* p<0.001; \*\* p<0.01; \* p<0.05

Notes: Conditional logit model of choice of hospital for elective and emergency hip replacement patients treated between April 2010 and March 2013. Waiting time and quality metrics are lagged by one year. Coefficients are marginal utilities for the 'reference patient'. Elective and emergency patients are matched exactly on observed characteristics (age, gender, past emergency utilisation in last year (none, once, or more), income deprivation of neighbourhood, number of Elixhauser comorbid conditions, year of treatment) and the 'reference patient' in both patient populations is defined according to the average (prior to matching) characteristics of the elective patient sample. Choice sets include only providers that treat at least 30 elective and 30 emergency hip replacement patient in this period. WTT is the ratio of the coefficient on the quality variable to the marginal utility of distance evaluated at the median distance (in km). Model is estimated with a full set of dummy variables interacted with hospital characteristics and other interaction terms. All models also contain a full set of interactions of age, gender, past utilisation, Elixhauser comorbidities, and deprivation with hospital characteristics and distance (not reported). Standard errors are clustered at GP practice level.

Both models suggest that OHS change scores have less influence on the provider used by emergency patients than for elective patient. The provider used by emergency patients is also less affected by more traditional readmission and mortality rates, though differences are statistically insignificant and less precisely estimated. In the second specification in Table 5, with closely matched patients, the estimated marginal utility of OHS changes ( $\beta_q^{Emer}=0.058$ ) is just over one half of that for elective patients ( $\beta_q^{Elec}=0.110$ ) and significant at  $p<0.05$ . If we assume that emergency patients' demand is entirely inelastic to variation in observed elective quality and that the estimated association for emergency patients is a result of omitted variables that affect emergency and elective patients in the same way, then the difference in the marginal utility of OHS changes ( $\beta_q^\Delta=0.052$ ) can be interpreted as a lower bound estimate of the true effect of OHS change score on elective patient utility. The WTT for a one SD increase in OHS change scores then is 0.3km (SE=0.103), which is substantially smaller than the 0.9km estimated in our main specification (see Table 2).<sup>28</sup>

Our second sensitivity check for possible bias due to unobserved hospital characteristics is to estimate our baseline specification (1) for elective patients with the addition of hospital fixed effects. In Table 6 in the model estimated with choice sets including ISTCs, PROM quality still has a statistically significant effect on demand, whereas emergency readmission rates no longer do. The WTT to travel for PROM quality is however nearly 90% lower than that calculated from the results in Table 2 (0.1km vs 0.9km). Also, mortality rates are now statistically significantly positively associated with demand. This may be the result of market entry of low-mortality ISTCs towards the end of our study period. Results are broadly similar when patients' choice sets are restricted to NHS hospitals, although we now find statistically insignificant coefficient estimates on all variables but distance. This is likely to be due to the limited within-provider variation over time in quality metrics and the fixed effects absorbing part of the effect of time-invariant quality on choice.

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<sup>28</sup>Emergency patients are, on average, less willing to travel than elective patients. This is reflected by a more negative coefficient on the cubic distance term in Tables 4 and 5 so that utility decreases more rapidly as distance increases. Furthermore, emergency patients tend to be older than elective patients and age is associated with increased disutility from travel. This emphasises the need to compare WTTs for a defined reference patient, not at sample averages.

Table 6: Choice model controlling for unobserved time-invariant hospital effects

	All providers (1)		NHS providers only (2)	
	Est	SE	Est	SE
Change in Oxford Hip Score score	0.017	0.006**	0.014	0.007
28-day emergency readmission rate (%)	0.005	0.003	0.002	0.004
1-year revision rate (%)	0.003	0.010	0.001	0.012
28-day mortality rate (%)	0.045	0.022*	0.028	0.028
Distance (in km)	-0.293	0.007***	-0.334	0.010***
Distance <sup>2</sup>	0.003	0.000***	0.003	0.000***
Distance <sup>3</sup>	-0.00001	0.000***	-0.00001	0.000***
Waiting time (proportion waiting >120 days)	0.013	0.061	0.045	0.066
WTT(OHS change)	0.108	0.041**	0.077	0.042
WTT(Readmission rate)	0.050	0.037	0.014	0.040
WTT(Revision rate)	0.013	0.036	0.005	0.039
WTT(Mortality rate)	0.072	0.035*	0.040	0.040
Number of patients	170,916		146,839	
Number of providers	228		144	
BIC	394,881		246,842	
Pseudo R <sup>2</sup>	0.698		0.762	

\*\*\* p<0.001; \*\* p<0.01; \* p<0.05

Notes: Conditional logit model of choice of hospital for elective hip replacement patients treated between April 2010 and March 2013. Waiting time and quality metrics are lagged by one year. Coefficients are marginal utilities. WTT is the ratio of the coefficient on the quality variable to the marginal utility of distance evaluated at the average distance to the chosen provider. Model in (1) does not impose restrictions on the type of provider in patients' choice sets. Model in (2) is based on a restricted choice set of NHS providers, thereby excluding patients that selected ISTCs. All models include indicator variables for hospitals (not reported). All models also contain a full set of interactions of age, gender, past utilisation, Elixhauser comorbidities, and deprivation with hospital characteristics and distance (not reported). Standard errors are clustered at GP practice level.

#### 4.4 Public reporting

The public release of hospital quality information was intended to improve patients' knowledge about hospital quality and, thus, alter demand patterns. But patients and their GPs may already have had expectations about hospital quality (e.g. from the experience of other patients in the area) so that the new data may simply measure what was already known to them (Dranove and Sfekas 2008). We investigate this by exploiting a feature of the data collection process.<sup>29</sup> Information on patients' OHS was collected from April 2009 onwards but hospital PROM scores were not reported in the public domain until early 2010 due to the lag in post-operative data collection. Hence, choices of patients treated in the financial year 2009/10 (i.e. prior to our sample) could not have been influenced by the public release of OHS change scores for 2009/10.

We estimate a conditional logit model for patients in 2009/10 and 2010/11 in which we assume that patient utility  $i$  from hospital  $j$  in year  $t$  is

$$\begin{aligned}
 U_{ijt} = & D'_{ij}\beta_{d,i} + D'^2_{ij}\beta_{d^2,i} + D'^3_{ij}\beta_{d^3,i} + Q^*_{jt-1}\beta_{q,i} + OHS'_{j,2009/10}\beta_{OHS,i} \\
 & + I_{t=2010/11}OHS'_{j,2009/10}\lambda_{OHS,i} + W'_{jt-1}\beta_{w,i} + Z'_{jt}\beta_{z,i} + \nu_{ijt}
 \end{aligned} \tag{10}$$

This is the same as our model in (1) except that we assume that patients in 2009/10 choose as if they knew the OHS change scores for 2009/10 and patients in 2010/11 choose knowing the

<sup>29</sup>Chernew et al. (2008) and Dafny and Dranove (2008) both adopt a different approach and estimate Bayesian learning models to gauge patients' prior knowledge of health insurance quality and subsequent changes when report cards were released.

OHS change scores for 2009/10.  $Q_{jt-1}^*$  denotes the other lagged quality variables (i.e. emergency readmission rates, mortality rates, revision rates) that were available to both patient groups.

We find that  $\beta_{OHS}=0.057$  (SE=0.028) and  $\lambda_{OHS} = -0.009$  (SE=0.008). This suggests that patients in 2009/10 acted as if they knew the as yet unpublished OHS quality scores and that their choice behaviour was the same as that of patients choosing in 2010/11 when the OHS quality scores were published. Hence, the hospitals' OHS change scores may capture an aspect of quality which was known and valued by patients, and the publication of PROMs in the public domain does not seem to have altered this relation in the year of its introduction or subsequent years.

#### 4.5 Responsiveness to auxiliary quality information

An alternative way to explore whether patients have an understanding and therefore respond to hospital quality is to test whether hospital choice is influenced by other publicly available quality metrics which are unlikely to be consulted as part of the choice process. Hip and knee replacements are typically performed by the same surgeons using common production inputs (e.g. same operation rooms, nursing input, diagnostic services, etc.). Hence, knee replacement-specific quality metrics may be informative about the quality of orthopaedic care provided since the correlation coefficient between the OHS and OKS change scores is 0.434.

We have re-estimated our main specification and included the change in Oxford Knee Score (OKS) as an additional regressor. Our sample is reduced to 169,391 hip replacement patients (550 provider-year observations) since not all providers have OKS change scores recorded and/or treat knee replacement patients. We find a positive and statistically significant coefficient on lagged OKS change scores of 0.121 (SE=0.008). The coefficient on lagged OHS is slightly reduced to 0.088 (SE=0.008), presumably due to the correlation between both metrics and the coefficient on lagged OKS picking up some of what was previously picked up by the OHS coefficient. All other coefficients are similar.

The significant coefficient on knee replacement quality in explaining choice of hip replacement provider could be because both knee replacement quality and hip replacement quality measures convey information to patients and their GP advisors about the quality of care they are likely to experience in the provider's orthopaedic department. Or, if we believe it is implausible that patients access information about knee replacement quality when choosing a hip replacement provider, we can interpret the coefficient as revealing to the econometrician that there are aspects of quality observable by patients, over and above those revealed in published quality metrics, which are correlated with knee replacement quality. In either case, the finding provides additional support for believing that patient choice of provider is influenced by quality.

## 5 The economic effects of quality on demand

We use the results from choice models to illustrate the effect of quality differentiation on hospital demand. Column four and five of Table 7 provide the marginal utilities and the willingness to travel for one SD improvements in the quality measures. The sixth and seventh columns show the average total and relative change in demand from a one SD improvement in quality, and column eight gives the own quality demand elasticities. Quality improvements on the three failure measures correspond



to decreases in rates. We provide calculations based on the baseline specification in Table 2, the hospital fixed effects specification in Table 6, and the specification comparing elective and emergency patients in Table 4. We focus our discussion on the latter since, under the assumption that elective and emergency patients have the same preferences over unobserved hospital characteristics, it accounts for unobservable hospital effects but is more precisely estimated than the fixed effects model. The marginal utilities used in these calculations are the estimated differences between elective and emergency patients.

Table 7: Effect sizes of hospital quality measures

Quality indicator	Observed		Marginal utility	Effect of SD improvement in quality			Elasticity of demand
	Mean	SD		WTT	Demand change	% Demand change	
<i>Baseline specification</i>							
Change in Oxford Hip Score	19.8	1.4	0.130	0.9	35.3	9.8	1.4
Emergency readmission rate (in %)	5.7	2.4	0.053	0.6	24.5	6.8	0.2
Revision rate (in %)	0.9	0.8	0.017	0.1	2.6	0.7	0.01
Mortality rate (in %)	0.2	0.4	0.038	0.1	2.7	0.7	0.004
<i>Time-invariant hospital fixed effects</i>							
Change in Oxford Hip Score	19.8	1.4	0.017	0.1	4.6	1.2	0.02
Emergency readmission rate (in %)	5.7	2.4	0.005	-0.1	-2.1	-0.6	-0.01
Revision rate (in %)	0.9	0.8	0.003	-0.01	-0.5	-0.1	-0.002
Mortality rate (in %)	0.2	0.4	0.045	-0.1	-3.1	-0.8	-0.004
<i>Elective vs emergency comparison</i>							
Change in Oxford Hip Score	19.8	1.4	0.058	0.5	15.9	4.4	0.6
Emergency readmission rate (in %)	5.7	2.4	-0.010	0.2	4.8	1.3	0.03
Revision rate (in %)	0.9	0.8	0.046	-0.1	-7.3	-2.0	-0.02
Mortality rate (in %)	0.2	0.4	-0.027	0.1	1.9	0.5	0.003

SD = Standard deviation; MU = Marginal utility; WTT = Willingness to travel

Notes: WTT is the ratio of the coefficient on the quality variable to the marginal utility of distance evaluated at the average distance to the chosen provider. Changes in volume and elasticities are averaged across hospital-year observations and are weighted by predicted demand  $\hat{Y}_{ijt} = \sum_{i \in M_{jt}} P_{ijt}$ . The WTT, effects of a SD improvement and elasticities for the three failure measures are expressed so that they reflect decreases in rates.

The expected increase in demand for a one SD increase in OHS is 16 patients, or 4.4% of predicted demand at current quality levels. Decreases in mortality and emergency admission rates are associated with increases in demand, although the associations of these quality metrics with demand are not statistically significant. The marginal utility of quality as measured through revision rates is negative for both elective and emergency patients but more so for the latter so that quality improvements are associated with a negative effect on demand (see Section 3.2). The effect of a one SD increase in OHS is larger than that of a one SD decrease in readmission rate.

There is substantial variation across providers in the effect of OHS change scores on own demand (Figure 2). The number of additional patients arising from a one SD increase in OHS ranges from 3 to 56 (mean=15.9). The relative volume increase from a one SD increase in OHS ranges from 1% to 8% (mean=4.4%). The estimated elasticities range from 0.1 to 1.2 (mean = 0.6). About 42% of the variation in elasticities is explained by the amount of competition a provider faces, here measured by the Herfindahl-Hirschman Index (HHI).<sup>30</sup> Providers in more competitive areas (low HHI) face larger quality elasticities than those in less competitive areas (high HHI), with elasticities falling by

<sup>30</sup>The HHI for provider  $j$  is calculated as the sum of the squared market shares of all providers  $j^* = 1, \dots, J^*$  that service LSOA  $a = 1, \dots, A$ , here denoted as  $s_{aj}$ , weighted by the proportion of the provider's observed total activity

approximately 0.14 per 0.1 increase in HHI (assuming a linear effect;  $p < 0.001$ ) (Figure 3). Markets are more competitive in areas where independent sector treatment centres are active. However, this result should be interpreted cautiously since the functional form of the choice model does not allow patients' preferences for quality to vary by provider type.

We also examine the effect of changes in the quality of other providers on a provider's demand. Higher cross-quality demand elasticities make it more likely that increases in one provider's quality will trigger an increase in the quality of other providers. Figure 4 shows how cross-quality elasticities decline rapidly as the distances between providers increase. Whereas a 1% increase in a competitor's PROM quality is associated with a -0.32% reduction in demand if the competitor is located within 10km, this falls to -0.11% when the competitor is 30km away. Hence, quality competition is likely to be restricted geographically.

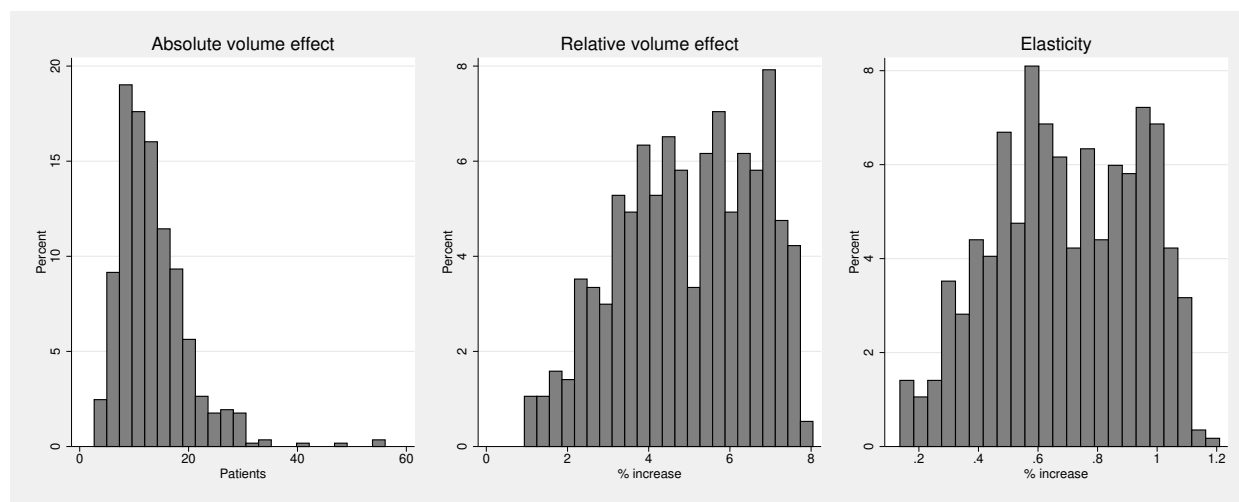


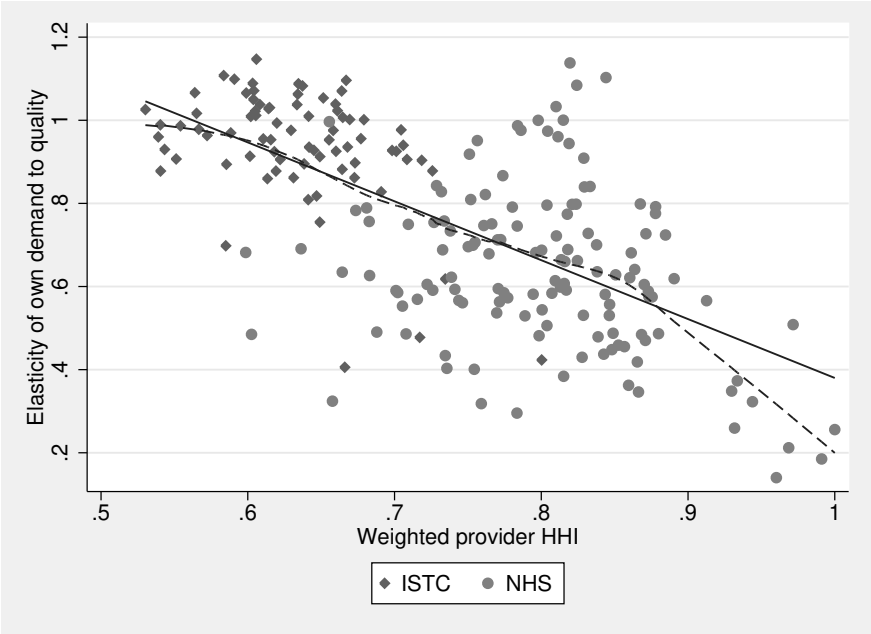
Figure 2: Distribution of changes in hospital demand as a result of a SD increase in Oxford Hip Score change scores and quality elasticity of demand

originating from this LSOA,  $s_{ja}$ , so that

$$HHI_j = \sum_a s_{ja} * [\sum_{j^*} (s_{aj^*})^2] \quad (11)$$

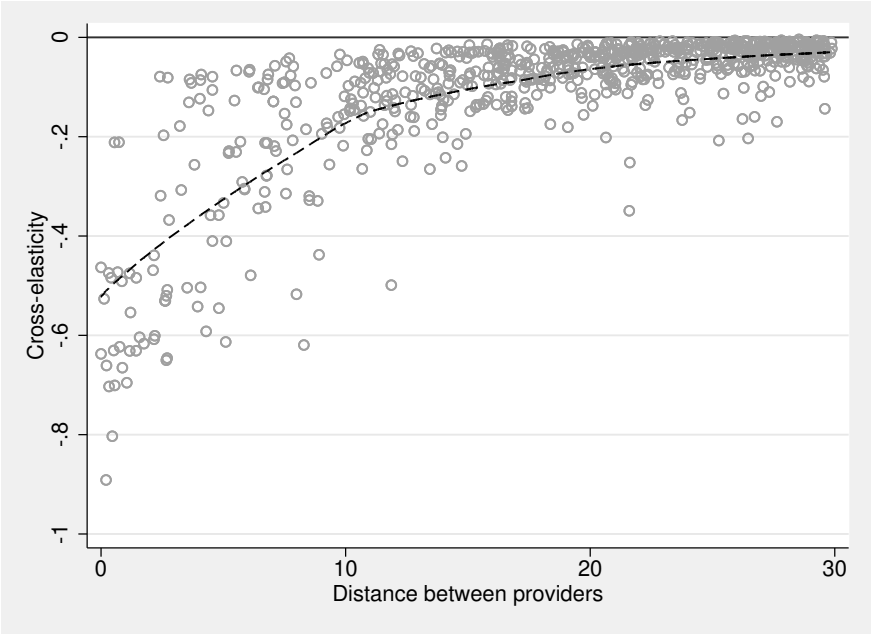
Hospital catchment areas are defined as all LSOAs within a radius of 30km around the hospital.

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Notes: Solid line shows best linear fit (Intercept = 1.80 (SE=0.08), slope = -1.42 (SE=0.10),  $R^2 = 0.42$ ). Dashed line shows LOWESS curve.

Figure 3: Differences in quality elasticity of demand between providers in competitive (low HHI) and non-competitive (high HHI) markets



Notes: Dashed line shows LOWESS curve.

Figure 4: Percentage change in demand as a result of percentage change in competitor's quality

## 6 Discussion and concluding remarks

This paper is the first to test whether patient choice of hospital is influenced by hospital quality as measured by the change in health status and functioning rather than by traditional failure measures such as readmission and mortality rates. We use data on observed choices for all NHS-funded hip replacement patients treated between April 2010 and March 2013 in public and private hospitals in England.

The average health gain, as measured by the PROMs-based OHS change score, is only weakly correlated with the simple condition-specific mortality, revision and emergency readmission rates across hospitals. This suggests that choice models which do not include PROMs-based measures may miss important factors affecting patient choice of hospital. This is borne out by the results from our choice models. We find that elective hospital demand responds to observed quality as measured by PROMs after conditioning on patient characteristics, distance to hospital and other quality metrics. Hospital demand is relatively more responsive to OHS change quality than emergency readmission rates. There is no statistically significant association of choice of provider with mortality, though this may be because the mortality risk for an elective hip replacement is very small. Nor was there an association with revision rates after primary hip replacement surgery. Finally, we found that patients may respond to hospital quality even when corresponding information is not made publicly available, yet.

Our results are relevant for policy. First, they show that providers can attract additional patients by raising quality, which is a necessary condition for competition to improve quality. Second, we find that demand is more responsive to quality measures based on the change in patient health status due to treatment, rather than to crude measures such as rates of mortality or emergency readmission. Thus hospitals wishing to attract patients can do so by improving aspects of quality with a more immediate link to outcomes experienced by all patients. Third, the public release of information on hospital quality may not in itself trigger a change in demand if patients have other channels by which they can infer hospital quality. Fourth, our results emphasise the importance of market structure in determining incentives for competing on quality: the effect of quality changes on the providers' ability to attract patients away from rival hospitals decreases rapidly with distance. Thus some providers with few nearby rivals face little incentive to raise quality. This is likely to be true of all types of competition, since the number of rivals is likely to be in part determined by the number of potential patients, but is not always acknowledged in the health policy debate about stimulating quality improvement efforts through increased competition. Of course, whether or not providers engage in quality competition based on published quality information depends on whether they *perceive* their demand to be elastic to quality changes and on how much they value their reputation. We cannot answer these questions with our data. Finally, our estimated effect may, at least in part, be driven by unobserved hospital characteristics correlated with observable quality. We attempted to allow for this. Using emergency hip replacement patients as a control group who should not be affected by elective quality suggests that the willingness to travel for higher PROM quality could be up to 50% smaller. A model including hospital fixed effects suggested that willingness to travel could as much as 90% smaller. These alternative models either rely on strong assumptions or are poorly identified because quality scores did not vary much over time. Nevertheless, they suggest that the 10% increase in demand for a one standard deviation increase

in PROM quality implied by our baseline model is likely to be an upper bound estimate.

We also explore whether patient preferences vary according to observed and unobserved patient characteristics. We find that the preference for PROM quality increases with age and decreases with income deprivation and comorbidity burden. Qualitatively similar results are obtained for preferences for quality as approximated by emergency readmission rates. We find that patient reported pre-operative Oxford Hip Score is only weakly correlated at patient level with other measures of pre-operative morbidity, such as recorded morbidities or number of previous admissions, which can be extracted from routine hospital records and are commonly used in the literature. We do not find evidence that preferences for quality vary with pre-operative health status as reported by the patient herself. But because healthier patients derive less disutility from travel, they have, *ceteris paribus*, a higher willingness to travel for quality. This finding may help shed light on the underlying mechanism of the ‘*distance bias*’ that has been described in other studies of hospital demand (Gowrisankaran and Town 1999; Geweke et al. 2003).

There remains scope for further research. First, we cannot tell whether the estimated effect of quality is driven by patients’ choices or choices by their GPs or by bargaining between patients and their GPs. Who is taking the decision has implications for the design of policies intended to influence choice of provider. Second, we did not investigate whether patients undergoing knee replacement, groin hernia repair or varicose vein surgery, for which PROMs-based quality measures are also available, are responsive to quality. These patients differ from hip replacement patients. For example, knee replacement patients are generally younger and, possibly, more willing and able to search for hospital quality information online. Future work could explore difference in demand patterns across treatments. Third, our findings may be specific to the condition under study. Patients undergoing surgery with considerable risk of mortality may be more sensitive to quality information since the health costs of choosing an inferior provider would likely be more significant. For example Gaynor et al. (2012) study choices made by coronary bypass surgery patients and find that they are sensitive to procedure-specific hospital mortality rates. Hence, the choice context may affect both the general sensitivity to hospital quality as well as the importance of individual failure measures such as emergency readmission or death; both of which are rare after hip replacement. Fourth, there may be scope for quasi-experimental studies using hospitals that undertook quality improvement plans and comparing them with hospitals that did not. Any changes in quality scores observed in the former group but not the latter are likely to reflect genuine improvements, not statistical noise, and would allow a more precise estimation of the effect of quality on demand. Fifth, the role of other quality measures, such as reputation or overall patient experience and satisfaction, could be explored when they become available.<sup>31</sup>

In conclusion, our results suggest that patients’ choice of hospital is influenced by the health gain from treatment, not just by the likelihood of extreme, rare events such as death or an emergency readmission.

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<sup>31</sup>In 2013 the NHS launched a “Friends and Family Test” asking patients whether they would recommend their hospital to friends or family.

# Appendix

Table A1: Mixed logit choice model

Variable	Mean		Standard deviation	
	Est	SE	Est	SE
Change in Oxford Hip Score	0.130	0.008***	-0.001	0.001
28-day emergency readmission rate (%)	-0.053	0.004***	-0.001	0.001
1-year revision rate (%)	-0.017	0.010	-0.001	0.001
28-day mortality rate (%)	-0.039	0.028	-0.019	0.069
Distance (in km)	-0.270	0.007***		
Distance <sup>2</sup>	0.002	0.000***		
Distance <sup>3</sup>	0.000	0.000***		
NHS trust - medium	-0.572	0.031***		
NHS trust - multi-service	-0.663	0.096***		
NHS trust - small	-0.832	0.039***		
NHS trust - specialist	1.016	0.075***		
NHS trust - teaching	-0.444	0.034***		
Independent sector treatment centre	-1.564	0.039***		
Primary care trust	-1.256	0.206***		
Waiting time (proportion waiting >120 days)	-0.157	0.077*		
WTT(OHS change)	0.899	0.056***		
WTT(Readmission rate)	-0.625	0.050***		
WTT(Revision rate)	-0.067	0.041		
WTT(Mortality rate)	-0.068	0.048		
Number of patients	170,916			
Number of providers	228			
BIC	442,785			

\*\*\* p<0.001; \*\* p<0.01; \* p<0.05

Notes: Random coefficient (mixed) multinomial logit model of choice of hospital for elective hip replacement patients treated between April 2010 and March 2013. Waiting time and quality metrics are lagged by one year. Coefficients are marginal utilities. Random coefficients are specified for OHS change, readmission rate, revision rate and mortality rate. WTT is the ratio of the coefficient on the quality variable to the marginal utility of distance evaluated at the average distance to the chosen hospital (in km). Interaction terms with patient characteristics are not reported (available on request). Standard errors are clustered at GP practice level. The mean coefficients do differ from those reported in Table 2 for the conditional logit model if there is less rounding.

Table A2: Sensitivity analyses

Variable	Model (1)		Model (2)		Model (3)		Model (4)	
	Est	SE	Est	SE	Est	SE	Est	SE
Change in PROM score	0.104	0.008***	0.132	0.008***	5.253	0.301***	0.138	0.011***
28-day emergency readmission rate (%)	-0.052	0.005***	-0.054	0.004***	-0.057	0.004***	-0.055	0.006***
1-year revision rate (%)	-0.026	0.012*	-0.016	0.010	-0.019	0.011	-0.065	0.015***
28-day mortality rate (%)	-0.098	0.033**	-0.038	0.028	-0.032	0.028	0.039	0.036
Distance (in km)	-0.265	0.006***	-0.270	0.007***	-0.270	0.007***	-0.315	0.011***
Distance <sup>2</sup>	0.002	0.000***	0.002	0.000***	0.002	0.000***	0.003	0.000***
Distance <sup>3</sup>	0.000	0.000***	0.000	0.000***	0.000	0.000***	0.000	0.000***
NHS trust - medium	-0.569	0.034***	-0.573	0.031***	-0.584	0.032***	-0.715	0.038***
NHS trust - multi-service	-0.705	0.094***	-0.653	0.095***	-0.671	0.094***	-0.696	0.099***
NHS trust - small	-0.850	0.040***	-0.833	0.039***	-0.836	0.040***	-0.954	0.044***
NHS trust - specialist	1.021	0.074***	1.043	0.075***	1.064	0.076***	1.083	0.086***
NHS trust - teaching	-0.517	0.035***	-0.457	0.034***	-0.406	0.034***	-0.510	0.039***
Independent sector treatment centre	-1.736	0.062***	-1.487	0.048***	-1.486	0.038***		
Primary care trust	-1.017	0.198***	-1.273	0.206***	-1.212	0.205***	-1.349	0.219***
Waiting time	-0.376	0.091***	0.028	0.015	-0.220	0.077**	-0.312	0.090***
WTT(PROM change)	0.738	0.059***	0.915	0.056***	0.861	0.051***	0.832	0.065***
WTT(Readmission rate)	-0.622	0.058***	-0.629	0.050***	-0.663	0.050***	-0.564	0.062***
WTT(Revision rate)	-0.106	0.050*	-0.063	0.041	-0.075	0.044	-0.228	0.053***
WTT(Mortality rate)	-0.176	0.060**	-0.068	0.048	-0.057	0.049	0.060	0.056
Number of patients	120,377		170,916		169,621		146,839	
Number of providers	230		228		223		144	
BIC	331,496		442,697		432,611		282,596	
Pseudo R <sup>2</sup>	0.637		0.659		0.661		0.726	

\*\*\* p<0.001; \*\* p<0.01; \* p<0.05

Notes: Conditional logit model of choice of hospital for elective hip replacement patients treated between April 2010 and March 2013. Waiting time and quality metrics are lagged by one year if not otherwise stated. Coefficients are marginal utilities. WTT is the ratio of the coefficient on the quality variable to the marginal utility of distance evaluated at the average distance to the chosen hospital. Interaction terms with patient characteristics are not reported (available on request). Standard errors are clustered at GP practice level.

Model (1) - Waiting time and quality metrics are contemporaneous. Based on observed choices for patients treated between April 2009 and March 2012. Since April 2012 PROM scores have been reported separately for primary and revision hip replacement surgeries so that our measures of PROM quality are no longer comparable.

Model (2) - Median waiting time substituted for proportion of patients waiting longer than 120 days (both lagged).

Model (3) - Lagged EQ-5D change scores substituted for lagged OHS change scores.

Model (4) - Patients' choice sets exclude independent sector treatment centres.

Table A3: Estimated willingness to travel in different choice sets

	30 closest		50 closest		100 closest	
	Est	SE	Est	SE	Est	SE
WTT(PROM change)	0.907	0.055***	0.899	0.056***	0.904	0.057***
WTT(Readmission rate)	-0.604	0.050***	-0.625	0.050***	-0.642	0.051***
WTT(Revision rate)	-0.062	0.040	-0.067	0.041	-0.072	0.042
WTT(Mortality rate)	-0.069	0.048	-0.068	0.049	-0.070	0.049

\*\*\* p<0.001; \*\* p<0.01; \* p<0.05

Notes: Conditional logit model of choice of hospital for elective hip replacement patients treated between April 2010 and March 2013. Waiting time and quality metrics are lagged by one year. Willingness to travel (WTT) is the ratio of the coefficient on the quality variable to the marginal utility of distance evaluated at the average distance to the chosen hospital. Standard errors are clustered at GP practice level. Full results available on request.

Table A4: Descriptive statistics - emergency sample

Variable	Obs	Mean	SD	ICC
<b><i>Patient characteristics</i></b>				
Distance travelled (in km)	73,496	14.2	27.1	
Distance travelled past closest provider (in km)	73,496	4.2	25.3	
Number of providers within 10km radius	73,496	1.0	1.2	
Number of providers within 30km radius	73,496	5.0	4.7	
Age	73,496	80.9	9.8	
Male	73,496	0.3	0.4	
Past utilisation	73,496	0.7	1.2	
Number of Elixhauser conditions	73,496	1.0	1.6	
Income deprivation	73,496	0.1	0.1	
<b><i>Provider characteristics</i></b>				
Observed volume	393	187.2	87.0	80.7%
Waiting time (proportion waiting > 120 days)	393	0.2	0.1	43.7%
Change in Oxford Hip Score	393	19.4	1.3	47.9%
28-day emergency readmission rate (%)	393	5.97	2.22	37.0%
1-year revision rate (%)	393	0.95	0.72	22.4%
28-day mortality rate (%)	393	0.20	0.25	4.5%

Obs = Observations; SD = Standard deviation; ICC = Intraclass correlation coefficient.

Notes: Patient characteristics for emergency patients treated between April 2010 and March 2013. Waiting time and quality metrics are for financial years 2009/10 to 2011/12. Provider characteristics are unweighted. The intraclass correlation coefficient (ICC) measures the proportion of variation that occurs between providers, rather than over time.



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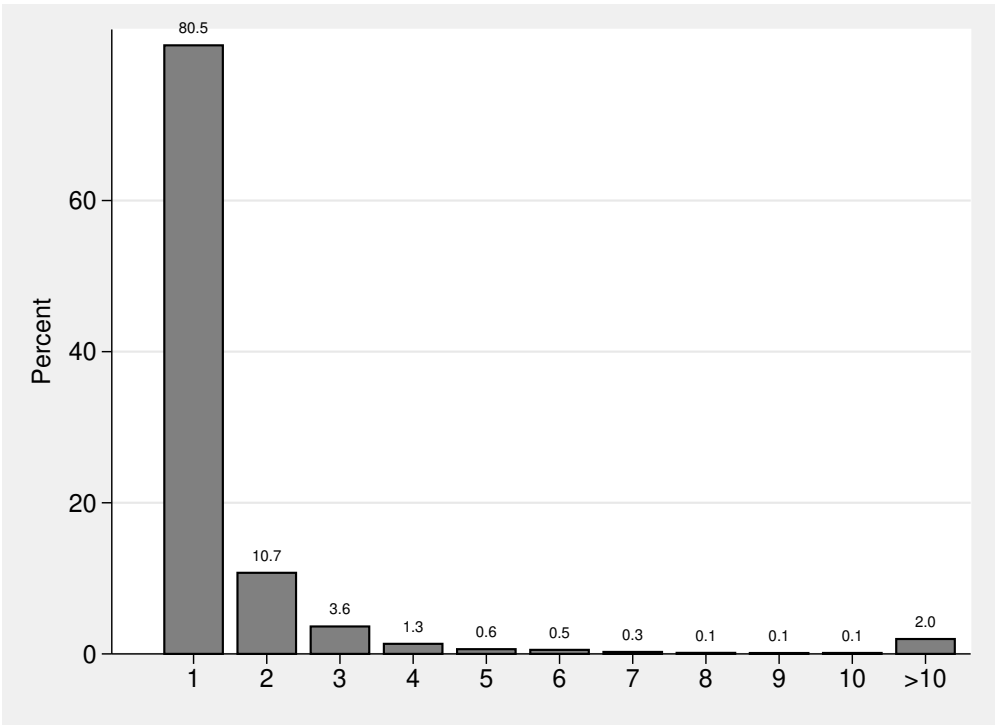


Figure A1: Percentage of emergency patients who went to their Nth nearest hospital

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