Article:
Gravelle, Hugh Stanley Emrys, Moscelli, Giuseppe, Santos, Rita et al. (2024) Hospital closure in urban and rural areas and patients' welfare. Regional Science and Urban Economics. 104064. ISSN: 0166-0462

https://doi.org/10.1016/j.regsciurbeco.2024.104064

Regional Science and Urban Economics 109 (2024) 104064

Contents lists available at ScienceDirect

Regional Science and Urban Economics

journal homepage: www.elsevier.com/locate/regec

Hospital closure in urban and rural areas and patients' welfare

Hugh Gravelle [a,*], Giuseppe Moscelli [b], Rita Santos [a], Luigi Siciliani [a,c]

[a] Economics of Social and Health Care Research Unit, Centre for Health Economics, University of York, United Kingdom
[b] Department of Economics, University of Surrey and IZA, United Kingdom
[c] Department of Economics and Related Studies, University of York, United kingdom

ARTICLE INFO

Keywords:
Patient choice
Conditional logit
Hospital closure
Quality

ABSTRACT

The hospital sector is frequently subject to reconfigurations, with some departments closing and new ones opening. Using a conditional logit model based on observed patient choices, we quantify the effects of a hospital department closure on the welfare of elective hip replacement patients in England. We simulate eight separate closures of the provider with lowest quality, as measured by one of four quality measures: revisions, emergency readmissions, 30-day mortality, change in the Oxford Hip Score, in urban and rural areas. The average reduction in welfare for patients who attended the closed hospital is equivalent to having to travel between two and ten *additional* kilometres for treatment, compared to their average travel distance, pre-closure, of 17.4 km. The reduction in patient welfare is generally more pronounced when closing a hospital in a rural area (about 50% higher when quality is measured by the Oxford Hip Score and emergency readmissions).

1. Introduction

Health spending continues to rise across OECD countries driven by an ageing population and technological innovation (OECD, 2023). Hospital spending accounts for a significant share of health spending, about 39% in 2018 across the EU (OECD/European Union, 2020). Following the COVID-19 pandemic, there is renewed pressure to contain costs while maintaining quality standards.

The hospital sector is frequently subject to reconfigurations with some departments closing and new ones opening. Such reconfigurations are sometimes motivated by the fact that investments in expensive equipment require scale economies that only larger departments may be able to achieve, and that trend reductions in length of stay reduce the beds needed to address a given demand (Gaughan et al., 2020). Such closures can be politically sensitive because some patients have to travel further to gain access to hospital services (Bloom et al., 2015) and have worse access. But if the closed provider had low quality, average quality will increase. Thus, some patients will gain in some dimensions and loose in others from hospital closures.

In this study, we use a conditional logit model of patient choice to simulate the effects of hospital department closure in England on patients' utility, quality and distance travelled. After estimating the choice model, we remove the hospital to be closed from the patients' choice sets, and predict patients' choices with this smaller choice set. We estimate the average increase in distance travelled and changes in average quality for patients confronted by the restricted choice set and compute the resulting change in patient utility. The closure increases the average quality of care but also increases the average distance travelled by patients. All patients are worse off since their choice set is reduced but the magnitudes of their utility losses depend on whether they were treated in the closing hospital, how much worse its quality was than the remaining providers, and patient preferences over quality and distance to provider.

We quantify these changes in patient utility, quality of care, and distance travelled using data on patients having an elective hip replacement in the English National Health Services (NHS). Hip replacement is a common non-emergency (elective) surgery where a damaged hip joint is replaced with an artificial one. NHS hospital care is tax financed and is free at the point of consumption. Since 2006 patients have been able to choose any hospital in England for elective care (Moscelli et al., 2021), though they tend to choose one of their closest providers (Moscelli et al., 2016).

We use the data and the patient choice model in Gutacker et al. (2016) to simulate the effects of the closure of eight different hospitals defined by whether they performed worst in terms of one of four quality measures (health gain, emergency readmissions, revisions, or mortality) and whether they were located in an urban or rural area. We focus on hospitals with the lowest quality as these can be the subject of regulatory interventions based on quality (Care Quality Commission, 2018). Rural areas tend to have smaller and fewer hospitals and patients have to travel further to gain access to hospital services.

We find that for patients most affected by the simulated closure (those

* Corresponding author.
E-mail addresses: hugh.gravelle@york.ac.uk (H. Gravelle), g.moscelli@surrey.ac.uk (G. Moscelli), luigi.siciliani@york.ac.uk (L. Siciliani).

https://doi.org/10.1016/j.regsciurbeco.2024.104064
Received 28 August 2023; Received in revised form 14 October 2024; Accepted 1 November 2024
Available online 5 November 2024

who attended the closed hospital), the utility loss is equivalent to the loss that they would have experienced from travelling between 2.00 and 10.25 km (km) further for treatment. This is respectively equal to 11.5% and 58.9% of the average actual travel distance to chosen providers (17.40 km).

The utility loss is generally more pronounced when the closed hospital with lowest quality is in a rural area. For example, when the hospital with the worst Oxford Hip Score is closed, the utility loss is equivalent to an increase in distance of 3.03 km when the closed hospital is in a rural area and 2.00 km in an urban area. When the provider with the highest readmission rate is closed, the utility loss is equivalent to an additional 6.13 km travelled for closure of a provider in a rural area and 4.17 km for closure of a provider in an urban area. The average equivalent additional distance travelled when the provider with the highest mortality rate is closed is 10.26 km if located in a rural area and 2.04 km when the closed provider is located in an urban area. By contrast, when the closed hospital has the highest revision rate, the equivalent additional distance is greater if the closed hospital is in an urban area (7.61 km) than in a rural area (6.95 km).

1.1. Related literature

There is a growing empirical literature investigating the effect of quality on patient choice of the hospital (see Gaynor and Town (2011) for a review). In England, Gaynor et al. (2016) show that following the introduction of choice reforms in 2006, patients having a coronary artery bypass were more likely to choose hospitals with lower condition-specific mortality rates.

Similarly, there is evidence that patients having a hip replacement in England were more likely to choose hospitals with lower readmission rates (Moscelli et al., 2016), greater health gains, as measured by patient-reported outcome measures (Gutacker et al., 2016), and lower overall mortality rates and MRSA (Methicillin Resistant Staphylococcus Aureus) infection rates (Beckert et al., 2012). The responsiveness of demand for a hospital to its quality is however low, and proximity to provider remains the most important driver of patient choice of the hospital.

Studies in other countries have also estimated the effect of quality on patient choice for other conditions. Expectant mothers in Germany are willing to travel further to give birth in maternity clinics with higher reported quality as measured by clinical indicators and satisfaction scores (Avdic et al., 2019). Angioplasty patients in the Netherlands are more likely to choose hospitals with a good reputation (overall and for cardiology) and low readmissions after treatment for heart failure (Varkevisser et al., 2012).

Angioplasty patients in Italy are willing to travel further to avoid longer waiting times and clinical quality (mortality), and the willingness to travel is higher amongst those who are more severely ill (Bruni et al., 2021). Patients with cancer of the digestive system are willing to travel to a distant hospital for a quality increase from the 75th to the 25th percentile, and the willingness to travel is higher for younger and more educated patients (Balia et al., 2020).

None of the above studies examines hospital closures. Capps et al. (2010) use a patient choice model to study the effect of five hospital closures in two US states. They find urban hospital bailouts reduce aggregate social welfare because the cost savings from closures are more than offset by the reduction in the monetary value of the increase in patient travel distance. Beckert et al. (2012) uses a patient choice model to simulate the effect of a hospital merger (as opposed to a closure) in England between pairs of hospitals on the demand elasticity with respect to quality of the merging and non-merging hospitals.

Other studies have retrospectively evaluated the effects of hospital closures. For example, Lindrooth et al. (2003) estimate the effect of urban hospitals' closure in the US on the operating efficiency of the remaining hospitals in the local market, and find that costs per admission declined by 2–4%. Buchmueller et al. (2006) find that urban hospital closures in California increased distance to the closest hospital and increased deaths from heart attacks and unintentional injuries. Petek (2022) investigates the effect of entries and exits of hospitals in the US, finding that entries cause sharp increases in volumes of inpatient care and emergency visits, and hospital exits cause reductions in volumes and visits, but neither have any effects on mortality in the short term. Also focusing on US hospitals, Alexander and Richards (2023) find that rural hospital closures generated persistent employment reductions within health care occupations for the local economies where the closure occurred, but consumer financial health and housing markets were unaffected. Closures are also relevant in the context of other public services, such as education. For example, Freier et al. (2021) evaluated the effect of grammar school closures in Germany. Differently from these studies, our approach is prospective, rather than retrospective. Regulators and policymakers can assess prospectively the effect of closure of a specific hospital, rather than evaluating retrospectively the effects following actual hospital closures. The approach can also be applied to evaluate the prospective welfare effects of reconfigurations which involve the opening of new providers.

The next section describes the choice model and the calculation of welfare effects. Section 3 describes the data and Section 4 has results. Section 5 provides some robustness checks. Section 6 concludes with a discussion of implications and limitations.

2. Methods

We estimate a conditional logit choice model (Train, 2009) in which utility of patient i from attending hospital h is

$$U_{ih} = V_{ih} + \varepsilon_{ih} = \boldsymbol{D}_{ih}\boldsymbol{\beta}_i + \boldsymbol{Q}_h\boldsymbol{\gamma}_i + \varepsilon_{ih} \tag{1}$$

where $\boldsymbol{Q}_h$ is a vector of variables related to hospital quality, $\boldsymbol{D}_{ih}$ is a vector of powers (linear, quadratic, cubic) of i's distance from hospital h. We allow for patient preferences over distance and quality to vary with a vector $\boldsymbol{X}_i$ of patient characteristics, $\boldsymbol{\beta}_i = \boldsymbol{\beta} + \boldsymbol{X}_i\boldsymbol{\rho}$ and $\boldsymbol{\gamma}_i = \boldsymbol{\gamma} + \boldsymbol{X}_i\boldsymbol{\delta}$. The errors ε_{ih} are due to our, rather than the patient's, imperfect observation of all the factors affecting patient utility. Assuming the errors ε_{ih} are extreme value i.i.d., the probability that patient i chooses hospital h is

$$P^o_{ih} = \frac{exp(\boldsymbol{D}_{ih}\boldsymbol{\beta}_i + \boldsymbol{Q}_h\boldsymbol{\gamma}_i)}{\sum_{h' \in S^o_i} exp(\boldsymbol{D}_{ih'}\boldsymbol{\beta}_i + \boldsymbol{Q}_{h'}\boldsymbol{\gamma}_i)} \tag{2}$$

where S^o_i is the initial choice set of patient i.

2.1. Expected effects of a hospital closure

We conduct the following thought experiment to estimate the effect of closure of a hospital on a set of n individuals with observed characteristics $\boldsymbol{D}_{ih}$ and $\boldsymbol{X}_i$ ($i = 1, \ldots, n$). Suppose that one hospital h^c is closed and denote the post-closure choice set by S^c_i. The estimated probability that a patient i with characteristics $\boldsymbol{D}_{ih}$ and $\boldsymbol{X}_i$ would have chosen hospital $h \in S^c_i$ is

$$P^c_{ih} = \frac{exp(\boldsymbol{D}_{ih}\boldsymbol{\beta}_i + \boldsymbol{Q}_h\boldsymbol{\gamma}_i)}{\sum_{h' \in S^c_i} exp(\boldsymbol{D}_{ih'}\boldsymbol{\beta}_i + \boldsymbol{Q}_{h'}\boldsymbol{\gamma}_i)} > P^o_{ih} = \frac{exp(\boldsymbol{D}_{ih}\boldsymbol{\beta}_i + \boldsymbol{Q}_h\boldsymbol{\gamma}_i)}{\sum_{h' \in S^o_i} exp(\boldsymbol{D}_{ih'}\boldsymbol{\beta}_i + \boldsymbol{Q}_{h'}\boldsymbol{\gamma}_i)} \tag{3}$$

and P^c_{ih} is higher than P^o_{ih} because $S^c_i \subset S^o_i$.

In line with previous work, we assume that there are no outside options. We assume that after the closure all patients are treated by the remaining NHS hospitals in our sample. We also assume that removing a provider from the choice set does not change preferences over hospital characteristics (see Section 5.1 for an alternative approach) and that the closure of a hospital has no effect on the characteristics of the remaining providers.

The expected change in quality for patient i due to closure is

$$\Delta^q_i = \sum_{h \in S^o_i} P^o_{ih} q_h - \sum_{h \in S^c_i} P^c_{ih} q_h \tag{4}$$

Recall that the policy thought experiment applies results from a choice model estimated using the observed choices of patients whose choice sets include hospital h^c to predict probabilistically the unobserved choices of patients facing choice sets with and without h^c.

The average expected effect on quality across n patients is

$$\overline{\Delta}^q = n^{-1}\sum_{i=1}^{n}\Delta_i^q \tag{5}$$

The change in expected travelled distance for patient i is

$$\Delta_i^d = E_{h\in S_i^o}d_{ih} - E_{h\in S_i^c}d_{ih} = \sum_{h\in S_i^o}P_{ih}^o d_{ih} - \sum_{h\in S_i^c}P_{ih}^c d_{ih} \tag{6}$$

where d_{ih} is the distance from patient i to hospital h. The change in expected distance averaged across all patients is $\overline{\Delta}^d = n^{-1}\sum_{i=1}^{n}\Delta_i^d$.

2.2. Effect of closure on patient utility

The reduction in expected utility for patient i due to closure is:

$$\Delta_i^U = E_{h\in S_i^o}U_{ih} - E_{h\in S_i^c}U_{ih} = \sum_{h\in S_i^o}P_{ih}^o U_{ih} - \sum_{h\in S_i^c}P_{ih}^c U_{ih} \tag{7}$$

Substituting $U_{ih} = V_{ih} + \varepsilon_{ih}$ into Δ_i^U, we can rewrite (8) as (Williams, 1977; Small and Rosen, 1981; Train, 2009; Capps et al., 2010; see Appendix 1 for details)

$$\Delta_i^U = ln\left(\sum\nolimits_{h\in S_i^o}\exp\left(V_{ih}\right)\right) - ln\left(\sum\nolimits_{h\in S_i^c}\exp(V_{ih})\right) = ln\left(\frac{1}{1-P_{ih^c}^o}\right) \tag{8}$$

Unsurprisingly, the expected utility loss for patient i from closing hospital h^c is larger the greater the probability that patient i would have chosen it if it was open. Since the estimated coefficients in conditional logit models are defined only up to a proportional transformation, which depends on the variance of the error term, we standardise the average expected utility reduction as

$$\overline{\Delta}^{SU} = n^{-1}\sum_{i=1}^{n}\frac{\Delta_i^U}{(-\beta_i)} \tag{9}$$

where $(\beta_i < 0)$ is the marginal disutility of distance for individual i. $\overline{\Delta}^{SU}$ is the average change in expected utility measured in units of distance (kilometres).

If utility is a linear function of distance, and does not vary with patient characteristics, the marginal disutility of distance β_i will be the same for all individuals. If the best fitting choice model has utility as a non-linear function of distance, we can compute marginal utility at some arbitrary but plausible distance. For example, we could use the average distance of all patients from providers in their choice sets. If the preferred choice model specification has patient characteristics such as age interacted with distance we can compute the marginal utility of distance at the mean patient age and mean distance. Notice that any individual characteristics which affect utility are in V_{ih} and hence in Δ_i^U. The purpose of rescaling Δ_i^U is to yield a measure of the change in utility which does not depend on the arbitrary cardinal scale of utility, or on the particular hospital closure or on individual characteristics. We therefore specify β_i so that it is invariant across individuals.

Note that although we focus on closures, the method can also be applied to simulate the effects of opening of a hospital department by adding the new hospital with its assumed set of characteristics to every patient choice set, and calculating choice probabilities and expected utilities for patients faced with the larger choice set using the estimated coefficients from the conditional logit model based on the pre-change choice sets.

3. Data

To illustrate the calculation of the effect of hospital closures, we use the data and the patient choice specification in Gutacker et al. (2016). Briefly, we use patient-level data from Hospital Episode Statistics (HES) for all elective admissions for patients aged 18 or over who underwent NHS-funded primary hip replacement surgery between April 2010 and March 2013 in NHS or private providers. We exclude patients attending providers with less than 30 patients in that year. Privately funded patients are also excluded.

We have four measures of hospital clinical quality, all assumed to influence patient choice of provider. The first is the average risk-adjusted Oxford Hip Score (OHS) computed and published by the Health & Social Care Information Centre for each hospital (Health & Social Care Information Centre, 2013). The case-mix adjustment methodology considers a range of patient characteristics including age, sex, pre-operative PROM score, socio-economic status, comorbidity burden, whether the patient lives alone as well as other indicators of disability. The other three quality measures are the risk-adjusted annual emergency readmission rate within 28 days of discharge after their initial elective procedure, mortality rates within 28 days of their index admission and 1-year revision rates from the date of the primary hip replacement surgery.

We control for hospital waiting times, computed as the proportion of patients in each hospital who waited longer than 120 days between the specialist's decision to add the patient to the waiting list and admission to hospital for treatment (the inpatient wait).

Patient characteristics include age, gender, past emergency admissions, the number of Elixhauser comorbid conditions recorded in admissions in the previous year (Elixhauser et al., 1998), pre-operative OHS score, and income deprivation. We measure patient distance from a hospital as the straight-line distance from the centroid of their Lower Super Output Area (LSOA). Income deprivation is based on the proportion of residents claiming benefits measured at the LSOA level. LSOAs are small geographical areas with 1500 population. Past emergency admissions are measured as the number of admissions in the year prior to surgery.

The estimation sample has 170,916 elective hip replacement patients in 228 providers. Summary statistics and the results of the conditional logit model specification are available in Table 1, equations (1) and (3), and Table 2 in Gutacker et al. (2016), and are not repeated here. When estimating the conditional logit model, the patient choice set was restricted to the 50 nearest providers. They find that a one standard deviation increase in the average health gain (as measured by the Oxford Hip Score) increases demand by up to 9.8%, whereas one standard deviation increase in emergency readmission rates and mortality rates reduce demand by 6.8% and 0.7%, respectively.

4. Results

In this section, we simulate the effects of eight different types of hospital closure. We have four clinical hospital quality variables (health gains based on the Oxford Hip Score, risk-adjusted annual 28-day emergency readmission, 28-day mortality rates and 1-year revision rates after primary hip replacement surgery). Distances to hospitals differ markedly in urban and rural areas. We simulate the closure of the hospital that had the lowest health outcome for each of the four outcomes, first conditional on hospitals being located in an urban area, and then conditional on hospitals being located in a rural area. This gives rise to eight possible hospital closures, which we discuss below.

For each closure we estimate the effect on average expected quality $\overline{\Delta}^q$ for each of the four quality measures, average expected distance travelled $\overline{\Delta}^d$, average expected utility $\overline{\Delta}^U$, and average expected standardised utility $\overline{\Delta}^{SU}$, using the results from the hospital choice model in Gutacker et al. (2016, Table 2). We report the estimated average expected effects for (i) all patients, (ii) patients with the same observed characteristics as those who actually chose the closed hospital, and (iii) patients with the same observed characteristics as those who

Table 1
Closure of urban and rural NHS Trusts with lowest Oxford Hip Score.

	Urban			Rural		
	affected	treated	untreated	affected	treated	untreated
Number of Patients	44046	543	43503	41354	865	40489
Change in Utility	−0.018	−0.409	−0.013	−0.022	−0.620	−0.009
Change in Standardized Utility (km)	−0.088	−2.001	−0.064	−0.105	−3.030	−0.043
Expected OHS change - Full Choice Set	19.854	19.067	19.864	19.725	19.905	19.722
Expected OHS change - Post Closure Choice Set	19.905	20.205	19.902	19.747	20.576	19.730
Difference in Expected OHS change (Closure - Full)	0.051	1.138	0.037	0.022	0.671	0.008
% Expected Readmissions - Full Choice Set	4.822	5.178	4.818	5.010	5.028	5.010
% Expected Readmissions - Post Closure Choice Set	4.810	4.936	4.808	5.021	5.345	5.014
Difference in % Expected Readmissions (Closure - Full)	−0.012	−0.242	−0.009	0.011	0.317	0.004
% Expected Revisions - Full Choice Set	0.588	0.790	0.585	0.614	0.768	0.611
% Expected Revisions - Post Closure Choice Set	0.591	0.912	0.587	0.620	0.931	0.613
% Difference in Expected Revisions (Closure - Full)	0.003	0.122	0.002	0.005	0.163	0.002
% Expected Deaths - Full Choice Set	0.169	0.216	0.168	0.172	0.134	0.173
% Expected Deaths - Post Closure Choice Set	0.171	0.270	0.170	0.169	0.047	0.171
Difference in % Expected Deaths (Closure - Full)	0.002	0.053	0.002	−0.003	−0.087	−0.001
Expected Distance (km) - Full Choice Set	13.832	8.873	13.894	14.747	13.373	14.776
Expected Distance (km) - Post Closure Choice Set	13.865	11.051	13.900	14.803	16.154	14.774
Difference in Expected Distance (km) (Closure - Full)	0.033	2.177	0.006	0.057	2.780	−0.002

Note: “affected” patients chose one of the providers in the initial pre-closure choice set; “treated” patients initially chose the provider which was closed. OHS: Oxford Hip Score.

did not chose the closed hospital. In discussing the results, we avoid repetition by referring, a little loosely, to the last two groups as those who attended the closed hospital and those who did not.

4.1. *Closures of urban and rural hospital with lowest post-operative health (Oxford Hip Score)*

Table 1 has results for closing the urban and rural hospital with the lowest risk-adjusted post-operative health, as measured by the Oxford Hip Score. Out of the 170,916 patients in our sample, 44,046 had chosen the *urban* hospital with the lowest OHS in their choice set (defined as the 50 hospitals closest to the patient). The closure of this hospital increases, by construction, the average health gain over all patients who could have chosen it, from 19.85 to 19.91 points (0.05 points). Patients who attended the closed hospital have a relatively much greater expected gain from 19.07 to 20.20 points (1.14 points), as they move from the hospital with lowest quality to one of the other hospitals in their choice set.

The effect of the closure on the estimated average emergency readmission, revisions or mortality, depends on the correlation between the OHS and other quality indicators. While the closure reduces emergency readmissions from 4.822% to 4.810%, revisions increase from 0.588% to 0.591% and deaths from 0.169% to 0.171%. The effects are larger for patients who would have chosen the closed provider: their probabilities of emergency admission fall from 5.178% to 4.936%, of revisions increases from 0.790% to 0.912%, and of death increases from 0.216% to 0.270%.

The average expected distance across all patients increases only slightly from 13.83 km to 13.86 km. However, for the 543 patients who attended the closed hospital, distance increases from 8.87 km to 11.05 km. The loss of expected utility from closing the hospital is equivalent to an increase in distance of 0.09 km across all patients, and 2.00 km for the 543 patients who had attended the closed hospital.

We now investigate the effect of closing the *rural* hospital with worse post-operative health. 41,354 patients are affected by the closure of the rural hospital with the worst OHS of whom 865 attended the closed hospital. The OHS increases overall by 0.02 points across all patients and by 0.67 points for those who attended the closed hospital (from 19.91 OHS points to 20.58). Emergency readmissions and revisions however increase while mortality reduces. The expected distance across all patients increases from 14.75 km to 14.80 km. For patients who attended the closed hospital, the distance increases by 2.78 km (from 13.37 km to 16.15 km). The loss of utility is equivalent to an increase in distance of 0.11 km across all patients, and equal to 3.03 km for those who attended the closed hospital.

We briefly compare the results between the urban and rural hospital. As expected, patients who used to attend the closed rural hospital travelled a longer distance relative to the closed urban hospital (13.37 km vs 8.87 km). The difference in expected distance is higher when closing the rural hospital rather than the urban hospital with lowest quality. The effect of closure on standardised utility is also higher when the rural

Table 2
Closure of urban and rural NHS Trust with highest readmission rate.

	Urban			*Rural*		
	affected	treated	untreated	affected	treated	untreated
Number of Patients	29563	641	28922	18891	991	17900
Change in Utility	−0.031	−0.852	−0.013	−0.079	−1.254	−0.014
Change in Standardized Utility (km)	−0.151	−4.165	−0.063	−0.388	−6.128	−0.070
Expected OHS change - Full Choice Set	19.292	18.372	19.313	20.115	20.644	20.086
Expected OHS change - Post Closure Choice Set	19.254	17.294	19.297	20.150	21.116	20.096
Difference in Expected OHS change (Closure - Full)	−0.038	−1.078	−0.015	0.035	0.472	0.011
% Expected Readmissions - Full Choice Set	6.504	9.757	6.432	5.905	7.515	5.816
% Expected Readmissions - Post Closure Choice Set	6.396	7.352	6.375	5.770	5.706	5.774
Difference in % Expected Readmissions (Closure - Full)	−0.107	−2.405	−0.056	−0.135	−1.809	−0.042
% Expected Revisions - Full Choice Set	0.678	0.475	0.682	0.620	0.304	0.637
% Expected Revisions - Post Closure Choice Set	0.683	0.598	0.685	0.641	0.602	0.643
% Difference in Expected Revisions (Closure - Full)	0.006	0.123	0.003	0.021	0.298	0.006
% Expected Deaths - Full Choice Set	0.133	0.085	0.134	0.133	0.082	0.136
% Expected Deaths - Post Closure Choice Set	0.137	0.168	0.136	0.132	0.071	0.136
Difference in % Expected Deaths (Closure - Full)	0.004	0.083	0.002	−0.001	−0.011	0.000
Expected Distance (km) - Full Choice Set	14.375	11.008	14.449	18.587	20.975	18.455
Expected Distance (km) - Post Closure Choice Set	14.548	18.057	14.470	19.304	34.584	18.458
Difference in Expected Distance (km) (Closure - Full)	0.173	7.049	0.021	0.717	13.610	0.004

Note: “affected” patients chose one of the providers in the initial pre-closure choice set; “treated” patients initially chose the provider which was closed.

hospital with the worst OHS performance is closed, and this is despite the much larger increase in post-operative health (0.671 versus 0.051).

4.2. Closure of urban and rural hospital with highest readmission rates

Table 2 suggests that the expected readmission rate across all patients falls after closure of the *urban* hospital with highest readmission rates by 0.11 percentage points for all patients but by 2.41 percentage points for those 641 patients who would have attended the closing hospital. However, revisions and mortality increase, and health gains decrease.

The average distance increases by 0.17 km across all patients and by 7 km for those who attended the closed hospital (from 11.01 km to 18.06 km), which is more than double the increases in Table 1. The reduction in utility is also greater and equivalent to an increase in distance of 0.15 km across all patients and equivalent to 4.17 km for those who attended the closed hospital.

Table 2 suggests that when the hospital is located in a *rural* area the results are qualitatively similar to when the closed hospital is in an urban area, but, as in Table 1, the effect on standardised utility is larger if the hospital is located in a rural area. The expected reduction in readmission rates is 0.14 percentage points across all patients and 1.8 percentage points for those who attended the closing hospital. The average health gain increases, the mortality rate falls, and revisions increase.

The expected distance travelled increases by 0.72 km across all patients and by 13.6 km for those who attended the closing rural hospital (from 20.98 km to 34.58 km). The loss of utility is equivalent to an increase in distance of 0.39 km across all patients, and 6.13 km for those patients who attended the closing hospital. The effect on utility is 47% higher for the rural hospital than for the urban hospital for patients who attended the closing hospital (6.13 km vs. 4.17 km). For this group of patients, the effect on the distance travelled caused by a closure is also 80% higher for the rural versus the urban hospital (13.6 km vs. 7.5 km). Rural patients are therefore significantly affected by the closure also considering that patients attending the closing rural hospital travelled on average 20.98 km before the closure.

4.3. Closure of urban and rural hospital with highest revisions

Table 3 reports the effects of the simulated closure of the urban and rural hospital with the highest revisions rate. Closing the *urban* hospital has a negligible effect on the expected revision rate across all patients and reduces it by 0.001 percentage points for patients attending the closing hospital. The expected distance increases by 0.60 km across all patients and by 11.49 km for patients who attended the closed hospital (from 12.98 km to 24.47 km). The loss of utility from closing the hospital with the highest revisions rates in an urban area is equivalent to an increase in distance of 0.42 km across all patients, and 7.61 km for those who attended the closing hospital.

Closing the *rural* hospital with highest revision rates reduces the expected revision rate by 0.064 percentage points across all patients and by 0.276 percentage points for patients who attended the closing hospital. The expected distance increases by 0.59 km across all patients and by 2.83 km for patients who attended the closing hospital (from 25.06 km to 27.89 km). The loss of utility from closing the hospital with the highest revisions rate in a rural area is equivalent to an increase in distance of 1.7 km across all patients, and 6.95 km for those who attended the closing hospital. Relative to the examples provided in Tables 1 and 2, the utility effect for rural hospital is comparable and even smaller than the effect for the urban hospital. But it is still the case that patients attending the closing rural hospital travel longer distance than those attending the closing urban hospital with highest revisions rate.

4.4. Closure of urban and rural hospital with highest mortality

Last, Table 4 reports the effects of the simulated closures of urban and rural hospitals with the highest mortality rate. Closing the *urban* hospital reduced the mortality rate across all patients by 0.002 percentage points and by 0.120 percentage points for patients attending the closing hospital. The expected distance is virtually unchanged across all patients and increases by 2.64 km for patients who attended the closing hospital (from 7.19 km to 9.83 km). The loss of utility from closing down the hospital with highest mortality in an urban area is equivalent to an increase in distance of 0.06 km across all patients, and 2.03 km for those patients who attended the closing hospital.

Closing the *rural* hospital with highest mortality rate reduced the expected mortality across all patients by 0.005 percentage points and by 0.186 percentage points for patients attending the closing hospital. The expected distance increases by 0.48 km across all patients and by 23.37 km across patients who attended the closing hospital (from 18.93 km to 42.30 km). The loss of utility from closing down the hospital with highest mortality in a rural area is equivalent to an increase in distance of 0.22 km across all patients, and 10.25 km for those patients who attended the closing hospital. Again, patients in a rural area are affected more by the closure of a hospital than patients in an urban area.

5. Robustness checks

5.1. Excluding the closed hospital from the patient choice set

In our approach, we assume that removing a hospital provider from the choice set does not change preferences over hospital characteristics. We therefore estimate the choice model based on the choice set of all the patients in our sample, including those who choose the simulated closing hospital. Our justification is that patient preferences over distance and quality should be representative of all patients in need of a hip replacement in our sample. On the other hand, estimation of the patients' preference will depend on the choice set, and will therefore differ if we exclude the closing hospital when estimating the patient choice model.

As a robustness check, we have therefore re-estimated for each simulated closure the patient choice model by excluding from the choice set the hospital that is hypothetically closed by the policymakers according to our thought experiment. We then use the estimates from this choice model to simulate the effects of the closure, by using the same procedure outlined in Section 2 for all patients included in our sample. We therefore assume that the choice behaviour of patients admitted to the excluded hospital, if they had not had that hospital available in their choice set, is the same as the choice behaviour of patients who did not choose that hospital.[1] The results for the eight conditional logit models are presented in Table A1 in Appendix 2 for the main variables (distance, quality and type of hospital). Given that we remove one hospital at the time, it is not surprising that the results are similar across the eight specifications.

Tables A2-A5 provide the results using the same structure used for Tables 1–4 simulating the effect of closing the urban and rural hospital with lowest quality. The results are generally similar under the two approaches. Comparing Table 1 and Table A2, the average expected distance from closing the urban hospital with lowest Oxford Hip Score across all patients increases to 13.871 km in Table A2, which is very similar to 13.865 in Table 1. For the 543 patients who attended the closed hospital, distance increases post closure to 11.061 km in Table A2, which is very similar to 11.051 in Table 1. The loss of expected utility from those affected by the closure is equivalent to an increase in distance of 1.977 in Table A2 (again similar to 2.001 km in Table 1).

In Table A3, the loss of expected utility from closing the urban hospital with highest readmission rate is equivalent to an increase in distance of 4.113 km for those who attended the closed hospital, which is similar to 4.165 km reported in Table 2. In Table A4, the loss in expected utility from closing down the urban hospital with highest revision rates is equivalent to an increase in distance of 8.042 km (relative to 7.612 km in Table 3). In Table A5, the loss in expected utility from

[1] We thank an anonymous reviewer for this suggestion.

Table 3
Closure of urban and rural NHS Trust with highest revisions rate.

	Urban			*Rural*		
	affected	treated	untreated	affected	treated	untreated
Number of Patients	19712	630	19082	10330	1508	8822
Change in Utility	−0.086	−1.558	−0.038	−0.349	−1.423	−0.165
Change in Standardized Utility (km)	−0.421	−7.612	−0.183	−1.704	−6.953	−0.807
Expected OHS change - Full Choice Set	19.722	18.384	19.766	20.677	20.306	20.740
Expected OHS change - Post Closure Choice Set	19.995	20.841	19.967	20.946	21.306	20.884
Difference in Expected OHS change (Closure Full)	0.273	2.457	0.201	0.269	1.000	0.144
% Expected Readmissions - Full Choice Set	4.877	4.771	4.880	3.841	3.864	3.837
% Expected Readmissions - Post Closure Choice Set	4.837	4.599	4.845	3.753	3.449	3.805
Difference in % Expected Readmissions (Closure - Full)	−0.040	−0.172	−0.036	−0.088	−0.415	−0.032
% Expected Revisions - Full Choice Set	0.503	0.165	0.514	0.598	1.041	0.522
% Expected Revisions - Post Closure Choice Set	0.503	0.164	0.514	0.534	0.765	0.494
% Difference in Expected Revisions (Closure - Full)	0.000	−0.001	0.000	−0.064	−0.276	−0.028
% Expected Deaths - Full Choice Set	0.135	0.081	0.137	0.178	0.186	0.176
% Expected Deaths - Post Closure Choice Set	0.144	0.248	0.141	0.136	0.019	0.157
Difference in % Expected Deaths (Closure - Full)	0.009	0.167	0.004	−0.041	−0.167	−0.020
Expected Distance (km) - Full Choice Set	13.489	12.979	13.506	17.647	25.058	16.380
Expected Distance (km) - Post Closure Choice Set	14.091	24.466	13.748	18.239	27.886	16.591
Difference in Expected Distance (km) (Closure - Full)	0.602	11.487	0.243	0.592	2.827	0.210

Note: "affected" patients chose one of the providers in the initial pre-closure choice set; "treated" patients initially chose the provider which was closed.

closing down the urban hospital with highest mortality is equivalent to an increase in distance of 1.961 km (relative to 2.037 in Table 4). The results are also similar when comparing the effect of closure of rural hospitals with the lowest quality.

5.2. Closing hospitals in the lowest 5th percentile of the distribution of quality across hospitals

The analysis so far has focussed on simulating the effect of closure of the urban or rural hospital with lowest quality. Alternative regulatory interventions are possible. For example, a regulator could decide to close hospitals in the lowest 5th percentile of the quality distribution. Given that we have 228 providers in our sample, this would involve closing more than ten hospitals. We simulate again the effect of closure of providers in the lowest 5th percentile of the distribution for each of the four quality measures. The results are provided in Tables 5–8. The (average) loss of utility from these closures is generally comparable to those provided in the main analysis. For patients affected by the closure, the utility loss is equivalent to an increase in distance that ranges between 3.85 km and 6.36 km across quality measures. The increase in distance that arises following the hospital closures is also comparable. For the patients affected by the closures, the distance increases between four and 11 km. It is perhaps surprising that the average loss of utility for patients affected by a closure is not higher when more hospitals are closed. This is due to closures being scattered across the country rather than being concentrated in a particular area. Although the average utility loss is comparable, the total utility loss will be larger as many more patients are affected by closures (between about 3800 and 6000 patients).

6. Discussion and conclusions

Our analysis has illustrated a method to quantify the effect of hospital closure on patient welfare, quality and distance travelled for publicly-funded patients in need of a hip replacement in England. Hospitals or departments within hospitals with low quality can be targeted by regulatory authorities for closure or reconfiguration. There is pressure to close down small facilities and expand larger ones to exploit scale economies. But closing down facilities can face opposition by patients and the general public due to concerns of reduced access and this is reflected in hot debates in political campaigns.

We find that the effects of hospital closure on patients' welfare vary considerably depending on which hospital is closed. The loss to patients who would have attended the closed hospital, which affects between about 100 and 1500 patients (when closing one single urban or rural hospital with lowest quality), are equivalent to the loss of utility arising from travelling between 2.00 and 10.25 additional kilometres. The effect accounts respectively for 11.5% and 58.9% of the average distance travelled by patients before the closure (and equal to 17.40 km).

The patient welfare loss arising from a closure is generally more pronounced when the hospital is located in a rural area rather than an

Table 4
Closure of urban and rural NHS Trust with highest post operative mortality.

	Urban			Rural		
	affected	treated	untreated	affected	treated	untreated
Number of Patients	34424	136	34288	39029	732	38297
Change in Utility	−0.011	−0.417	−0.010	−0.047	−2.098	−0.007
Change in Standardized Utility (km)	−0.056	−2.037	−0.048	−0.228	−10.251	−0.036
Expected OHS change - Full Choice Set	19.307	18.293	19.311	20.294	21.013	20.280
Expected OHS change - Post Closure Choice Set	19.333	18.914	19.335	20.282	20.563	20.276
Difference in Expected OHS change -(Closure - Full)	0.026	0.621	0.024	−0.012	−0.450	−0.004
% Expected Readmissions - Full Choice Set	5.715	5.371	5.717	4.345	2.806	4.375
% Expected Readmissions - Post Closure Choice Set	5.744	6.563	5.741	4.382	4.154	4.386
Difference in % Expected Readmissions (Closure - Full)	0.029	1.192	0.024	0.037	1.348	0.012
% Expected Revisions - Full Choice Set	0.954	1.080	0.953	0.611	0.580	0.612
% Expected Revisions - Post Closure Choice Set	0.957	1.267	0.955	0.613	0.613	0.612
% Difference in Expected Revisions (Closure - Full)	0.003	0.186	0.002	0.001	0.033	0.001
% Expected Deaths - Full Choice Set	0.132	0.220	0.132	0.180	0.337	0.177
% Expected Deaths - Post Closure Choice Set	0.130	0.100	0.130	0.175	0.151	0.176
Difference in % Expected Deaths (Closure - Full)	−0.002	−0.120	−0.002	−0.005	−0.186	−0.001
Expected Distance (km) - Full Choice Set	13.553	7.188	13.578	14.850	18.933	14.772
Expected Distance (km) - Post Closure Choice Set	13.531	9.830	13.545	15.325	42.305	14.809
Difference in Expected Distance (km) (Closure - Full)	−0.022	2.642	−0.032	0.475	23.371	0.037

Note: "affected" patients chose one of the providers in the initial pre-closure choice set; "treated" patients initially chose the provider which was closed.

Table 5
Closure of NHS Trusts in the lowest 5th percentile of Oxford Hip Score.

	Affected	Treated	Untreated
Number of Patients	162478	4534	157944
Change in Utility	−0.051	−0.913	−0.027
Change in Standardized Utility (km)	−0.251	−4.461	−0.130
Expected OHS change - Full Choice Set	19.760	18.445	19.798
Expected OHS change - Post Closure Choice Set	19.862	19.876	19.876
Difference in Expected OHS change (Closure Full)	0.102	1.431	0.078
% Expected Readmissions - Full Choice Set	5.517	6.099	5.500
% Expected Readmissions - Post Closure Choice Set	5.508	5.493	5.493
Difference in % Expected Readmissions (Closure - Full)	−0.009	−0.606	−0.007
% Expected Revisions - Full Choice Set	0.605	0.804	0.599
% Expected Revisions - Post Closure Choice Set	0.602	0.597	0.597
% Difference in Expected Revisions (Closure - Full)	−0.003	−0.207	−0.002
% Expected Deaths - Full Choice Set	0.151	0.166	0.150
% Expected Deaths - Post Closure Choice Set	0.151	0.151	0.151
Difference in % Expected Deaths (Closure - Full)	0.000	−0.014	0.001
Expected Distance (km) - Full Choice Set	14.005	9.833	14.125
Expected Distance (km) - Post Closure Choice Set	14.185	14.137	14.137
Difference in Expected Distance (km) (Closure - Full)	0.180	4.304	0.012

urban area. The result is plausible because patients in rural areas have to travel longer distances when a provider is closed down and have to choose another provider based on trade-offs between quality and distance that are captured by the conditional logit choice model. The utility loss is about 50% higher for the rural hospital when the closing hospital is chosen based on the lowest Oxford Hip Score or the highest emergency readmission rate (and equivalent to the loss arising from an increase in distance of 3.03 km vs 2.00 km for the Oxford Hip Score, and 6.13 km vs 4.17 km for readmission rates). The utility loss is even higher in the rural hospital when the closed hospital is chosen based on the mortality rate and equivalent to an increase in travelled distance by 10.26 km.

These findings have equity implications because rural patients already travel longer distances relative to patients in urban areas. Patients attending the closing hospitals in urban areas travelled between 7.18 km and 12.98 km before closure, while those in rural areas travelled between 13.73 km and 25.06 km. Therefore, any closure in a rural area is likely to further increase inequalities in access between urban and rural patients.

Table 6
Closure of NHS Trusts in the highest 5th percentile of readmission rate.

	Affected	Treated	Untreated
Number of Patients	88351	5955	82396
Change in Utility	−0.093	−0.776	−0.043
Change in Standardized Utility (km)	−0.461	−3.852	−0.216
Expected OHS change - Full Choice Set	19.739	20.004	19.720
Expected OHS change - Post Closure Choice Set	19.709	19.752	19.706
Difference in Expected OHS change (Closure Full)	−0.030	−0.252	−0.014
% Expected Readmissions - Full Choice Set	6.083	7.596	5.974
% Expected Readmissions - Post Closure Choice Set	5.935	6.472	5.896
Difference in % Expected Readmissions (Closure - Full)	−0.148	−1.124	−0.078
% Expected Revisions - Full Choice Set	0.617	0.630	0.616
% Expected Revisions - Post Closure Choice Set	0.625	0.709	0.619
% Difference in Expected Revisions (Closure - Full)	0.008	0.080	0.003
% Expected Deaths - Full Choice Set	0.149	0.151	0.149
% Expected Deaths - Post Closure Choice Set	0.144	0.118	0.146
Difference in % Expected Deaths (Closure - Full)	−0.005	−0.033	−0.003
Expected Distance (km) - Full Choice Set	14.695	11.786	14.906
Expected Distance (km) - Post Closure Choice Set	15.038	17.054	14.892
Difference in Expected Distance (km) (Closure - Full)	0.343	5.268	−0.013

Table 7
Closure of NHS Trusts in the highest 5th percentile of revision rates.

	Affected	Treated	Untreated
Number of Patients	135399	3831	131568
Change in Utility	−0.050	−0.879	−0.026
Change in Standardized Utility (km)	−0.243	−4.279	−0.126
Expected OHS change - Full Choice Set	19.757	19.084	19.776
Expected OHS change - Post Closure Choice Set	19.895	19.976	19.893
Difference in Expected OHS change (Closure Full)	0.138	0.891	0.116
% Expected Readmissions - Full Choice Set	5.545	6.216	5.526
% Expected Readmissions - Post Closure Choice Set	5.507	5.660	5.503
Difference in % Expected Readmissions (Closure - Full)	−0.038	−0.556	−0.023
% Expected Revisions - Full Choice Set	0.601	0.859	0.594
% Expected Revisions - Post Closure Choice Set	0.586	0.637	0.585
% Difference in Expected Revisions (Closure - Full)	−0.015	−0.222	−0.009
% Expected Deaths - Full Choice Set	0.156	0.183	0.155
% Expected Deaths - Post Closure Choice Set	0.155	0.162	0.155
Difference in % Expected Deaths (Closure - Full)	−0.001	−0.021	0.000
Expected Distance (km) - Full Choice Set	14.168	13.322	14.193
Expected Distance (km) - Post Closure Choice Set	14.357	19.637	14.203
Difference in Expected Distance (km) (Closure - Full)	0.189	6.315	0.011

Regulators will have a range of criteria when deciding whether to close a hospital or not. These are likely to be aligned with health system objectives such as quality, access and reduction in inequalities. Our analysis suggests that the trade-off between quality and access crucially depends on patients' and hospital location. The loss of utility for rural hospitals is higher than for urban hospitals. Three rural hospitals had no other rival hospitals (within a catchment area of 30 kms), while one had two other hospitals. Urban hospitals have at least four competitors (within a catchment area of 30 kms) and some had more than ten. Our estimates from the utility loss provide a tool to quantify such losses and trade them off against possible improvements in quality which patients may obtain from other hospitals. The disutility from closing down a hospital is in our analysis smaller when there are many providers. This is intuitive because this will minimise the loss from having to travel further, which is valued by patients. This suggests that regulators are more likely to close hospitals with low quality in urban areas. However, this only holds if there is sufficient capacity that can be absorbed by the

Table 8
Closure of NHS Trusts in the highest 5th percentile of mortality rates.

	Affected	Treated	Untreated
Number of Patients	147935	4303	143382
Change in Utility	−0.077	−1.311	−0.034
Change in Standardized Utility (km)	−0.372	−6.361	−0.164
Expected OHS change - Full Choice Set	19.846	20.018	19.837
Expected OHS change - Post Closure Choice Set	19.836	19.552	19.835
Difference in Expected OHS change (Closure Full)	−0.010	−0.465	−0.002
% Expected Readmissions - Full Choice Set	5.275	4.731	5.286
% Expected Readmissions - Post Closure Choice Set	5.279	4.699	5.293
Difference in % Expected Readmissions (Closure - Full)	0.004	−0.031	0.007
% Expected Revisions - Full Choice Set	0.607	0.737	0.606
% Expected Revisions - Post Closure Choice Set	0.602	0.592	0.603
% Difference in Expected Revisions (Closure - Full)	−0.005	−0.145	−0.003
% Expected Deaths - Full Choice Set	0.157	0.307	0.153
% Expected Deaths - Post Closure Choice Set	0.146	0.134	0.147
Difference in % Expected Deaths (Closure - Full)	−0.011	−0.173	−0.006
Expected Distance (km) - Full Choice Set	13.863	14.061	13.871
Expected Distance (km) - Post Closure Choice Set	14.290	25.357	13.929
Difference in Expected Distance (km) (Closure - Full)	0.427	11.295	0.058

remaining providers. Although there are more providers in urban areas, population and need may be proportionally higher, in which case closing down a hospital may create an excess demand which will translate into unmet need. Therefore, before approving a closure, regulators will have to assess existing capacity against the overall need within the area, in addition to the number of other hospitals. Last, our analysis looks at different quality measures that span from specific ones to hip replacement, such as the Oxford Hip Score and hip revisions, to generic ones, such as readmissions and mortality rates. Our analysis suggests that the utility loss from closing hospitals is comparable across quality indicators. This suggests that regulators need to use a multidimensional performance assessment framework based on a range of quality indicators before deciding whether to close a hospital.

The study has some limitations. First, we assumed that patients are always treated by the NHS, i.e. either by NHS hospitals or by private hospitals for care commissioned and funded by the NHS. Closure may induce some patients not to seek care at all, or to seek care in the private sector (i.e. without NHS-funded care). Second, we assumed that, following the closure, the quality of the other hospitals remains unaffected. However, the closure will reduce potential hospital competition which may reduce quality and reduce the quality of other hospitals (Gravelle et al., 2014; Lisi et al., 2021).

Third, we assumed that patients can be easily reallocated to hospitals not undergoing a closure. However, the volume of some hospitals will grow as patients reallocate to other hospitals, possibly leading to increases in waiting times and this may change the pattern of demand and hence travel distances. An increase in waiting times for the hospitals in the catchment area of the closing hospital could in turn influence patient choice following closure. Note however that in our choice model we only include the proportion of patients in each hospital who waited longer than 120 days (about four months). Therefore, an increase in the mean waiting time for some hospitals will affect choice only if it also affects the "long waits" measured by the proportion of patients waiting longer than four months. Moreover, if the increase in waiting times affects all hospitals in a patient choice set, then the impact on the patient choice of hospital is likely to be small or modest depending on the assumptions made on the relative waiting time increase across different hospitals. Last, as mentioned above, longer waiting times could also reduce overall demand for public health care, though the empirical evidence suggests that demand is generally inelastic to waiting times and about −0.1 or −0.2 (Martin et al., 2007; Gravelle et al., 2003). Modelling such reduction in demand would require assumptions on the distribution of patients who opt out of publicly-funded care (for example choosing instead privately-funded care), which would reduce the number of patients faced by publicly-funded providers. In summary, it should be possible to account for these changes by building on previous analyses such as those by Beckert et al. (2012), Gaynor et al. (2016) and Moscelli et al. (2021) and examining the effects of hospital closure respectively on demand elasticities, hospital quality and waiting times.

CRediT authorship contribution statement

Hugh Gravelle: Conceptualization, Methodology, Writing – original draft. **Giuseppe Moscelli:** Data curation, Formal analysis, Investigation, Methodology, Writing – review & editing, Conceptualization. **Rita Santos:** Formal analysis, Data curation, Writing – review & editing. **Luigi Siciliani:** Conceptualization, Investigation, Project administration, Writing – original draft.

Declaration of competing interest

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

Acknowledgements

This research is funded by the National Institute for Health and Care Research (NIHR) Policy Research Programme (reference 103/0001). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care. Hospital Episode Statistics are Copyright 2002–2016, re-used with the permission of NHS Digital (DARS-NIC-84254-J2G1Q-v2.13).

Appendix 1. Derivation of equation (8)

The expected utility loss to patient i from the closure of hospital $h^c \in S_i^o$ is

$$\Delta_i^U = ln\left(\sum\nolimits_{h\in S_i^o} \exp\left(V_{ih}\right)\right) - ln\left(\sum\nolimits_{h\in S_i^c} \exp(V_{ih})\right) = ln\frac{\sum_{h\in S_i^o} \exp\left(V_{ih}\right)}{\sum_{h\in S_i^c} \exp\left(V_{ih}\right)}$$

$$= ln\frac{\sum_{h\in S_i^o} \exp\left(V_{ih}\right)}{\sum_{h\in S_i^o} \exp\left(V_{ih}\right) - \exp\left(V_{ih^c}\right)} = ln\frac{1}{1 - \frac{\exp\left(V_{ih^c}\right)}{\sum_{h\in S_i^o} \exp\left(V_{ih}\right)}} = ln\left(\frac{1}{1 - P_{ih^c}^o}\right)$$

where $P_{ih^c}^o$ is the probability that patient i chose hospital h^c.

Appendix 2. Excluding the closed hospital from the patient choice set

Table A1
Conditional logit models estimates, excluding from the choice set the closed hospitals (5th percentile of quality distribution).

	Readmissions		Readmissions		Revisions		Revisions		Mortality		Mortality		OHS		OHS	
	Urban		Rural		Urban		Rural		Urban		Rural		Urban		Rural	
	b	se	b	se	b	se	b	se	b	se	b	se	b	se	b	se
Distance (in km)	−0.270	0.007	−0.270	0.007	−0.271	0.007	−0.270	0.007	−0.269	0.007	−0.270	0.007	−0.268	0.007	−0.270	0.007
Distance^2	0.002	0.000	0.003	0.000	0.002	0.000	0.002	0.000	0.002	0.000	0.003	0.000	0.002	0.000	0.002	0.000
Distance^3	−0.00001	0.00000	−0.00001	0.00000	−0.00001	0.00000	−0.00001	0.00000	−0.00001	0.00000	−0.00001	0.00000	−0.00001	0.00000	−0.00001	0.00000
NHS Trust - medium	−0.572	0.032	−0.569	0.031	−0.572	0.031	−0.587	0.031	−0.561	0.031	−0.573	0.031	−0.564	0.032	−0.567	0.031
NHS Trust - multi-service	−0.663	0.096	−0.663	0.096	−0.657	0.096	−0.677	0.096	−0.670	0.096	−0.665	0.096	−0.656	0.096	−0.663	0.095
NHS Trust - small	−0.832	0.039	−0.855	0.040	−0.830	0.039	−0.847	0.039	−0.826	0.039	−0.840	0.040	−0.827	0.040	−0.852	0.040
NHS Trust - specialist	1.015	0.075	1.016	0.074	1.020	0.075	1.007	0.075	1.020	0.074	1.017	0.075	1.005	0.074	1.014	0.074
NHS Trust - teaching	−0.442	0.034	−0.441	0.034	−0.427	0.034	−0.458	0.034	−0.445	0.034	−0.446	0.034	−0.443	0.034	−0.444	0.034
Independent sector	−1.567	0.039	−1.557	0.039	−1.557	0.039	−1.602	0.039	−1.558	0.038	−1.564	0.039	−1.550	0.039	−1.561	0.039
Treatment centre	−1.258	0.206	−1.259	0.205	−1.258	0.205	−1.264	0.206	−1.255	0.205	−1.256	0.205	−1.253	0.205	−1.255	0.205
Waiting time (proportion waiting >120 days)	−0.161	0.077	−0.135	0.077	−0.160	0.076	−0.175	0.077	−0.144	0.076	−0.162	0.077	−0.121	0.078	−0.162	0.077
Change in OHS	0.131	0.008	0.129	0.008	0.125	0.008	0.129	0.008	0.129	0.008	0.130	0.008	0.126	0.008	0.133	0.008
28-day emergency readmission rate (%)	−0.055	0.004	−0.056	0.004	−0.053	0.004	−0.054	0.004	−0.056	0.004	−0.052	0.004	−0.053	0.004	−0.053	0.004
1-year revision rate (%)	−0.015	0.010	−0.013	0.010	−0.017	0.010	−0.013	0.010	−0.019	0.010	−0.016	0.010	−0.016	0.010	−0.017	0.010
28-day mortality rate (%)	−0.037	0.028	−0.033	0.027	−0.045	0.028	−0.030	0.028	−0.010	0.028	−0.037	0.028	−0.042	0.028	−0.040	0.028
N	7454758		7448857		7462821		7430955		7470306		7437543		7441303		7430290	
AIC	439089.4		439098.4		438746.5		437381.7		440428.5		440075.8		438915.7		438935.2	
BIC	440333.6		440342.5		439990.8		438625.6		441672.9		441319.8		440159.8		440179.1	

Table A2
Closure of urban and rural NHS Trust with lowest Oxford Hip Score

	Urban			Rural		
	affected	treated	untreated	affected	treated	untreated
Number of Patients	44046	543	43503	41354	865	40489
Change in Utility	−0.068	−0.403	−0.064	0.038	−0.554	0.051
Change in Standardized Utility (km)	−0.332	−1.977	−0.311	0.187	−2.712	0.249
Expected OHS change - Full Choice Set	19.854	19.067	19.864	19.725	19.905	19.722
Expected OHS change - Post Closure Choice Set	19.904	20.202	19.901	19.747	20.577	19.729
Difference in Expected OHS change (Closure - Full)	0.050	1.135	0.037	0.021	0.672	0.008
% Expected Readmissions - Full Choice Set	4.822	5.178	4.818	5.010	5.028	5.010
% Expected Readmissions - Post Closure Choice Set	4.811	4.935	4.809	5.019	5.343	5.012
Difference in % Expected Readmissions (Closure - Full)	−0.011	−0.242	−0.009	0.009	0.315	0.002
% Expected Revisions - Full Choice Set	0.588	0.790	0.585	0.614	0.768	0.611
% Expected Revisions - Post Closure Choice Set	0.591	0.912	0.587	0.620	0.931	0.613
% Difference in Expected Revisions (Closure - Full)	0.003	0.121	0.002	0.005	0.163	0.002
% Expected Deaths - Full Choice Set	0.169	0.216	0.168	0.172	0.134	0.173
% Expected Deaths - Post Closure Choice Set	0.171	0.270	0.170	0.169	0.047	0.171
Difference in % Expected Deaths (Closure - Full)	0.003	0.053	0.002	−0.003	−0.087	−0.001
Expected Distance (km) - Full Choice Set	13.832	8.873	13.894	14.747	13.373	14.776
Expected Distance (km) - Post Closure Choice Set	13.871	11.061	13.906	14.821	16.158	14.793
Difference in Expected Distance (km) (Closure - Full)	0.039	2.188	0.012	0.075	2.785	0.017

Table A3
Closure of urban and rural NHS Trust with highest readmission rate

	Urban			Rural		
	affected	treated	untreated	affected	treated	untreated
Number of Patients	29563	641	28922	18891	991	17900
Change in Utility	−0.022	−0.842	−0.003	−0.098	−1.270	−0.033
Change in Standardized Utility (km)	−0.106	−4.113	−0.017	−0.478	−6.203	−0.162
Expected OHS change - Full Choice Set	19.292	18.372	19.313	20.115	20.644	20.086
Expected OHS change - Post Closure Choice Set	19.255	17.295	19.298	20.149	21.112	20.096
Difference in Expected OHS change (Closure - Full)	−0.038	−1.078	−0.014	0.035	0.468	0.011
% Expected Readmissions - Full Choice Set	6.504	9.757	6.432	5.905	7.515	5.816
% Expected Readmissions - Post Closure Choice Set	6.395	7.349	6.374	5.768	5.704	5.772
Difference in % Expected Readmissions (Closure - Full)	−0.109	−2.408	−0.058	−0.136	−1.811	−0.044
% Expected Revisions - Full Choice Set	0.678	0.475	0.682	0.620	0.304	0.637
% Expected Revisions - Post Closure Choice Set	0.683	0.597	0.685	0.640	0.601	0.643
% Difference in Expected Revisions (Closure - Full)	0.005	0.123	0.003	0.021	0.297	0.005
% Expected Deaths - Full Choice Set	0.133	0.085	0.134	0.133	0.082	0.136
% Expected Deaths - Post Closure Choice Set	0.137	0.168	0.136	0.133	0.072	0.136
Difference in % Expected Deaths (Closure - Full)	0.003	0.083	0.002	−0.001	−0.011	0.000
Expected Distance (km) - Full Choice Set	14.375	11.008	14.449	18.587	20.975	18.455
Expected Distance (km) - Post Closure Choice Set	14.553	18.070	14.475	19.361	34.709	18.511
Difference in Expected Distance (km) (Closure - Full)	0.178	7.062	0.026	0.773	13.734	0.056

Table A4
Closure of urban and rural NHS Trust with highest revision rate

	Urban			Rural		
	affected	treated	untreated	affected	treated	untreated
Number of Patients	19712	630	19082	10330	1508	8822
Change in Utility	−0.181	−1.651	−0.133	−0.384	−1.474	−0.197
Change in Standardized Utility (km)	−0.883	−8.042	−0.647	−1.873	−7.197	−0.963
Expected OHS change - Full Choice Set	19.722	18.384	19.766	20.677	20.306	20.740
Expected OHS change - Post Closure Choice Set	19.993	20.844	19.965	20.943	21.303	20.881
Difference in Expected OHS change (Closure - Full)	0.271	2.459	0.199	0.266	0.997	0.141
% Expected Readmissions - Full Choice Set	4.877	4.771	4.880	3.841	3.864	3.837
% Expected Readmissions - Post Closure Choice Set	4.838	4.599	4.846	3.757	3.450	3.810
Difference in % Expected Readmissions (Closure - Full)	−0.039	−0.172	−0.035	−0.083	−0.414	−0.027
% Expected Revisions - Full Choice Set	0.503	0.165	0.514	0.598	1.041	0.522
% Expected Revisions - Post Closure Choice Set	0.503	0.164	0.515	0.534	0.764	0.495
% Difference in Expected Revisions (Closure - Full)	0.000	−0.001	0.000	−0.064	−0.277	−0.028
% Expected Deaths - Full Choice Set	0.135	0.081	0.137	0.178	0.186	0.176
% Expected Deaths - Post Closure Choice Set	0.144	0.248	0.141	0.137	0.019	0.157
Difference in % Expected Deaths (Closure - Full)	0.009	0.167	0.004	−0.041	−0.167	−0.019
Expected Distance (km) - Full Choice Set	13.489	12.979	13.506	17.647	25.058	16.380
Expected Distance (km) - Post Closure Choice Set	14.064	24.398	13.723	18.277	28.025	16.611
Difference in Expected Distance (km) (Closure - Full)	0.575	11.420	0.217	0.630	2.966	0.230

Table A5
Closure of urban and rural NHS Trusts with highest post operative mortality

	Urban			Rural		
	affected	treated	untreated	affected	treated	untreated
Number of Patients	34424	136	34288	39029	732	38297
Change in Utility	−0.028	−0.401	−0.027	−0.034	−2.078	0.005
Change in Standardized Utility (km)	−0.137	−1.961	−0.130	−0.167	−10.157	0.024
Expected OHS change - Full Choice Set	19.307	18.293	19.311	20.294	21.013	20.280
Expected OHS change - Post Closure Choice Set	19.335	18.920	19.337	20.282	20.563	20.277
Difference in Expected OHS change (Closure - Full)	0.028	0.627	0.026	−0.012	−0.451	−0.004
% Expected Readmissions - Full Choice Set	5.715	5.371	5.717	4.345	2.806	4.375
% Expected Readmissions - Post Closure Choice Set	5.744	6.564	5.741	4.382	4.155	4.386
Difference in % Expected Readmissions (Closure - Full)	0.029	1.193	0.024	0.037	1.349	0.012
% Expected Revisions - Full Choice Set	0.954	1.080	0.953	0.611	0.580	0.612
% Expected Revisions - Post Closure Choice Set	0.957	1.271	0.956	0.613	0.614	0.613
% Difference in Expected Revisions (Closure - Full)	0.004	0.191	0.003	0.001	0.034	0.001
% Expected Deaths - Full Choice Set	0.132	0.220	0.132	0.180	0.337	0.177
% Expected Deaths - Post Closure Choice Set	0.130	0.101	0.130	0.175	0.151	0.176
Difference in % Expected Deaths (Closure - Full)	−0.002	−0.119	−0.002	−0.005	−0.186	−0.001
Expected Distance (km) - Full Choice Set	13.553	7.188	13.578	14.850	18.933	14.772
Expected Distance (km) - Post Closure Choice Set	13.541	9.848	13.556	15.336	42.337	14.820
Difference in Expected Distance (km) (Closure - Full)	−0.011	2.660	−0.022	0.485	23.403	0.047

Data availability

The authors do not have permission to share data.

References

Alexander, D., Richards, M.R., 2023. Economic consequences of hospital closures. J. Publ. Econ. 221, 104821.

Avdic, D., Moscelli, G., Pilny, A., Sriubaite, I., 2019. Subjective and objective quality and choice of hospital: evidence from maternal care services in Germany. J. Health Econ. 68, 102229.

Balia, S., Brau, R., Moro, D., 2020. Choice of hospital and long-distances: evidence from Italy. Reg. Sci. Urban Econ. 81, 103502.

Beckert, W., Christensen, M., Collyer, K., 2012. Choice of NHS-funded hospital services in England. Econ. J. 122 (560), 400–417.

Bloom, N., Propper, C., Seiler, S., Van Reenen, J., 2015. The impact of competition on management quality: evidence from public hospitals. Rev. Econ. Stud. 82 (2), 457–489.

Bruni, M.L., Ugolini, C., Verzulli, R., 2021. Should I wait or should I go? Travelling versus waiting for better healthcare. Reg. Sci. Urban Econ., 103697

Buchmueller, T.C., Jacobson, M., Wold, C., 2006. How far to the hospital?: the effect of hospital closures on access to care. J. Health Econ. 25 (4), 740–761.

Capps, C., Dranove, D., Lindrooth, R.C., 2010. Hospital closure and economic efficiency. J. Health Econ. 29 (1), 87–109.

Care Quality Commission, 2018. About the care quality commission. https://www.livewellsouthwest.co.uk/wp-content/uploads/2018/03/About-the-Care-Quality-Commission.pdf.

Elixhauser, A., Steiner, C., Harris, D.R., Coffey, R.M., 1998. Comorbidity measures for use with administrative data. Med. Care 8–27.

Freier, R., Simmler, M., Wittrock, C., 2021. Public good provision and local employment–evidence from Grammar School Closures in East Germany. Reg. Sci. Urban Econ. 88, 103672.

Gaughan, J., Siciliani, L., Gravelle, H., Moscelli, G., 2020. Do small hospitals have lower quality? Evidence from the English NHS. Soc. Sci. Med. 265, 113500.

Gaynor, M., Town, R., 2011. Competition in health care markets. In: Pauly, M., McGuire, T., Barros, P.P. (Eds.), Handbook of Health Economics, pp. 499–637. North-Holland.

Gaynor, M., Propper, C., Seiler, S., 2016. Free to choose? Reform, choice, and consideration sets in the English national health service. Am. Econ. Rev. 106 (11), 3521–3557.

Gravelle, H., Smith, P., Xavier, A., 2003. Performance signals in the public sector: the case of health care. Oxf. Econ. Pap. 55 (1), 81–103.

Gravelle, H., Santos, R., Siciliani, L., 2014. Does a hospital's quality depend on the quality of other hospitals? A spatial econometrics approach. Reg. Sci. Urban Econ. 49, 203–216.

Gutacker, N., Siciliani, L., Moscelli, G., Gravelle, H., 2016. Choice of hospital: which type of quality matters? J. Health Econ. 50, 230–246.

Health & Social Care Information Centre, 2013. Finalised patient reported outcome measures (PROMs) in England: April 2011 to March 2012. http://www.hscic.gov.uk/catalogue/PUB11359/final-proms-eng-apr11-mar12-fin-report-v2.pdf.

Lindrooth, R.C., Sasso, A.T.L., Bazzoli, G.J., 2003. The effect of urban hospital closure on markets. J. Health Econ. 22 (5), 691–712.

Lisi, D., Moscone, F., Tosetti, E., Vinciotti, V., 2021. Hospital quality interdependence in a competitive institutional environment: evidence from Italy. Reg. Sci. Urban Econ. 89, 103696.

Martin, S., Rice, N., Jacobs, R., Smith, P., 2007. The market for elective surgery: joint estimation of supply and demand. J. Health Econ. 26 (2), 263–285.

Moscelli, G., Gravelle, H., Siciliani, L., 2021. The effect of hospital competition on quality for non-emergency patients – evidence from the English NHS. Rand J. Econ. 52 (2), 382–414.

Moscelli, G., Siciliani, L., Gutacker, N., Gravelle, H., 2016. Location, quality and choice of hospital: evidence from England 2002–2013. Reg. Sci. Urban Econ. 60, 112–124.

OECD/European Union, 2020. Health at a Glance: Europe 2020: State of Health in the EU Cycle. OECD Publishing, Paris, France. https://doi.org/10.1787/82129230-en.

OECD, 2023. Health at a Glance. OECD Publishing, Paris, France.

Petek, N., 2022. The marginal benefit of hospitals: evidence from the effect of entry and exit on utilization and mortality rates. J. Health Econ. 86, 102688.

Small, K.A., Rosen, H.S., 1981. Applied welfare economics with discrete choice models. Econometrica: J. Econom. Soc. 105–130.

Train, K.E., 2009. Discrete Choice Methods with Simulation. Cambridge University Press.

Varkevisser, M., van der Geest, S., Schut, F., 2012. Do patients choose hospitals with high quality ratings? Empirical evidence from the market for angioplasty in The Netherlands. J. Health Econ. 31 (2), 371–378.

Williams, H., 1977. On the formation of travel demand models and economic evaluation measures of user benefits. Environ. Plann. 9, 285–344.