Article:

Longo, Francesco orcid.org/0000-0002-1833-7328, Siciliani, Luigi orcid.org/0000-0003-1739-7289, Gravelle, Hugh Stanley Emrys orcid.org/0000-0002-7753-4233 et al. (1 more author) (2017) Do Hospitals Respond to Rivals' Quality and Efficiency? A Spatial Panel Econometric Analysis. Health Economics. pp. 38-62. ISSN 1057-9230

https://doi.org/10.1002/hec.3569

Do Hospitals Respond to Rivals' Quality and Efficiency? A Spatial Panel Econometric Analysis

Francesco Longo[a,b,*] Luigi Siciliani[a,b] Hugh Gravelle[b] Rita Santos[b]

[a] *Department of Economic and Related Studies, University of York, York, UK*
[b] *Centre for Health Economics, University of York, York, UK*

JEL Classification: C21, C23, I11, L3, L11
Keywords: quality, efficiency, hospitals, competition, spatial econometrics.

Abstract word count: 189 (max 200)
Body text word count: 5,369 (max 5,000)
Table count: 8
Appendix Table count: 9

ACKNOWLEDGEMENTS
Francesco Longo was funded by the Economic and Social Research Council (grant number ES/J500215/1). Luigi Siciliani, Hugh Gravelle, and Rita Santos were funded by a grant from the Department of Health to the Policy Research Unit in the Economics of Health and Social Care System (Ref 103/0001). Rita Santos was also funded by an NIHR Doctoral Research Fellowship (DRF-2014-07-055). The views expressed are those of the authors and not necessarily those of the funders.

CONFLICT OF INTEREST
The authors have no conflict of interest to declare.

* Correspondence to: Centre for Health Economics, University of York, York, YO10 5DD, UK. E-mail: francesco.longo@york.ac.uk

ABSTRACT

We investigate whether hospitals in the English National Health Service change their quality or efficiency in response to changes in quality or efficiency of neighbouring hospitals. We first provide a theoretical model which predicts that a hospital will not respond to changes in the efficiency of its rivals but may change its quality or efficiency in response to changes in the quality of rivals, though the direction of the response is ambiguous. We use data on eight quality measures (including mortality, emergency readmissions, patient reported outcome, and patient satisfaction) and six efficiency measures (including bed occupancy, cancelled operations, and costs) for public hospitals between 2010/11 and 2013/14 to estimate both spatial cross-sectional and spatial fixed and random effects panel data models. We find that although quality and efficiency measures are unconditionally spatially correlated, the spatial regression models suggest that a hospital's quality or efficiency does not respond to its rivals' quality or efficiency, except for a hospital's overall mortality which is positively associated with that of its rivals. The results are robust to allowing for spatially correlated covariates and spatial correlated errors and to instrumenting rivals' quality and efficiency.

1. INTRODUCTION

Quality and efficiency are fundamental goals for policymakers in the hospital sector. In the presence of fixed prices, policymakers have argued that competition may induce hospitals to compete on quality to attract patients and to enhance their efficiency (Gaynor, 2007). Investigations of the effect of competition on quality and efficiency in the US, the United Kingdom, and other OECD countries have produced mixed results (section 1.1).

In this study, rather than examining the relationship between measures of competition and hospital quality and efficiency, we use an alternative approach by examining hospitals' strategic interactions. For example, in a competitive environment we may expect a hospital to respond to an increase in quality by a rival hospital by also increasing quality: in industrial economics terms qualities are *strategic* complements. We present a simple theory model (Section 2) which shows that this intuition can be correct if treatment costs are increasing in quality. The reduction in demand which follows from an increase in rival's quality reduces total treatment cost of providing quality and at the margin incentivises the hospital to increase quality. There is however an offsetting effect: the reduction in quality also reduces incentives to contain cost which reduces the profit margin on additional patients. We therefore investigate empirically whether quality and efficiency are strategic complements or strategic substitutes so that higher rivals' quality (efficiency) induces a hospital to increase or reduce its quality (efficiency).

We consider both clinical and non-clinical dimensions of quality. We measure clinical quality through risk-adjusted overall mortality and readmission rate, and mortality rates for high-volume conditions such as hip fracture and stroke. Since the vast majority of patients do not die or have an emergency readmission we also measure health gains for a common elective procedure (hip replacement) using patients-reported outcomes (PROMs). We capture non-clinical dimensions of patients' experience using patient satisfaction with their overall hospital experience, hospital cleanliness, and the extent to which clinicians involved the patients in the treatment decision. We measure hospital efficiency through indicators for bed occupancy, cancelled elective operations, and cost indices for overall hospital activity, elective and non-elective activity, and for hip replacement. All these measures are in the public domain so that hospital managers and senior physicians are in principle able to compare themselves with their rivals.

The global Moran's I test suggests that most of the quality and efficiency indicators are unconditionally spatially correlated. We estimate spatial cross-sectional models by quasi-maximum likelihood (ML) controlling for observable determinants of quality and efficiency. To control for unobserved time-invariant determinants of quality and efficiency, we also estimate spatial panel models with hospital fixed or random effects. These models suggest that a hospital's quality or efficiency does not respond to its rivals' quality or efficiency, except for a hospital's overall mortality which is positively associated with that of its rivals. The results are robust to allowing for spatially correlated covariates and spatially correlated errors and to instrumenting rivals' quality and efficiency.

Sections 1.1 and 1.2 review the literature and the institutional background. Section 2 provides a simple theoretical model. Section 3 outlines the empirical strategy. Section 4 describes the data. Section 5 discusses the results, and Section 6 concludes.

1.1. Related literature

Our study contributes to the literature on hospital competition and, more broadly, to spatial econometrics applications in health economics. Early studies focus on the relationship between hospital competition and efficiency in the US. They show that non-price competition combined with a cost-based reimbursement system may lead to overprovision of hospital services (e.g. Joskow, 1980, Robinson and Luft, 1985). Later studies find a beneficial effect of price competition on costs (e.g. Zwanziger and Melnick, 1988, Bamezai et al., 1999). Studies on the impact of hospital competition on clinical quality, measured usually by mortality, have mixed results. Some find that competition improves quality (Kessler and McClellan, 2000, Kessler and Geppert, 2005), others that competition reduces quality (Gowrisankaran and Town, 2003) or has no effect (Mukamel et al., 2001).

UK studies also have mixed results. While some find that competition increases efficiency (Cooper et al., 2012, Gaynor et al., 2013) others report no association (Söderlund et al., 1997). Some studies find negative effects of competition on quality when prices are not fixed and negotiated with the purchaser (Propper et al., 2004, Propper et al., 2008); some later studies find positive effects where prices were fixed within a DRG type system (Cooper et al., 2011, Gaynor et al., 2013, Bloom et al., 2015), and some find mixed effects based on the quality indicator (Gravelle et al., 2014a).

A smaller number of studies take a different approach: rather than examining the quasi-reduced form relationship between market structure and quality or price, they use spatial econometric methods to investigate strategic interactions amongst hospitals by examining whether a hospital's quality or price depends on the quality or price of its rivals. Mobley (2003) and Mobley et al. (2009) examine strategic complementarity in prices within the US context where hospital prices are not fixed. Similarly, Choné et al. (2014) study strategic complementarity of GPs' prices in France using an instrumental variables (IV) approach. Gravelle et al. (2014b) use a cross section of English data and find that four out of sixteen clinical and patient-reported hospital quality measures are strategic complements.

We contribute to this literature in a number of ways. First, we complement the theory model in Brekke et al. (2012), which shows that competition can influence efficiency through its effect on quality, and the finding in Cooper et al. (2012), which suggest that market structure affects efficiency, by examining strategic interactions amongst hospitals with respect to efficiency. Second, we employ panel data to control for unobserved time-invariant heterogeneity. Third, previous studies on strategic interactions amongst hospitals have been cross-sectional and so may be biased when estimated by ML because of unobserved factors generating spatial correlations amongst hospitals. We therefore address potential endogeneity in cross-sectional models by using an IV approach.

More generally, our study contributes to the small but growing literature on spatial econometrics applications in health economics. As well as hospital competition, this literature discusses alternative sources of spatial dependence across healthcare authorities. Following Manski (1993), Moscone and Knapp (2005) propose a classification of spatial effects for mental health expenditure in England. More recently, Atella et al. (2014) investigate spillovers in healthcare expenditure amongst Italian local health authorities and Guccio and Lisi (2016) look at interactions amongst hospitals' caesarean section rates. Another strand of this literature focuses on healthcare expenditure and its determinants. Some studies investigate whether spatial interactions affect expenditure (Moscone et al., 2007a, Moscone et al., 2007b). Other studies allow for spatial dependence to identify the effect of other factors, such as income, on healthcare expenditure (Costa-i-Font and Pons-Novell, 2007, Baltagi and Moscone, 2010, Moscone and Tosetti, 2010, Baltagi et al., 2016). Other studies show that it is necessary to allow for spatial correlations when examining the determinants on health outcomes, such as mortality (Lorant et al., 2001), avoidable emergency admissions (Mobley et al., 2006, Weeks et al., 2016), admission, discharge and treatment indicators (Bech and Lauridsen, 2008, Baltagi and Yen, 2014, Gaughan et al., 2015), and HIV prevalence rate (Docquier et al., 2014).

The present study extends the analysis by Gravelle et al. (2014b) on strategic interactions amongst English hospitals in several directions. In terms of research question, we focus on strategic interactions in efficiency in addition to quality. Gravelle et al. (2014b) use cross-sectional data from the financial year 2009/10 while our study covers the more recent and longer period from 2010/11 to 2013/14, which gives us the opportunity to exploit panel data methods. We also analyse quality indicators not included by Gravelle et al. (2014b), i.e. the PROMs for two high-volume orthopaedic procedures (hip and knee replacement). Most importantly, we employ a ML panel spatial lag model and a cross-sectional IV approach. We also use a richer set of demand and supply shifters to better account for potential factors generating spatial correlations. Our results are different but compatible with those obtained by Gravelle et al. (2014b) as discussed in greater detail in Section 5.3.

1.2. Institutional background

The English National Health Service (NHS) provides healthcare which is universal, tax financed, and free at the point of use. The Department of Health distributes capitated funding to around 150 local health authorities which use it to pay for secondary healthcare provided to NHS patients by public and private hospitals. Public hospitals are run by NHS Trusts or NHS Foundation Trusts, the latter having greater financial autonomy. Some NHS hospital trusts are teaching trusts providing research and teaching, and some are specialist trusts focusing on a limited range of conditions or client groups.

Hospitals are mainly funded through a prospective payment system, the National Tariff Payment System. This is based on Healthcare Resource Groups (HRGs), a patient classification system similar to the American Diagnosis-Related Group or DRG. The HRGs categorise patients into homogeneous groups depending on diagnoses, procedures, and some patient characteristics. A fixed tariff is calculated for each HRG group as its national cost averaged across providers but with adjustments for individual hospitals to reflect exogenous variations in input prices and the higher costs of specialised care (Department of Health, 2013).

Hospital competition has been encouraged by relaxing restrictions on patients' choice of hospital for elective care. Since 2008 patients have been allowed to choose any qualified provider (Department of Health, 2009). Choice is facilitated through the website 'NHS Choices', which provides information on hospital performance (e.g. mortality, waiting times).

2. THEORETICAL MODEL

We sketch a simple two-provider model of quality competition and cost reducing effort. Hospital i has demand function $D_i\left(q_i, q_j\right)$ which is increasing in own quality q_i and decreasing in the quality of hospital j. The objective function of hospital i is:

$$U_i = \left[p - c_i\left(q_i, e_i; \theta_i\right)\right] D_i\left(q_i, q_j; \theta_i\right) - G_i\left(q_i, e_i; \theta_i\right) \quad (1)$$

where p is the fixed price per treatment that the hospital receives from a third-party payer. $c_i\left(q_i, e_i\right)$ are variable treatment costs, which are increasing in quality and decreasing in cost-containment effort or efficiency e_i. $G_i\left(q_i, e_i\right)$ are monetary and non-monetary fixed costs which are increasing in both quality and cost-containment (managerial) effort. We assume that quality and cost-containment effort are substitutes, i.e. $G_{iq_ie_i}\left(q_i, e_i\right) > 0$, since both are types of managerial effort. To keep computations simple, we assume that quality and efficiency are instead independent in variable costs, i.e. $c_{iq_ie_i}\left(q_i, e_i\right) = 0$. θ_i is a vector of shift parameters (such as local input prices, population demographics, and morbidity).

Hospital i chooses quality and efficiency to satisfy:

$$U_{iq_i} = \left[p - c_i\left(q_i, e_i; \theta_i\right)\right] D_{iq_i}(q_i, q_j; \theta_i) - c_{iq_i}\left(q_i, e_i; \theta_i\right) D_i(q_i, q_j; \theta_i) - G_{iq_i}\left(q_i, e_i; \theta_i\right) = 0 \quad (2)$$

$$U_{ie_i} = -c_{ie_i}\left(q_i, e_i; \theta_i\right) D_i\left(q_i, q_j; \theta_i\right) - G_{ie_i}\left(q_i, e_i; \theta_i\right) = 0 \quad (3)$$

where $D_{iq_i} > 0$, $c_{iq_i} > 0$, and $G_{iq_i} > 0$, and denote partial derivatives with respect to quality. With strictly concave utility functions these optimality conditions are also sufficient. Note that the price must exceed the marginal cost of treating additional patients if the hospital is to be induced to provide positive quality. The optimal quality is determined such that the marginal profit from higher additional demand is equal to the marginal cost of quality. The optimal level of efficiency (cost-containment effort) is such that the marginal benefit from lower costs and higher profits are equal to the marginal disutility from efficiency.

The first order conditions (2) and (3) define the reaction functions for hospital *i*'s quality and efficiency as functions of the choice of quality by hospital *j*:

$$q_i = q_i^R(q_j;\theta_i) \tag{4}$$

$$e_i = e_i^R(q_j;\theta_i). \tag{5}$$

Since neither of the first order conditions depends on the efficiency of hospital *j*, it is apparent that quality and efficiency of hospital *i* are strategically independent of the efficiency of hospital *j*.

Totally differentiating the first order conditions we obtain:

$$\begin{aligned}\frac{\partial q_i^R}{\partial q_j} &= \left\{-U_{iq_iq_j}U_{ie_ie_i} + U_{ie_iq_j}U_{iq_ie_i}\right\}\Delta^{-1} = \\ &= \left\{-[\underbrace{(p-c_i)}_{+}\underset{?}{D_{iq_iq_j}} - \underset{+}{c_{iq_i}}\underset{-}{D_{iq_j}}]\underset{-}{U_{ie_ie_i}} - \underset{-}{c_{ie_i}}\underset{-}{D_{iq_j}}\underset{+}{U_{iq_ie_i}}\right\}\Delta^{-1}\end{aligned} \tag{6}$$

where $\Delta = U_{iq_iq_i}U_{ie_ie_i} - U_{iq_ie_i}{}^2 > 0$ by the concavity of the objective function. The term in square brackets in (6) is the direct effect of the rival's quality on the marginal profit from higher quality. It is not obvious whether an increase in rival's quality reduces or increases the marginal gain in patient numbers from higher quality. Suppose for simplicity that $D_{iq_iq_j}$ is zero. The second part of the square bracketed term is the reduction in the variable cost because the increase in rival's quality reduces demand and so the marginal cost of output of hospital i, which then responds by increasing quality. However, the second term in the curly bracket shows that the lower demand also reduces incentives to contain costs (indirect effect) and so variable cost may increase, making increases in quality to attract additional patients less profitable.

3. METHODS

We investigate whether hospitals' quality or efficiency responds to the quality or efficiency of their rivals estimating cross-sectional linear versions of the reaction functions by ML:

$$y_i = \rho \sum\nolimits_j w_{ij} y_j + \beta' X_i + \varepsilon_i \tag{7}$$

where y_i is the quality or efficiency of hospital i ($i = 1,\ldots,I$); y_j is the quality or efficiency of hospital i's rival j ($j \neq i$); w_{ij} are spatial weights, X_i is a vector of covariates including demand shifters (e.g. population density, proportion of elderly individuals), supply shifters (e.g. number of managers, proportion of consultants), hospital type (e.g. foundation trusts, teaching hospitals) and a constant; and ε_i is the error term. In matrix form we estimate:

$$Y = \rho WY + X\beta + \varepsilon \tag{8}$$

where W is the spatial weight matrix composed of the elements w_{ij}. The spatial weights are generated from the inverse distance function:

$$w_{ij} = \begin{cases} 0 & \text{if} \quad i = j \\ d_{ij}^{-1} & \text{if} \quad d_{ij} \leq 30 \text{ km and } i \neq j \\ 0 & \text{if} \quad d_{ij} > 30 \text{ km and } i \neq j \end{cases} \tag{9}$$

where d_{ij} is the straight line distance between hospital i and j. We assume, as in recent literature, that 30 km is the radius within which hospitals compete (Gaynor et al., 2012a, Bloom et al., 2015). Hospitals that are further away within a 30 km radius have a lower weight, and hospitals that are further than 30 km have a zero weight. The weight matrix W is row standardised, i.e. the elements of each row sum to one. WY is therefore a weighted average of the rivals' quality or efficiency.

The key coefficient is ρ. If $\rho > 0$ then quality (efficiency) increases in response to an increase in rivals' quality (efficiency). But there are two other potential reasons for spatial correlation in outcomes. First, a hospital's quality may vary with characteristics of rival hospitals, such as proportion of foundation trusts amongst rivals. Second, unobserved characteristics common across rival hospitals may affect quality in a given area. For instance, rival hospitals with appealing neighbourhoods are more likely to attract and employ skilled doctors and managers, and provide similar quality. If we fail to account for these factors, spatial correlation will be spurious.

There is an analogy between our spatial approach and the peer-effects literature where the identification issue is known as the "*reflection problem*" (Manski, 1993). Strategic interactions amongst hospitals, as captured by the rivals' quality or efficiency (WY), are the *endogenous effects* of the peer-effects literature. Observed characteristics of rival hospitals (WX) are the *contextual effects* and unobserved hospital characteristics similar across rivals are *correlated effects* contained in the error term ε.

To control for time-invariant unobserved factors, we estimate spatial panel models using the fixed (FE) or random-effects (RE) ML estimator:[1]

$$y_{it} = \rho \sum_j w_{ij} y_{jt} + \beta' X_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \tag{10}$$

where γ_t is a year indicator. The hospital effect α_i captures unobserved time-invariant hospital heterogeneity and will therefore potentially reduce time-invariant bias from contextual and correlated effects. Estimates, however, might still be biased in the presence of unobserved time-varying factors affecting the patient case-mix. For instance, patient comorbidities and

[1] We use the Stata user-written command `spreg` to estimate cross-sectional models (Drukker et al., 2015), and `xsmle` to estimate panel models (Belotti et al., 2014).

severity not captured by the risk adjustment may lead to higher hospital mortality rates. Risk-adjustment methodologies generally use routine patient data that reflect the information collected through DRG-type patient classification systems. Although such systems provide a large number of patient categories, there is recognition that they can only imperfectly capture patient complexity (e.g. Mason et al., 2011, Gutacker et al., 2013). Since patient comorbidities and severity vary over time, we cannot rule them out as a potential source of endogeneity.

We test the robustness of our results in a number of ways. First, we estimate the spatial Durbin model (SDM) adding all the spatially lagged covariates (*WX*) to the cross-sectional and panel models. This will reduce potential bias due to contextual effects. Second, we allow for correlated effects which lead to spatially correlated errors by estimating spatial autocorrelation (SAC) models with spatially lagged errors: $\varepsilon_{it} = \lambda \sum_j w_{ij} \varepsilon_{jt} + \xi_{it}$. Third, following the theory in section 2, we test whether a hospital's quality (efficiency) responds to rivals' efficiency (quality) by adding a spatially lagged efficiency (quality) measure to the main regressions. We also examine whether results are sensitive to extending the radius within which hospitals compete to 60 km or 90 km.

Finally, in cross-sectional models, to further address potential bias from contextual and correlated effects we use two-stage least squares (2SLS) instrumenting WY_t with its two or three year lagged value (WY_{t-2} or WY_{t-3}). An instrument is valid (Stock and Watson, 2003, p.423) if it is exogenous (not a regressor in the second stage regression and uncorrelated with unobserved factors captured by the error term) and relevant (correlated with the instrumented endogenous variable). We argue that, whilst current outcomes are potentially influenced by rival's current outcomes (or possibly last period outcomes), adjustment is sufficiently rapid that current outcomes are not affected by what rivals were doing two or three years previously. Some studies on the English NHS (Gaynor et al., 2012b, Sivey, 2012, Gutacker et al., 2016) show that patients choose hospitals with higher quality and lower waiting times. For example, Gutacker et al. (2016) find that the demand of a hospital decreases by 0.63% if a rival located within 10 km increases its PROMs quality by 1%. Hospitals are therefore unlikely to delay their reaction to changes in rivals' performance by two or three years in order to avoid reductions in the volume of patients treated and, hence, revenue. On the other hand, WY_{t-2} (or WY_{t-3}) is likely to be relevant because hospital quality is unlikely to change rapidly over time so that WY_{t-2} (or WY_{t-3}) will be a good predictor of WY_t. We can also test for relevance in the first stage model.

4. DATA

We have eight quality indicators and six efficiency indicators measured at hospital trust level and have four years of data (from 2010/11 to 2013/14, except for the readmission rate where we use data for 2008/09 to 2011/12).[2] Such indicators are issued annually or quarterly in the public domain, with the most recent collection released in 2010 (patient reported outcome measures).[3] They are therefore available to providers.[4]

4.1. Quality indicators

The risk-adjusted Summary Hospital-level Mortality Indicator (SHMI) is the ratio of the actual number of deaths from all causes in hospital or within 30 days of discharge to the number of deaths expected given the characteristics of patients. The expected deaths are

[2] Detailed definitions of the quality and efficiency indicators are included in the appendix (Table A1 and Table A2). The publication of the emergency readmission rate has been suspended because of a revision of the methodology.

[3] The SHMI was published annually until 2011 and quarterly afterwards. Bed occupancy data were released annually up to 2009/10 and quarterly afterwards. Cancelled elective operations have been issued quarterly since their first publication in 1996/97. All other indicators have annual frequency.

[4] The SHMI is only available for general hospitals but not for specialist hospitals. The reference cost index for hip replacement is not directly available as the other reference cost indexes. Its calculation, however, follows the same transparent methodology (Department of Health, 2014) and uses public data firstly released in January 2011.

estimated through a logistic regression controlling for differences in patient case-mix. We also use risk-adjusted mortality rates for two emergency conditions (hip fracture and stroke), and risk-adjusted emergency readmissions for all conditions. These three indicators are calculated through an indirect standardisation methodology that multiplies the ratio between observed and expected events (deaths or readmissions) by the national rate of patients. The expected events are in this case the product between the number of patients for a provider and the national rate of patients for each risk-adjustment category (e.g. gender-age combination) summed over all categories.

We use risk-adjusted average health change for elective hip replacement patients derived from PROMs (patient reported outcome measures) data. On the basis of the EQ-5D questionnaire (Brooks, 1996, Brooks et al., 2005), the change in a patient's health is calculated as difference between the self-assessed health status of elective patients before and six months after their surgery. Clinical quality indicators and PROMs are available from the health and social care information centre (HSCIC).[5]

We use three patient satisfaction indicators for overall experience, hospital cleanliness, and involvement in treatment decisions. Patients were asked to rate their hospital experience on a scale between 0 and 100, whereas 0 indicates extreme dissatisfaction and 100 complete satisfaction. The indicators are obtained by averaging the patient rates across hospitals and they are risk-adjusted using patients' gender, age, ethnic group, and admission method (elective or emergency). They are available from the annual NHS Inpatient Surveys conducted for the Care Quality Commission.

[5] The SHMI is adjusted for gender, age, admission method, year index, Charlson comorbidity index, and diagnosis. Hip fracture and stroke mortality are adjusted for gender and age. The emergency readmission rate is adjusted for gender, age, admission method, diagnosis, and procedure. The health change after hip replacement is adjusted for patient characteristics (e.g. gender, age, ethnics), initial health status, self-assessed health status, economic deprivation, comorbidity, procedure, and post-operative length of stay.

4.2. Efficiency indicators

The bed occupancy rate is the ratio of occupied to available hospital beds (e.g. Zuckerman et al., 1994). We measure the rate of cancelled elective operations as the ratio of the number of cancelled elective operations for non-clinical reasons to the number of elective admissions (Rumbold et al., 2015). The reference cost index (RCI) compares a hospital's total costs with the national average total costs for the same HRG groups. A RCI greater than 100 indicates higher than average costs. We also use the RCI for elective and non-elective activity, and for hip replacement.

4.3. Control variables

Our control variables include demand and supply shifters. Demand shifters comprise: demographic variables such as *population density* and *proportion of individuals aged 65 and over*, which we calculate using annual mid-year population estimates; socioeconomic measures: *proportion of individuals employed or looking for a job*, *proportion of individuals with a degree*, and *proportion of owner occupier households*; and a measure of population health: *proportion of individuals in good or very good health*. Socioeconomic and health measures are computed using 2011 Census data for all small areas within a 15 km radius.[6]

Supply shifters include: the *number of managers*, *junior doctors in training as a proportion of total clinical staff*, *consultants as a proportion of total clinical staff*, and the *number of beds*.[7] Junior doctors in training are qualified doctors under postgraduate training at the start of their medical career. Consultants lead teams of lower grade doctors and are primarily responsible for patients. Increasing the proportion of experienced doctors is likely

[6] These areas (Lower Layer Super Output Areas) have on average 1,500 inhabitants and a minimum of 1,000.

[7] The total clinical staff is the total number of doctors, nurses, and allied professionals (e.g. therapists, healthcare scientists, technicians).

to improve patient outcomes and possibly efficiency.[8] Information on hospital staff is collected from the HSCIC, whilst NHS statistics provide the number of beds.[9] Finally, we control for type of hospital**:** *foundation trust*, *teaching hospital*, and *specialist hospital*.

4.4. Descriptive statistics

Table I has descriptive statistics. The number of hospital trusts varies between 106 (for hip fracture mortality rate) and 142 (for emergency readmission rate) across indicators. The sample size for each indicator is determined by the number of hospitals with at least one rival, and is constant over time because we use a balanced panel. Hospitals with no providers within a radius of 30 km (i.e. monopolists) are dropped because, by construction, they do not compete. In the case of the sample for overall patient satisfaction, 13% of hospitals are monopolists, 23% are exposed to low competition with one or two rivals, 38% are located in areas with three to nine rivals, and 26% have more than nine rivals (up to a maximum of 25 rivals).

The SHMI and the RCIs are on average 100 by construction. On average, patients undergoing hip replacement have an average health gain of 0.413 HRQoL and 79% of all patients report high overall satisfaction.

The summary statistics for the explanatories are for the overall patient satisfaction hospital sample. Amongst the demand shifters, for example, 15.7% of individuals are over 65 years old. 83 hospitals (62.9%) are foundation trusts, 24 (18.4%) are teaching, and 14 (10.6%) are specialist.

Since hospital catchment areas overlap by construction for hospitals with at least one

[8] Siciliani and Martin (2007) show that more consultants are associated with lower waiting times for elective care.

[9] Data on hospital staff are available from 2010/11 onwards. The number of managers, the proportion of junior doctors in training, and the proportion of consultants are therefore omitted in the regressions for the emergency readmission rate to allow comparability between cross-sectional and panel models.

rival, a hospital's demand shifters are always strongly (above 80%) correlated with its rivals'. In contrast, supply shifters have more variations across rivals.

5. RESULTS

Table II has the results of the global Moran's I test for overall spatial correlation of the quality and efficiency indicators.[10] Spatial correlation is significant (at 5% level) and positive for two clinical indicators (SHMI and emergency readmissions) and two patient-reported indicators (patient satisfaction on overall experience and hospital cleanliness). Its magnitude varies between moderate (0.150 for overall patient satisfaction in 2012/13) and high (0.528 for SHMI in 2012/13). All four cost indicators have a significant and positive spatial correlation ranging between 0.150 (for RCI for hip replacement in 2011/12) and 0.483 (for RCI in 2013/14).[11]

5.1. Regression results

Table III reports the estimated spatial lag coefficient ($\hat{\rho}$) from the ML models for each quality and efficiency indicator after controlling for demand shifters, supply shifters, and type of hospital (full results with coefficients on the covariates are in Appendix Table A3 and Table A4). In the cross-sectional models, SHMI has positive and statistically significant spatial lag for two years. 10% lower SHMI (higher quality) in rival hospitals increases the hospital's SHMI by 2.9% in 2010/11 and 2% in 2011/12. For other quality and efficiency indicators, we obtain a statistically insignificant or weakly significant (at 10% level) estimated spatial lag with a few exceptions (stroke mortality rate in 2013/14 and non-elective

[10] The global Moran's I test calculates the overall degree of spatial association between observations (Anselin, 2013). It differs from the local Moran's I test, which provides a measure of spatial clustering for each observation (Anselin, 1995).

[11] The local Moran's I test on quality and efficiency indicators in 2010/11 (available upon request) has some evidence of spatial correlations for London hospitals. Other hospitals not located in London, however, also exhibit a positive and significant local spatial correlation. The majority of hospitals show an insignificant local spatial correlation.

RCI in 2010/11).[12] Overall, there is weak statistical evidence of spatial correlation in cross-sectional models.

Unlike supply shifters and hospital type dummies, demand shifters play a major role in generating cross-sectional spatial correlation. Rival hospitals are indeed close neighbours sharing similar population characteristics.

Table III also has estimates of the spatial lag coefficient after controlling for unobserved time-invariant heterogeneity with FE and RE panel data models. There is a positive statistically significant spatial lag for two of the quality measures (0.172 for SHMI and 0.110 for overall patient satisfaction) and none of the efficiency models have statistically significant spatial lags.[13] In sum, the cross-sectional and panel ML estimates do not suggest that hospital quality or efficiency generally depends on rivals' quality or efficiency.

5.2. Robustness and sensitivity analysis

We also estimate the effect of the spatial lag WY in SDM models with spatially lagged covariates and SAC models which allow for spatial correlation in the error term. The SDM results in Table IV are broadly similar to those in Table III. Once we allow for possible contextual effects with spatially lagged covariates the only hospital outcome variable which is correlated with rival outcomes is SHMI. When we instead allow possible correlated effects with the SAC specification (Table V) we again find that SHMI is the only quality indicator spatially correlated with rivals. However, two of the six efficiency measures (cancelled elective procedures, elective reference cost index) are negatively correlated with those of

---

[12] We also test the robustness of our results for bed occupancy rate and the RCI to risk-adjustment by controlling for proportion of male patients, patient age, and proportion of emergency admissions in equation (7) and (10). The results (available upon request) remain similar to those reported in Table III.

[13] Results for cross-sectional and panel models also mirror the global Moran's I test on the residuals. Residuals are obtained from a linear regression, estimated by OLS, including all controls except the spatial lag of the dependent variable. Results are available on request.

rivals.

Likelihood ratio tests (reported in the Appendix Table A5) suggest that adding the spatial lags of covariates (the SDM specification) only improves model fit for overall patient satisfaction and the rate of cancelled elective operations. The SAC model only improves the fit in the case of cancelled elective operations. Thus, overall, allowing for contextual or correlated effects with SDM or SAC models does not change the results from the simpler specification.[14]

We also test whether a hospital's quality (efficiency) responds to rivals' efficiency (quality) by adding spatial lags of efficiency (quality) to the baseline model.[15] Results in Table VI are similar to those in Table III in respect of the effect of rivals' quality (efficiency) on hospital quality (efficiency). In addition, and in line with our theoretical predictions, we do not generally observe an effect of rivals' efficiency on a hospital's quality (Appendix Table A6). Our theory model does however imply that rivals' quality could affect hospital efficiency and we find some weak evidence for this (Appendix Table A7). For instance, higher rivals' quality, as measured by the SHMI, is significantly associated with better efficiency, as measured by the non-elective RCI, in 2010/11, 2011/12, and 2012/13. However, this association is only weakly significant (at 10% level) in 2013/14 and disappears in the panel model.

5.3. IV results

Table VII has the results from 2SLS cross-sectional models instrumenting the spatial lags of quality or efficiency with their temporal spatial lags $WY_{t\text{-}2}$ or $WY_{t\text{-}3}$. The instruments appear

[14] We also find that expanding the catchment areas to 60 km or 90 km from 30 km does not change the results of the baseline models reported in Table III. Results are available on request.

[15] We use rivals' bed occupancy rate and reference cost index as measures of rivals' efficiency, and rivals' SHMI and overall patient satisfaction as measures of rivals' quality.

relevant in that they have first stage F statistics greater than 10 (Staiger and Stock, 1997). The IV estimates also suggest little evidence of strategic interactions across hospitals in quality or efficiency: the spatial lag is significant at 5% level for only the SHMI in 2012-13 and the emergency readmissions in 2013-14.

The results in our study are compatible with those reported in Gravelle et al. (2014b), who analyse sixteen quality indicators for English hospitals in 2009/10 through a spatial lag model estimated by ML. The two studies have five indicators in common: three mortality indicators (overall mortality, hip fracture and stroke mortality) and two patient satisfaction indicators (satisfaction with hospital cleanliness and decision involvement).[16] Table VIII provides a direct comparison of the results. If we compare results from Gravelle et al. (2014b) in 2009/10 with ours in 2010/11 and 2011/12 (the two closest years), the spatial lag is significant for overall mortality and it is insignificant for hip fracture mortality in both studies. The stroke mortality spatial lag is weakly significant in Gravelle et al. (2014b) and insignificant in our study. The results for the patient satisfaction indicators differ. They are significant or weakly significant in Gravelle et al. (2014b) but insignificant in our model. The differences may be due to the different sample years and, in the case of satisfaction with decision involvement, to the inclusion of additional demand shifters.[17]

6. CONCLUSIONS

We investigated whether a hospital's quality or efficiency responds to an increase in quality or efficiency of its rivals. We test for unconditional spatial correlation using the global

[16] Gravelle et al. (2014b) explore the spatial dependence for other indicators not included in this study. Amongst these, they find a positive and significant spatial correlation for hip replacement readmissions and patient satisfaction on trust in the doctors. No (or weak) spatial dependence is instead observed for mortality from high and low risk conditions, deaths after surgery, hip replacement and stroke readmissions, hip and knee revisions, operations within two days from hip fracture, and redo rates for prostate resection.

[17] The additional demand shifters are: proportion of individuals aged 65 and over, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion owner occupier households, and proportion of individuals in good or very good health.

Moran's I test and find strong evidence of positive spatial correlation for four of the eight quality and four of the six efficiency indicators. But when we estimate ML spatial cross-sectional models that include covariates potentially affecting hospital demand and costs, we no longer observe statistically significant spatial dependence for most indicators. Only for overall hospital mortality there is significant correlation with rivals' quality. Similarly, we observe little evidence of spatial dependence, except for overall mortality, after controlling for unobserved time-invariant hospital heterogeneity in ML spatial panel models. Finally, after instrumenting the spatial lags of quality and efficiency by their temporal lags, we again find little evidence of spatial dependence. Hospital quality (efficiency), therefore, does not appear to respond to the quality (efficiency) of neighbouring hospitals.

In conclusion, our empirical analysis suggests the absence of hospital spillovers in quality and efficiency. The results are in line with our theoretical model, which shows that efficiencies are strategic independent. The model also implies that whether qualities are strategic complements or substitutes is in principle indeterminate. A hospital whose rivals have higher quality will, ceteris paribus, have lower demand and this may both reduce the marginal cost of providing quality but also weaken incentives to contain costs therefore reducing the price mark-up and the incentive to provide quality. These two effects may cancel out leaving quality unaffected by rivals' quality.

The lack of hospital strategic interaction on quality is not incompatible with the recent empirical literature (reviewed in section 1.1) which shows that areas with less concentrated hospital market structure (more competition) increases quality in England (Cooper et al., 2011, Gaynor et al., 2013, Bloom et al., 2015). For example, our model suggests that if the marginal cost of treatment is constant, then qualities are strategic independent. But in this scenario it is still the case that a market structure with a larger number of rivals increases the demand responsiveness and therefore the marginal revenue from an increase in quality (so that equilibrium quality increases in the number of providers).

These findings have policy implications. They suggest that policy interventions incentivising quality or efficiency at local level will not generate positive (or negative) spillovers to other hospitals. A local policy intervention, e.g. a Care Commissioning Group which introduces a pay for performance scheme in a hospital will change quality in that hospital but will not increase the quality in other nearby hospitals. Similarly, the adoption of a new technology which increases quality in one hospital will not necessarily spread out to other hospitals. In turn, this implies that there may be scope for policymakers to develop policies which encourage cooperation across hospitals. For example, in France a new policy tool was introduced in 2016 (*Groupement Hospitalier de Territoire*) to foster cooperation of public hospitals under which each hospital has to join a group associated with a teaching hospital, and can share activity, equipment, medical teams and a joint information system (Choné, 2017, Siciliani et al., 2017).

The results have also implications for antitrust policies. Brekke et al. (2016) for example suggest that if two hospitals merge they will reduce quality and costs, and non-merging rival hospitals might also reduce quality if quality is a strategic complements. Our study suggests that hospital mergers will not induce other non-merging hospitals also to reduce quality or costs. Policy makers can therefore concentrate on evaluating just the immediate effects of a potential merger on the merging hospitals.

REFERENCES

ANSELIN, L. 1995. Local indicators of spatial association—LISA. *Geographical analysis,* 27**,** 93-115.

ANSELIN, L. 2013. *Spatial econometrics: methods and models*, Springer Science & Business Media.

ATELLA, V., BELOTTI, F., DEPALO, D. & MORTARI, A. P. 2014. Measuring spatial effects in the presence of institutional constraints: The case of Italian Local Health Authority expenditure. *Regional Science and Urban Economics,* 49**,** 232-241.

BALTAGI, B. H., LAGRAVINESE, R., MOSCONE, F. & TOSETTI, E. 2016. Health care expenditure and income: a global perspective. *Health Economics*.

BALTAGI, B. H. & MOSCONE, F. 2010. Health care expenditure and income in the OECD reconsidered: Evidence from panel data. *Economic Modelling,* 27**,** 804-811.

BALTAGI, B. H. & YEN, Y.-F. 2014. Hospital treatment rates and spillover effects: Does ownership matter? *Regional Science and Urban Economics,* 49**,** 193-202.

BAMEZAI, A., ZWANZIGER, J., MELNICK, G. A. & MANN, J. M. 1999. Price competition and hospital cost growth in the United States (1989-1994). *Health Economics,* 8**,** 233-243.

BECH, M. & LAURIDSEN, J. 2008. Exploring the spatial pattern in hospital admissions. *Health policy,* 87**,** 50-62.

BELOTTI, F., HUGHES, G. & MORTARI, A. P. 2014. XSMLE: Stata module for spatial panel data models estimation. *Statistical Software Components*.

BLOOM, N., PROPPER, C., SEILER, S. & VAN REENEN, J. 2015. The impact of competition on management quality: evidence from public hospitals. *The Review of Economic Studies,* 82**,** 457-489.

BREKKE, K. R., SICILIANI, L. & STRAUME, O. R. 2012. Quality competition with profit constraints. *Journal of Economic Behavior & Organization,* 84**,** 642-659.

BREKKE, K. R., SICILIANI, L. & STRAUME, O. R. 2016. Hospital mergers with regulated prices. *The Scandinavian Journal of Economics,* Forthcoming.

BROOKS, R. 1996. EuroQol: the current state of play. *Health policy,* 37**,** 53-72.

BROOKS, R. G., KIND, P. & RABIN, R. 2005. *EQ-5D Concepts and Methods: A Developmental History*, Springer.

CHONÉ, P. 2017. Competition policy for health care provision in France. *Health Policy,* 121**,** 111-118.

CHONÉ, P., COUDIN, E. & PLA, A. 2014. Are physician fees responsive to competition? *HEDG Working Papers,* 14/20.

COOPER, Z., GIBBONS, S., JONES, S. & MCGUIRE, A. 2011. Does hospital competition save lives? evidence from the English NHS patient choice reforms*. *The Economic Journal,* 121**,** F228-F260.

COOPER, Z., GIBBONS, S., JONES, S. & MCGUIRE, A. 2012. Does competition improve public hospitals' efficiency?: evidence from a quasi-experiment in the English National Health Service.

COSTA-I-FONT, J. & PONS-NOVELL, J. 2007. Public health expenditure and spatial interactions in a decentralized national health system. *Health economics,* 16**,** 291-306.

DEPARTMENT OF HEALTH 2009. NHS Choice Timeline. London.

DEPARTMENT OF HEALTH 2013. Payment by Results Guidance for 2013-14. London.

DEPARTMENT OF HEALTH 2014. Reference cost 2013-14. London.

DOCQUIER, F., VASILAKIS, C. & MUNSI, D. T. 2014. International migration and the propagation of HIV in sub-Saharan Africa. *Journal of health economics,* 35**,** 20-33.

DRUKKER, D. M., PENG, H., PRUCHA, I. & RACIBORSKI, R. 2015. SPPACK: Stata module for cross-section spatial-autoregressive models.

GAUGHAN, J., GRAVELLE, H. & SICILIANI, L. 2015. Testing the Bed ‐ Blocking Hypothesis: Does Nursing and Care Home Supply Reduce Delayed Hospital Discharges? *Health economics,* 24**,** 32-44.

GAYNOR, M. 2007. Competition and Quality in Health Care Markets. *Foundations and Trends (R) in Microeconomics,* 2**,** 441-508.

GAYNOR, M., LAUDICELLA, M. & PROPPER, C. 2012a. Can governments do it better? Merger mania and hospital outcomes in the English NHS. *Journal of health*

economics, 31**,** 528-543.
GAYNOR, M., MORENO-SERRA, R. & PROPPER, C. 2013. Death by Market Power: Reform, Competition, and Patient Outcomes in the National Health Service. *American Economic Journal: Economic Policy,* 5**,** 134-166.
GAYNOR, M., PROPPER, C. & SEILER, S. 2012b. Free to choose? Reform and demand response in the English National Health Service. National Bureau of Economic Research.
GOWRISANKARAN, G. & TOWN, R. J. 2003. Competition, payers, and hospital quality1. *Health services research,* 38**,** 1403-1422.
GRAVELLE, H., MOSCELLI, G., SANTOS, R. & SICILIANI, L. 2014a. The Effects of Hospital Competition and Patient Choice on Mortality for AMI, Hip Fracture and Stroke Patients. *CHE Research Paper*.
GRAVELLE, H., SANTOS, R. & SICILIANI, L. 2014b. Does a hospital's quality depend on the quality of other hospitals? A spatial econometrics approach. *Regional science and urban economics,* 49**,** 203-216.
GUCCIO, C. & LISI, D. 2016. Thus do all. Social interactions in inappropriate behavior for childbirth services in a highly decentralized healthcare system. *Regional Science and Urban Economics,* 61**,** 1-17.
GUTACKER, N., BOJKE, C., DAIDONE, S., DEVLIN, N. J., PARKIN, D. & STREET, A. 2013. Truly inefficient or providing better quality of care? Analysing the relationship between risk‐adjusted hospital costs and patients' health outcomes. *Health economics,* 22**,** 931-947.
GUTACKER, N., SICILIANI, L., MOSCELLI, G. & GRAVELLE, H. 2016. Choice of hospital: Which type of quality matters? *Journal of Health Economics,* 50**,** 230-246.
JOSKOW, P. L. 1980. The effects of competition and regulation on hospital bed supply and the reservation quality of the hospital. *The Bell Journal of Economics***,** 421-447.
KESSLER, D. P. & GEPPERT, J. J. 2005. The effects of competition on variation in the quality and cost of medical care. *Journal of Economics & Management Strategy,* 14**,** 575-589.
KESSLER, D. P. & MCCLELLAN, M. B. 2000. Is Hospital Competition Socially Wasteful? *The Quarterly Journal of Economics,* 115**,** 577-615.
LORANT, V., THOMAS, I., DELIÈGE, D. & TONGLET, R. 2001. Deprivation and mortality: the implications of spatial autocorrelation for health resources allocation. *Social science & medicine,* 53**,** 1711-1719.
MANSKI, C. F. 1993. Identification of endogenous social effects: The reflection problem. *The review of economic studies,* 60**,** 531-542.
MASON, A., WARD, P. & STREET, A. 2011. England: the healthcare resource group system. *Diagnosis-related groups in Europe—moving towards transparency, efficiency and quality in hospitals***,** 24.
MOBLEY, L. R. 2003. Estimating hospital market pricing: an equilibrium approach using spatial econometrics. *Regional Science and Urban Economics,* 33**,** 489-516.
MOBLEY, L. R., FRECH III, H. & ANSELIN, L. 2009. Spatial interaction, spatial multipliers and hospital competition. *International Journal of the Economics of Business,* 16**,** 1-17.
MOBLEY, L. R., ROOT, E., ANSELIN, L., LOZANO-GRACIA, N. & KOSCHINSKY, J. 2006. Spatial analysis of elderly access to primary care services. *International journal of health geographics,* 5**,** 19.
MOSCONE, F. & KNAPP, M. 2005. Exploring the spatial pattern of mental health expenditure. *Journal of mental health policy and economics,* 8**,** 205.
MOSCONE, F., KNAPP, M. & TOSETTI, E. 2007a. Mental health expenditure in England: a spatial panel approach. *Journal of Health Economics,* 26**,** 842-864.
MOSCONE, F. & TOSETTI, E. 2010. Health expenditure and income in the United States. *Health Economics,* 19**,** 1385-1403.
MOSCONE, F., TOSETTI, E. & KNAPP, M. 2007b. SUR model with spatial effects: an application to mental health expenditure. *Health economics,* 16**,** 1403-1408.
MUKAMEL, D. B., ZWANZIGER, J. & TOMASZEWSKI, K. J. 2001. HMO penetration, competition, and risk-adjusted hospital mortality. *Health Services Research,* 36**,** 1019.
PROPPER, C., BURGESS, S. & GOSSAGE, D. 2008. Competition and quality: Evidence

from the NHS internal market 1991–9. *The Economic Journal,* 118**,** 138-170.
PROPPER, C., BURGESS, S. & GREEN, K. 2004. Does competition between hospitals improve the quality of care?: Hospital death rates and the NHS internal market. *Journal of Public Economics,* 88**,** 1247-1272.
ROBINSON, J. C. & LUFT, H. S. 1985. The impact of hospital market structure on patient volume, average length of stay, and the cost of care. *Journal of Health Economics,* 4**,** 333-356.
RUMBOLD, B. E., SMITH, J. A., HURST, J., CHARLESWORTH, A. & CLARKE, A. 2015. Improving productive efficiency in hospitals: findings from a review of the international evidence. *Health Economics, Policy and Law,* 10**,** 21-43.
SICILIANI, L., CHALKLEY, M. & GRAVELLE, H. 2017. Policies towards hospital and GP competition in five European countries. *Health Policy,* 121**,** 103-110.
SICILIANI, L. & MARTIN, S. 2007. An empirical analysis of the impact of choice on waiting times. *Health Economics,* 16**,** 763-779.
SIVEY, P. 2012. The effect of waiting time and distance on hospital choice for English cataract patients. *Health Economics,* 21**,** 444-456.
SÖDERLUND, N., CSABA, I., GRAY, A., MILNE, R. & RAFTERY, J. 1997. Impact of the NHS reforms on English hospital productivity: an analysis of the first three years. *Bmj,* 315**,** 1126-1129.
STAIGER, D. & STOCK, J. H. 1997. Instrumental Variables Regression with Weak Instruments. *Econometrica,* 65**,** 557-586.
STOCK, J. H. & WATSON, M. W. 2003. *Introduction to econometrics*, Addison Wesley Boston.
WEEKS, W. B., VENTELOU, B. & PARAPONARIS, A. 2016. Rates of admission for ambulatory care sensitive conditions in France in 2009–2010: trends, geographic variation, costs, and an international comparison. *The European Journal of Health Economics,* 17**,** 453-470.
ZUCKERMAN, S., HADLEY, J. & IEZZONI, L. 1994. Measuring hospital efficiency with frontier cost functions. *Journal of Health Economics,* 13**,** 255-280.
ZWANZIGER, J. & MELNICK, G. A. 1988. The effects of hospital competition and the Medicare PPS program on hospital cost behavior in California. *Journal of Health Economics,* 7**,** 301-320.

TABLES AND FIGURES

Table I – Descriptive statistics.

Variable	Obs	Trusts	Monop	Mean	Std. dev.			Min	Max
					Ov	Betw	With		
<u>*Quality indicator*</u>									
Clinical									
Summary Hospital-level Mortality Indicator	476	119	20	99.9	10.0	9.5	3.5	53.9	124.8
Hip fracture mortality rate (%)	424	106	19	7.2	1.9	1.4	1.3	2.4	14.6
Stroke mortality rate (%)	444	111	20	17.4	3.2	2.4	2.2	9.8	32.7
Emergency readmission rate (%)	568	142	20	11.1	1.4	1.3	0.6	5.1	17.2
Patient reported									
Average health change after hip replacement	428	107	19	0.413	0.033	0.022	0.025	0.264	0.538
Overall patient satisfaction	528	132	19	78.8	3.9	3.5	1.8	67.3	90.4
Patient satisfaction on hospital cleanliness	528	132	19	88.1	3.3	3.0	1.3	77.3	96.8
Patient satisfaction on decision involvement	528	132	19	72.0	3.9	3.4	2.0	61.8	85.4
<u>*Efficiency indicator*</u>									
Bed occupancy rate (%)	536	134	18	87.0	6.5	5.7	3.0	58.3	98.7
Rate of cancelled elective operation (%)	536	134	17	0.81	0.37	0.31	0.19	0.02	2.41
Reference cost index	560	140	18	100.6	10.8	10.2	3.5	81.1	148.2
Elective reference cost index	560	140	18	100.8	15.5	13.6	7.4	62.7	167.7
Non-elective reference cost index	560	140	18	102.4	17.9	16.0	8.1	70.4	213.1
Reference cost index for hip replacement	508	127	18	99.6	24.6	20.4	13.9	37.8	237.1
<u>*Control variable*</u>									
Demand shifter									
Population density (1,000 indv/km^2)				1.808	2.032	2.037	0.041	0.124	7.859
Proportion of individuals aged 65 and over (%)				15.7	3.1	3.1	0.6	9.2	25.2
Proportion of individuals employed or looking for a job (%)				70.0	2.9	2.9	0.0	63.9	76.7
Proportion of individuals with a degree (%)				18.4	7.9	7.9	0.0	7.4	35.9
Proportion of owner occupier households (%)				61.6	8.9	9.0	0.0	40.0	77.6
Proportion of individuals in good or very good health (%)				81.5	2.9	2.9	0.0	75.2	86.8
Supply shifter									
Number of managers (100)				0.66	0.44	0.43	0.11	0.04	3.59
Proportion of junior doctors in training (%)				2.6	1.1	1.1	0.3	0.0	6.7
Proportion of consultants (%)				6.3	1.1	1.0	0.4	2.2	11.7
Number of beds (1,000)				0.631	0.342	0.340	0.042	0.014	2.025
Hospital type									
Foundation trust				0.629	0.484	0.477	0.087	0	1
Teaching hospital				0.184	0.388	0.387	0.038	0	1
Specialist hospital				0.106	0.308	0.387	0.038	0	1

Obs=total number of observations, Trusts=number of non-monopolist hospital trusts, Monop=number of monopolists, Ov=overall, Betw=between, With=within

Descriptive statistics refer to the sample of providers with at least one rival.

Descriptive statistics on control variables are calculated on the overall patient satisfaction's sample.

Table II – Global Moran's I test for spatial correlation.

Indicator	2010/11	2011/12	2012/13	2013/14	All years
Quality					
Clinical					
Summary Hospital-level Mortality Indicator	0.516	0.460	0.528	0.507	0.487
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Hip fracture mortality rate	0.160	0.134	-0.013	0.090	0.081
	(0.040)**	(0.081)*	(0.968)	(0.230)	(0.000)***
Stroke mortality rate	-0.155	0.126	-0.073	-0.078	-0.040
	(0.067)*	(0.079)*	(0.421)	(0.387)	(0.060)*
Emergency readmission rate	0.163	0.235			0.165
	(0.009)***	(0.000)***			(0.000)***
Patient reported					
Average health change after hip replacement	0.053	0.089	0.037	-0.030	0.041
	(0.438)	(0.228)	(0.568)	(0.806)	(0.035)**
Overall patient satisfaction	0.210	0.202	0.150	0.116	0.158
	(0.002)***	(0.003)***	(0.026)**	(0.080)*	(0.000)***
Patient satisfaction on hospital cleanliness	0.154	0.128	0.160	0.208	0.164
	(0.022)**	(0.056)*	(0.018)**	(0.002)***	(0.000)***
Patient satisfaction on decision involvement	0.093	0.105	0.031	0.116	0.083
	(0.156)	(0.113)	(0.587)	(0.080)*	(0.000)***
Efficiency					
Bed occupancy rate	0.069	0.040	-0.098	0.009	0.004
	(0.277)	(0.502)	(0.195)	(0.813)	(0.720)
Rate of cancelled elective operations	0.155	-0.050	0.088	0.046	0.053
	(0.019)**	(0.546)	(0.172)	(0.444)	(0.002)***
Reference cost index	0.440	0.425	0.426	0.483	0.439
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Elective reference cost index	0.226	0.230	0.293	0.337	0.272
	(0.001)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Non-elective reference cost index	0.272	0.341	0.273	0.209	0.281
	(0.000)***	(0.000)***	(0.000)***	(0.001)***	(0.000)***
Reference cost index for hip replacement	0.189	0.150	0.196	0.260	0.201
	(0.006)***	(0.025)**	(0.005)***	(0.000)***	(0.000)***

Correlations computed with an inverse distance weight matrix of 30 km catchment area. Data on the emergency readmission rate are currently available up to 2011/12. The statistic in year 2012/13 and 2013/14 is therefore omitted. The statistic for all years is obtained using data from 2008/09 to 2011/12.

p-values (in parentheses) are calculated assuming a normal distribution of the indicator

*** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table III – Spatial lag coefficient.

Indicator	Cross-Section				Panel	
	2010/11	2011/12	2012/13	2013/14	FE	RE
Quality						
Clinical						
Summary Hospital-level Mortality Indicator	0.285	0.203	0.108	0.145	0.172	0.184
	(0.002)***	(0.044)**	(0.278)	(0.194)	(0.001)***	(0.000)***
Hip fracture mortality rate	-0.025	0.119	-0.179	-0.156	-0.007	0.002C
	(0.831)	(0.297)	(0.116)	(0.184)	(0.896)	(0.976)
Stroke mortality rate	-0.172	-0.171	-0.174	-0.272	-0.056	-0.059
	(0.117)	(0.136)	(0.130)	(0.025)**	(0.307)	(0.299)
Emergency readmission rate	0.070	0.137			0.100	0.130
	(0.483)	(0.140)			(0.055)*	(0.010)**
Patient reported						
Average health change after hip replacement	0.048	-0.029	-0.199	-0.163	-0.044	-0.024C
	(0.685)	(0.810)	(0.097)*	(0.124)	(0.456)	(0.682)
Overall patient satisfaction	0.100	0.095	0.048	0.105	0.110	0.122
	(0.178)	(0.190)	(0.534)	(0.185)	(0.034)**	(0.005)***
Patient satisfaction on hospital cleanliness	-0.012	0.000	-0.061	0.086	-0.063	-0.023
	(0.898)	(0.998)	(0.497)	(0.313)	(0.261)	(0.647)
Patient satisfaction on decision involvement	0.024	0.048	-0.073	0.055	-0.023	0.016
	(0.778)	(0.561)	(0.398)	(0.543)	(0.668)	(0.740)
Efficiency						
Bed occupancy rate	-0.008	-0.015	-0.173	-0.079	-0.031	-0.023C
	(0.932)	(0.887)	(0.073)*	(0.442)	(0.559)	(0.655)
Rate of cancelled elective operations	0.068	-0.157	0.032	-0.008	0.053	0.044C
	(0.476)	(0.151)	(0.749)	(0.934)	(0.289)	(0.380)
Reference cost index	-0.087	-0.079	-0.067	0.003	0.007	0.018
	(0.378)	(0.412)	(0.513)	(0.980)	(0.900)	(0.732)
Elective reference cost index	-0.003	-0.094	-0.051	-0.030	-0.039	-0.039C
	(0.973)	(0.323)	(0.612)	(0.776)	(0.447)	(0.437)
Non-elective reference cost index	-0.211	-0.108	-0.168	-0.121	-0.072	-0.060
	(0.037)**	(0.248)	(0.092)*	(0.287)	(0.185)	(0.251)
Reference cost index for hip replacement	-0.054	-0.117	0.067	0.085	-0.041	-0.021
	(0.626)	(0.332)	(0.532)	(0.448)	(0.474)	(0.707)

ML estimation. Each cross-sectional regression controls for: population density, proportion of individuals aged 65 and over, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of owner occupier households, proportion of individuals in good or very good health, number of managers, proportion of junior doctors in training, proportion of consultants, number of beds, foundation trust, teaching hospital, specialist hospital. The panel model also includes year dummies.

In the regressions for SHMI, hip fracture, and stroke mortality, the specialist dummy is omitted because of the absence of specialist hospitals in these samples.

Data on the emergency readmission rate are currently available up to 2011/12. Cross-sectional estimates in year 2012/13 and 2013/14 are therefore omitted. Panel estimates are obtained using data from 2008/09 to 2011/12. In addition, data on hospital staff are available from 2010/11 onwards. Hence, all regressions for the emergency readmission rate do not include the number of managers, the proportion of junior doctors in training, and the proportion of consultants.

C = the RE estimator passes the Hausman test at 5% level, and it is therefore consistent and efficient.

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table IV – Spatial lag coefficient with Spatial Durbin Model.

Indicator	Cross-Section				Panel	
	2010/11	2011/12	2012/13	2013/14	FE	RE
Quality						
Clinical						
Summary Hospital-level Mortality Indicator	0.201	0.139	0.053	0.143	0.152	0.172
	(0.063)*	(0.237)	(0.641)	(0.247)	(0.004)***	(0.001)***
Hip fracture mortality rate	-0.073	0.045	-0.249	-0.197	-0.010	-0.009[C]
	(0.544)	(0.707)	(0.027)**	(0.103)	(0.860)	(0.878)
Stroke mortality rate	-0.210	-0.181	-0.242	-0.246	-0.078	-0.056[C]
	(0.074)*	(0.127)	(0.035)**	(0.058)*	(0.170)	(0.326)
Emergency readmission rate	-0.026	0.030			0.095	0.118
	(0.835)	(0.781)			(0.070)*	(0.025)**
Patient reported						
Average health change after hip replacement	0.056	-0.062	-0.233	-0.264	-0.048	-0.031[C]
	(0.639)	(0.633)	(0.076)*	(0.024)**	(0.422)	(0.599)
Overall patient satisfaction	-0.137	-0.122	-0.096	0.012	0.073	0.085
	(0.171)	(0.265)	(0.380)	(0.914)	(0.160)	(0.102)
Patient satisfaction on hospital cleanliness	-0.076	-0.088	-0.137	-0.014	-0.060	-0.050[C]
	(0.507)	(0.438)	(0.240)	(0.906)	(0.293)	(0.371)
Patient satisfaction on decision involvement	-0.005	-0.052	-0.204	-0.084	-0.039	-0.019
	(0.959)	(0.629)	(0.061)*	(0.454)	(0.473)	(0.725)
Efficiency						
Bed occupancy rate	-0.058	-0.050	-0.115	-0.123	-0.036	-0.023[C]
	(0.600)	(0.674)	(0.300)	(0.265)	(0.508)	(0.679)
Rate of cancelled elective operations	0.052	-0.209	-0.130	-0.076	0.030	0.041
	(0.596)	(0.061)*	(0.246)	(0.487)	(0.553)	(0.415)
Reference cost index	-0.174	-0.153	-0.104	-0.091	-0.004	0.002
	(0.118)	(0.182)	(0.358)	(0.434)	(0.934)	(0.968)
Elective reference cost index	0.018	-0.105	-0.095	-0.161	-0.038	-0.040[C]
	(0.870)	(0.314)	(0.396)	(0.171)	(0.450)	(0.447)
Non-elective reference cost index	-0.283	-0.218	-0.268	-0.194	-0.076	-0.089
	(0.009)***	(0.050)*	(0.012)**	(0.101)	(0.160)	(0.104)
Reference cost index for hip replacement	-0.199	-0.191	0.056	0.014	-0.058	-0.048
	(0.092)*	(0.110)	(0.636)	(0.909)	(0.288)	(0.388)

ML estimation. Each cross-sectional regression controls for: population density, proportion of individuals aged 65 and over, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of owner occupier households, proportion of individuals in good or very good health, number of managers, proportion of junior doctors in training, proportion of consultants, number of beds, foundation trust, teaching hospital, specialist hospital. The Spatial Durbin Model includes the spatial lag of all regressors. The panel model also includes year dummies.

In the regressions for SHMI, hip fracture, and stroke mortality, the specialist dummy is omitted because of the absence of specialist hospitals in these samples.

Data on the emergency readmission rate are currently available up to 2011/12. Cross-sectional estimates in year 2012/13 and 2013/14 are therefore omitted. Panel estimates are obtained using data from 2008/09 to 2011/12. In addition, data on hospital staff are available from 2010/11 onwards. Hence, all regressions for the emergency readmission rate do not include the number of managers, the proportion of junior doctors in training, and the proportion of consultants.

C = the RE estimator passes the Hausman test at 5% level, and it is therefore consistent and efficient.

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table V – Spatial lag coefficient with spatially correlated disturbances (SAC model).

Indicator	Spatial lag	Cross-Section				Panel
		2010/11	2011/12	2012/13	2013/14	FE
Quality						
Clinical						
Summary Hospital-level Mortality Indicator	ρ	0.331**	0.108	0.240	0.085	0.345***
	λ	-0.080	0.154	-0.198	0.105	-0.204
Hip fracture mortality rate	ρ	0.133	0.045	0.193	0.239	-0.298*
	λ	-0.215	0.095	-0.450**	-0.429**	0.275*
Stroke mortality rate	ρ	0.099	-0.063	-0.293	-0.243	-0.009
	λ	-0.341	-0.132	0.145	-0.047	-0.051
Emergency readmission rate	ρ	0.160	0.360***			0.051
	λ	-0.152	-0.348**			0.052
Patient reported						
Average health change after hip replacement	ρ	-0.104	-0.001	-0.135	-0.017	0.012
	λ	0.193	-0.044	-0.093	-0.208	-0.063
Overall patient satisfaction	ρ	0.224***	0.117	0.097	0.033	0.199
	λ	-0.342**	-0.082	-0.107	0.142	-0.100
Patient satisfaction on hospital cleanliness	ρ	-0.016	0.051	0.005	0.140	-0.027
	λ	0.007	-0.093	-0.124	-0.095	-0.039
Patient satisfaction on decision involvement	ρ	-0.089	0.025	0.056	0.102	-0.093
	λ	0.189	0.043	-0.202	-0.080	0.071
Efficiency						
Bed occupancy rate	ρ	0.348**	0.006	-0.410***	-0.076	0.059
	λ	-0.417**	-0.030	0.295*	-0.004	-0.099
Rate of cancelled elective operations	ρ	0.549***	-0.013	0.418***	0.389***	-0.474***
	λ	-0.570***	-0.170	-0.510***	-0.507***	0.491***
Reference cost index	ρ	0.043	0.042	0.012	0.101	0.017
	λ	-0.219	-0.225	-0.124	-0.166	-0.012
Elective reference cost index	ρ	-0.215	0.086	0.083	0.107	-0.374***
	λ	0.261	-0.221	-0.192	-0.223	0.336***
Non-elective reference cost index	ρ	0.002	0.093	0.055	-0.013	-0.171
	λ	-0.304*	-0.341**	-0.315*	-0.175	0.114
Reference cost index for hip replacement	ρ	0.122	-0.032	0.048	0.150	-0.066
	λ	-0.267	-0.117	0.038	-0.085	-0.001

ML estimation. Each cross-sectional regression controls for: population density, proportion of individuals aged 65 and over, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of owner occupier households, proportion of individuals in good or very good health, number of managers, proportion of junior doctors in training, proportion of consultants, number of beds, foundation trust, teaching hospital, specialist hospital. The panel model also includes year dummies.

In the regressions for SHMI, hip fracture, and stroke mortality, the specialist dummy is omitted because of the absence of specialist hospitals in these samples.

Data on the emergency readmission rate are currently available up to 2011/12. Cross-sectional estimates in year 2012/13 and 2013/14 are therefore omitted. Panel estimates are obtained using data from 2008/09 to 2011/12. In addition, data on hospital staff are available from 2010/11 onwards. Hence, all regressions for the emergency readmission rate do not include the number of managers, the proportion of junior doctors in training, and the proportion of consultants.

The p-value is omitted. *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table VI – Spatial lag coefficient with additional spatial lags of quality or efficiency.

Indicator	Cross-Section				Panel	
	2010/11	2011/12	2012/13	2013/14	FE	RE
Quality						
Clinical						
Summary Hospital-level Mortality Indicator	0.212	0.159	0.098	0.156	0.170	0.181
	(0.043)**	(0.130)	(0.328)	(0.164)	(0.001)***	(0.000)***
Hip fracture mortality rate	0.016	0.094	-0.199	-0.205	-0.040	-0.021^{C}
	(0.891)	(0.403)	(0.085)*	(0.083)*	(0.468)	(0.710)
Stroke mortality rate	-0.156	-0.176	-0.189	-0.305	-0.060	-0.057^{C}
	(0.156)	(0.132)	(0.097)*	(0.013)**	(0.279)	(0.316)
Emergency readmission rate	0.091	0.092			0.065	0.114
	(0.327)	(0.351)			(0.233)	(0.028)**
Patient reported						
Average health change after hip replacement	-0.006	-0.064	-0.157	-0.195	-0.039	-0.035^{C}
	(0.958)	(0.606)	(0.207)	(0.082)*	(0.505)	(0.557)
Overall patient satisfaction	0.047	0.061	0.003	0.084	0.084	0.092
	(0.568)	(0.460)	(0.971)	(0.349)	(0.113)	(0.052)*
Patient satisfaction on hospital cleanliness	-0.016	-0.054	-0.082	0.044	-0.069	-0.045
	(0.873)	(0.565)	(0.371)	(0.624)	(0.218)	(0.382)
Patient satisfaction on decision involvement	0.035	0.075	-0.130	0.029	-0.032	-0.001
	(0.719)	(0.405)	(0.163)	(0.761)	(0.552)	(0.986)
Efficiency						
Bed occupancy rate	-0.054	-0.114	-0.097	0.049	-0.090	-0.053^{C}
	(0.619)	(0.333)	(0.401)	(0.641)	(0.136)	(0.367)
Rate of cancelled elective operations	0.084	-0.024	0.125	0.040	0.018	0.050
	(0.424)	(0.839)	(0.246)	(0.713)	(0.736)	(0.353)
Reference cost index	0.016	0.034	0.030	-0.049	0.046	0.059
	(0.886)	(0.757)	(0.787)	(0.682)	(0.430)	(0.297)
Elective reference cost index	0.016	0.034	0.030	-0.049	0.046	0.059
	(0.886)	(0.757)	(0.787)	(0.682)	(0.430)	(0.297)
Non-elective reference cost index	-0.064	-0.081	-0.145	-0.018	-0.076	0.025
	(0.572)	(0.468)	(0.189)	(0.884)	(0.179)	(0.647)
Reference cost index for hip replacement	-0.122	-0.187	-0.012	0.068	-0.107	-0.070
	(0.287)	(0.092)*	(0.919)	(0.555)	(0.058)*	(0.212)

ML estimation. Each cross-sectional regression controls for: population density, proportion of individuals aged 65 and over, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of owner occupier households, proportion of individuals in good or very good health, number of managers, proportion of junior doctors in training, proportion of consultants, number of beds, foundation trust, teaching hospital, specialist hospital. The efficiency indicators added to the regressions for the quality indicators are bed occupancy rate and RCI. The quality indicators added to the regressions for the efficiency indicators are SHMI and overall patient satisfaction. The panel model also includes year dummies.

In the regressions including SHMI, hip fracture and stroke mortality as dependent or independent variable, the specialist dummy is omitted because of the absence of specialist hospitals in these samples.

Data on the emergency readmission rate are currently available up to 2011/12. Cross-sectional estimates in year 2012/13 and 2013/14 are therefore omitted. Panel estimates are obtained using data from 2008/09 to 2011/12. In addition, data on hospital staff are available from 2010/11 onwards. Hence, all regressions for the emergency readmission rate do not include the number of managers, the proportion of junior doctors in training, and the proportion of consultants.

C = the RE estimator passes the Hausman test at 5% level, and it is therefore consistent and efficient.

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table VII – Spatial lag coefficient. IV estimates.

Indicator	WY_{t-2} 2012/13	WY_{t-2} 2013/14	WY_{t-3} 2013/14
<u>*Quality*</u>			
Clinical			
Summary Hospital-level Mortality Indicator	0.421	0.419	0.519
	(0.026)**	(0.069)*	(0.090)*
Hip fracture mortality rate	-0.092	0.389	-0.035
	(0.820)	(0.189)	(0.939)
Emergency readmission rate	0.321	0.313	0.307
	(0.065)*	(0.048)**	(0.087)*
Patient reported			
Overall patient satisfaction	0.123	0.097	0.089
	(0.281)	(0.385)	(0.467)
Patient satisfaction on hospital cleanliness	0.034	0.126	0.155
	(0.799)	(0.276)	(0.218)
Patient satisfaction on decision involvement	0.068	0.196	0.266
	(0.654)	(0.162)	(0.081)*
<u>*Efficiency*</u>			
Bed occupancy rate	-0.042	0.095	0.0003
	(0.807)	(0.568)	(0.999)
Rate of cancelled elective operations	0.315	-0.226	-0.074
	(0.286)	(0.231)	(0.792)
Reference cost index	-0.124	-0.056	-0.110
	(0.526)	(0.727)	(0.518)
Elective reference cost index	0.116	0.069	0.027
	(0.758)	(0.771)	(0.920)
Non-elective reference cost index	-0.057	-0.175	-0.339
	(0.780)	(0.530)	(0.272)
Reference cost index for hip replacement	0.524	0.660	0.625
	(0.074)*	(0.168)	(0.109)

IV estimation. The first-stage F statistic for each specification and outcome indicator is reported in parenthesis following the same order of the table (WY_{t-2} in 2012/13; WY_{t-2} in 2013/14; WY_{t-3} in 2013/14): SHMI (94.49; 95.69; 39.70), hip fracture mortality rate (16.58; 52.46; 14.30), emergency readmission rate (140.68; 168.39; 101.60), overall patient satisfaction (175.89; 261.03; 159.30), patient satisfaction on hospital cleanliness (282.66; 467.54; 234.30), patient satisfaction on decision involvement (100.42; 216.06; 145.80), bed occupancy rate (85.14; 135.99; 103.92), rate of cancelled elective operations (30.46; 105.08; 35.54), reference cost index (87.65; 206.49; 164.61), elective reference cost index (16.29; 56.77; 50.91), non-elective reference cost index (60.16; 59.51; 42.62), reference cost index for hip replacement (44.49; 13.39; 31.14).

Each regression controls for: population density, proportion of individuals aged 65 and over, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of owner occupier households, proportion of individuals in good/very good health, number of managers, proportion of junior doctors in training, proportion of consultants, number of beds, foundation trust, teaching hospital, specialist hospital.

In the regressions for SHMI, hip fracture, and stroke mortality, the specialist dummy is omitted because of the absence of specialist hospitals in these samples.

Data on the emergency readmission rate are currently available up to 2011/12. The estimate refers to the latest available years (2010/11 or 2011/12) and not to 2012/13 or 2013/14.

For stroke mortality and average health change after hip replacement, estimates are omitted because of the absence of a relevant instrument.

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table VIII – Comparison with results in Gravelle et al. (2014b).

Indicator		GSS (2014)	Our study			
		2009/10	2010/11	2011/12	2012/13	2013/14
Overall mortality	(1)	0.276	0.377	0.260	0.162	0.241
		(0.004)***	(0.000)***	(0.008)***	(0.106)	(0.027)**
	(2)	0.234	0.314	0.214	0.105	0.173
		(0.019)**	(0.001)***	(0.036)**	(0.304)	(0.119)
Hip fracture mortality rate	(1)	0.028	0.118	0.103	-0.121	-0.105
		(0.807)	(0.286)	(0.374)	(0.283)	(0.370)
	(2)	-0.066	-0.019	0.093	-0.218	-0.203
		(0.580)	(0.868)	(0.422)	(0.054)*	(0.087)*
Stroke mortality rate	(1)	0.179	-0.037	-0.172	-0.123	-0.291
		(0.100)*	(0.748)	(0.143)	(0.284)	(0.015)**
	(2)	0.147	-0.127	-0.203	-0.163	-0.316
		(0.189)	(0.265)	(0.083)*	(0.162)	(0.009)***
Patient satisfaction on hospital cleanliness	(1)	0.179	-0.003	-0.015	-0.060	0.045
		(0.070)*	(0.976)	(0.869)	(0.538)	(0.622)
	(2)	0.171	-0.045	-0.030	-0.111	0.009
		(0.077)*	(0.633)	(0.740)	(0.248)	(0.918)
Patient satisfaction on decision involvement	(1)	0.245	0.092	0.068	-0.022	0.060
		(0.012)**	(0.272)	(0.407)	(0.792)	(0.504)
	(2)	0.167	0.005	-0.038	-0.087	-0.031
		(0.102)	(0.953)	(0.649)	(0.317)	(0.736)

GSS (2014) = Gravelle at al. (2014b). Both GSS (2014) and our study's estimates are obtained by ML. While GGS (2014) use an inverse distance weight matrix with a 30 min travel distance threshold, we use a 30 km straight line distance threshold.

Specification (1) controls for: number of rivals, teaching trusts, foundation trusts, specialist hospitals, number of patients, market forces factor, population density, London trusts.

Specification (2) controls for all covariates in (1) and for: proportion of individuals aged 65 and over, proportion of individuals employed and looking for a job, proportion of individuals with a degree, proportion of owner occupier households, proportion of individuals with a degree, proportion of individuals in good and very good health.

The specialist dummy is omitted if the quality indicator's sample does not include specialist hospitals, i.e. for all indicators included in Gravelle, Santos, and Siciliani (2014) and for SHMI, hip fracture and stroke mortality rate.

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

APPENDIX

Table A1 – Definition for the quality indicators.

Quality indicators
The Summary Hospital-level Mortality Indicator (SHMI) is a ratio of the observed number of deaths to the expected number of deaths for a trust (provider). The observed number of deaths is the total number of finished provider spells for the trust which resulted in a death either in-hospital or within 30 days (inclusive) of discharge from the trust. The expected deaths are estimated through a logistic regression controlling for age, gender, admission method, year index, Charlson Comorbidity Index and diagnosis grouping. A three year dataset is used to create the risk-adjusted models.
The hip fracture mortality rate captures deaths within 30 days (from 0 to 29 days inclusive) of an emergency admission to hospital with a primary diagnosis of fractured proximal femur (ICD-10 codes S720, S721, S722). It is indirectly standardised by age and sex.
The stroke mortality rate captures deaths within 30 days (from 0 to 29 days inclusive) of an emergency admission to hospital with a primary diagnosis of stroke (all ICD-10 codes from I61 to I64). It is indirectly standardised by age and sex.
The emergency readmission rate captures the percentage of emergency admission to any hospital in England occurring within 28 days of the last discharge from hospital after admission. The rate is calculated considering all patients aged between 16 and 74. It is indirectly standardised by age, sex, method of admission of discharge spell, diagnosis within medical specialties, and procedure within surgical specialties.
Source: Health and Social Care Information Centre, NHS Digital Indicator Portal *Link*: https://indicators.hscic.gov.uk/webview/
The average health change after hip replacement is extracted from PROMs data. PROMs comprise a pair of questionnaires completed by the patient, one before and one after surgery (at least six months after for hip replacements). All patients, irrespective of their condition, are asked to complete a common set of questions about their health status. This includes sections about the patient's circumstances, pre-existing conditions and the EQ-5D health questionnaire consisting of a five-dimensional descriptive system and a visual analogue scale (EQ-VAS). Post-operative questionnaires also contain additional questions about the surgery, such as how the patient perceives the results of the operation and whether there were any post-operative complications, such as bleeding or wound problems. Patients undergoing hip replacement surgery are also asked to complete a condition-specific section. The collected data are risk-adjusted for patient characteristics (e.g. gender, age, ethnics), initial health status, self-assessed health status, economic deprivation, comorbidity, procedure, and post-operative length of stay.
Source: Health and Social Care Information Centre *Link*: http://content.digital.nhs.uk/proms
Patient satisfaction indicators are derived from the NHS Inpatient Surveys for the Care Quality Commission which is administered to a random sample of patients in all acute trusts. The variables relate to three questions to patients: 1) From 0 to 100, "Overall, how would you rate the care you received?" (Overall patient satisfaction); 2) From 0 to 100, "In your opinion, how clean was the hospital room or ward that you were in?" (Satisfaction on hospital cleanliness); 3) From 0 to 100, "Were you involved as much as you wanted to be in decisions about your care and treatment?" (Satisfaction on decision involvement). The data has been standardised to adjust for these differences in patient-mix using the respondent's age, gender, ethnic group and method of admission (emergency or elective).
Source: NHS patient surveys *Links*: http://www.nhssurveys.org/surveys , https://www.kingsfund.org.uk/publications/patients-experience-using-hospital-services

Table A2 – Definition for the efficiency indicators.

Efficiency indicators
The bed occupancy rate is the ratio of the overnight occupied beds to the overnight available beds. For wards open overnight, an occupied bed day is defined as one which is occupied at midnight on the day in question. The number of occupied beds excludes any bed days of occupation by well babies. The number of available beds only includes beds in units managed by the provider, not beds commissioned from other providers. It excludes any beds designated solely for the use of well babies. Such data are available quarterly.
The rate of cancelled elective operations is the ratio of the number of last minute cancellations by the hospital for non-clinical reasons to the number of elective patients. Last minute means on the day the patient was due to arrive, after the patient has arrived in hospital, or on the day of the operation or surgery. Elective cancelled operations are provided in each quarter. The number of elective patients is calculated as the sum of planned and waiting list admissions, where the admission is a finished admission episode, i.e. the first period of inpatient care under one consultant within one healthcare provider. The number of elective patients is published annually.
Source: NHS statistics *Link*: https://www.england.nhs.uk/statistics/statistical-work-areas/
The reference cost index shows the actual cost of an organisation's case-mix compared with the same case-mix delivered at national average cost. Each organisation's reference cost index is calculated by dividing its total costs (unit costs × activity) by the expected costs (national average mean unit cost × activity). The reference cost index is computed separately also for elective and non-elective activity. Elective activity refers to patients whose admission to hospital is planned, including day case patients. Non-elective activity refers to patients whose admission is not planned, including emergency admissions and admissions for maternity, births, and non-emergency patient transfers, and requires staying in hospital for more than one day. The reference cost index for hip replacement is calculated selecting the HRG codes: HB11A, HB11B, HB11C, HB12A, HB12B, and HB12C.
Source: Reference costs data *Link*: https://www.gov.uk/government/collections/nhs-reference-costs

Table A3 – ML estimates for the quality indicators in 2013/14.

	Regressor	SHMI	Hip fract. mortality	Stroke mortality	Emerg. readm.	Health change hip repl.	Overall satisf.	Satisf. on cleanlin.	Satisf. on involvem.
	Spatial lag of the dependent variable	0.145	-0.156	-0.272**	0.137	-0.163	0.105	0.086	0.055
Demand shifter	Population density	-0.903	0.032	0.240	-0.052	0.009**	0.156	0.246	-0.058
	Proportion of individuals aged 65 and over	-0.037	-0.268**	0.089	-0.216**	0.004***	0.330**	0.322**	0.624***
	Proportion of ind. employed or looking for a job	0.237	0.148	-0.109	-0.037	-0.001	0.044	0.058	0.080
	Proportion of individuals with a degree	-0.397	0.052	0.060	0.031	-0.002*	-0.069	-0.157*	-0.073
	Proportion of owner occupier households	0.019	0.103*	0.041	0.002	0.0000	-0.086	-0.081	-0.196*
	Proportion of ind. in good/very good health	-0.603	-0.541***	-0.164	-0.200	0.008**	0.147	0.043	0.279
Cost shifter	Number of managers	-1.797	-0.315	-1.606**		-0.004	0.435	-0.888	0.293
	Proportion of junior doctors in training	0.917	-0.016	0.637		-0.016***	-0.664**	-0.587**	-0.827**
	Proportion of consultants	-0.605	-0.160	0.404		0.002	0.090	0.117	0.049
	Number of beds	2.667	-0.165	-0.767	0.362	0.010	0.578	1.357	1.272
Type	Foundation trust	0.432	-0.224	-0.480	-0.049	-0.002	1.44***	0.523	1.434**
	Teaching hospital	-2.005	0.698	0.149	-0.160	-0.010	0.838	1.172	0.693
	Specialist hospital				-1.257***	-0.024	5.434***	4.620***	5.795***
	Constant	126.827***	39.683***	34.329*	31.199***	-0.067	56.281***	75.031***	43.391**
Variance		42.184	2.058***	8.212***	1.422***	0.001***	4.094***	5.156***	8.019***
Observations		119	106	111	142	107	132	132	132

ML estimation. Only cross-sectional results for 2013/14 are reported. Results for the emergency readmission rate refer to the most recent available financial year (2011/12).

In the regressions for SHMI, hip fracture, and stroke mortality, the specialist dummy is omitted because of the absence of specialist hospitals in these samples.

Estimates for the emergency readmission rate refer to 2011/12. Data on this variable are currently available up to 2011/12. Data on hospital staff are available from 2010/11 onwards. Hence, all regressions for the emergency readmission rate do not include the number of managers, the proportion of junior doctors in training, and the proportion of consultants.

*** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table A4 – ML estimates for the efficiency indicators in 2013/14.

	Regressor	Bed occupancy	Cancelled operations	RCI	Elective RCI	Non-elect. RCI	RCI for hip repl.
	Spatial lag of the dependent variable	-0.079	-0.008	0.003	-0.030	-0.121	0.096
Demand shifter	Population density	1.529**	0.043	2.06**	2.813**	1.754	0.590
	Proportion of individuals aged 65 and over	0.018	-0.010	-0.942**	-0.831	-0.821	-0.140
	Proportion of ind. employed or looking for a job	-0.215	0.016	1.341**	0.824	2.832**	2.623*
	Proportion of individuals with a degree	-0.421**	-0.027**	0.519**	-0.234	1.045**	0.635
	Proportion of owner occupier households	0.143	0.007	0.526**	0.036	0.482	-0.723
	Proportion of ind. in good/very good health	1.194*	0.028	-1.474*	0.141	-3.247*	-2.512
Cost shifter	Number of managers	0.364	0.048	2.602	0.147	3.677	-3.900
	Proportion of junior doctors in training	-0.051	-0.037	-0.398	1.164	0.205	1.974
	Proportion of consultants	-0.237	0.028	0.489	0.406	0.839	-1.076
	Number of beds	1.123	0.010	-0.018	-4.200	3.977	11.189
Type	Foundation trust	-2.458**	-0.145**	-1.342	-2.186	-1.717	4.757
	Teaching hospital	-1.148	0.170	0.614	2.456	0.087	-5.376
	Specialist hospital	-5.618*	-0.048	9.426***	11.789**	21.428***	25.155
	Constant	11.159	-2.494	91.661**	41.426	129.643	135.915
Variance		28.800***	0.118***	41.994***	110.523***	193.989***	298.786***
Observations		134	134	140	140	140	127

ML estimation. Only cross-sectional results for 2013/14 are reported

*** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table A5 – Likelihood Ratio test: spatial lag vs SDM or SAC model.

Indicator	Model	Cross-Section				Panel	
		2010/11	2011/12	2012/13	2013/14	FE	RE
<u>*Quality*</u>							
Clinical							
Summary Hospital-level Mortality Indicator	SDM	(0.254)	(0.047)**	(0.298)	(0.674)	(0.090)*	(0.539)
	SAC	(0.687)	(0.560)	(0.419)	(0.556)	(0.363)	
Hip fracture mortality rate	SDM	(0.246)	(0.024)**	(0.011)**	(0.638)	(0.812)	(0.149)
	SAC	(0.348)	(0.779)	(0.078)*	(0.189)	(0.333)	
Stroke mortality rate	SDM	(0.589)	(0.824)	(0.098)*	(0.492)	(0.198)	(0.459)
	SAC	(0.201)	(0.570)	(0.524)	(0.795)	(0.766)	
Emergency readmission rate	SDM	(0.656)	(0.092)*			(0.871)	(0.884)
	SAC	(0.659)	(0.087)*			(0.816)	
Patient reported							
Average health change after hip replacement	SDM	(0.010)***	(0.467)	(0.792)	(0.188)	(0.679)	(0.332)
	SAC	(0.491)	(0.831)	(0.671)	(0.408)	(0.643)	
Overall patient satisfaction	SDM	(0.000)***	(0.002)**	(0.173)	(0.090)*	(0.004)***	(0.013)**
	SAC	(0.045)**	(0.550)	(0.509)	(0.397)	(0.726)	
Patient satisfaction on hospital cleanliness	SDM	(0.194)	(0.386)	(0.819)	(0.909)	(0.741)	(0.797)
	SAC	(0.968)	(0.580)	(0.431)	(0.586)	(0.793)	
Patient satisfaction on decision involvement	SDM	(0.001)***	(0.012)**	(0.398)	(0.103)	(0.080)*	(0.012)**
	SAC	(0.453)	(0.790)	(0.353)	(0.705)	(0.815)	
<u>*Efficiency*</u>							
Bed occupancy rate	SDM	(0.711)	(0.655)	(0.768)	(0.081)*	(0.605)	(0.687)
	SAC	(0.200)	(0.895)	(0.184)	(0.989)	(0.616)	
Rate of cancelled elective operations	SDM	(0.940)	(0.209)	(0.020)**	(0.005)***	(0.016)**	(0.698)
	SAC	(0.015)**	(0.705)	(0.035)**	(0.075)*	(0.001)***	
Reference cost index	SDM	(0.295)	(0.530)	(0.966)	(0.613)	(0.013)**	(0.415)
	SAC	(0.201)	(0.151)	(0.428)	(0.338)	(0.928)	
Elective reference cost index	SDM	(0.537)	(0.270)	(0.315)	(0.142)	(0.000)***	(0.072)*
	SAC	(0.241)	(0.504)	(0.337)	(0.231)	(0.020)**	
Non-elective reference cost index	SDM	(0.058)*	(0.256)	(0.372)	(0.222)	(0.001)***	(0.170)
	SAC	(0.121)	(0.033)**	(0.075)*	(0.313)	(0.324)	
Reference cost index for hip replacement	SDM	(0.128)	(0.560)	(0.885)	(0.391)	(0.246)	(0.783)
	SAC	(0.180)	(0.632)	(0.850)	(0.675)	(0.995)	

Null hypothesis: the spatial lag model is nested in the SDM or SAC model

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table A6 – Spatial lag model for the quality indicators allowing for spatially lagged efficiency.

Variable		Quality indicators							
		SHMI	Hip fract. mortality	Stroke mortality	Readm.	Health change hip repl.	Overall satisf.	Satisf. on cleanliness	Satisf. on involvem.
Spatial lag	2010/11	0.212	0.016	-0.156	0.203	-0.006	0.047	-0.016	0.035
		(0.043)**	(0.891)	(0.156)	(0.047)**	(0.958)	(0.568)	(0.873)	(0.719)
Spatially lagged bed occupancy rate		0.281	-0.044	0.161	0.022	-0.001	-0.078	-0.004	0.006
		(0.142)	(0.372)	(0.014)**	(0.411)	(0.341)	(0.102)	(0.923)	(0.902)
Spatially lagged reference cost index		-0.154	0.014	0.002	0.033	-0.001	0.015	-0.067	0.031
		(0.420)	(0.775)	(0.972)	(0.132)	(0.060)*	(0.745)	(0.116)	(0.502)
Spatial lag	2011/12	0.159	0.094	-0.176	0.117	-0.064	0.061	-0.054	0.075
		(0.130)	(0.403)	(0.132)	(0.254)	(0.606)	(0.460)	(0.565)	(0.405)
Spatially lagged bed occupancy rate		0.495	0.026	0.038	0.051	-0.001	-0.069	-0.079	-0.051
		(0.019)**	(0.632)	(0.698)	(0.005)***	(0.133)	(0.171)	(0.071)*	(0.323)
Spatially lagged reference cost index		-0.070	-0.067	0.017	0.017	-0.001	-0.037	-0.080	-0.090
		(0.723)	(0.196)	(0.846)	(0.438)	(0.383)	(0.444)	(0.058)*	(0.070)*
Spatial lag	2012/13	0.098	-0.199	-0.189	0.091	-0.157	0.003	-0.082	-0.130
		(0.328)	(0.085)*	(0.097)*	(0.327)	(0.207)	(0.971)	(0.371)	(0.163)
Spatially lagged bed occupancy rate		0.551	0.0004	-0.057	0.018	0.000001	-0.063	-0.048	-0.102
		(0.004)***	(0.995)	(0.521)	(0.351)	(0.999)	(0.064)*	(0.222)	(0.028)**
Spatially lagged reference cost index		0.040	-0.023	-0.137	0.008	-0.0004	-0.060	-0.089	-0.134
		(0.812)	(0.682)	(0.080)*	(0.625)	(0.482)	(0.142)	(0.065)*	(0.015)**
Spatial lag	20113/14	0.156	-0.205	-0.305	0.092	-0.195	0.084	0.044	0.029
		(0.164)	(0.083)*	(0.013)**	(0.351)	(0.082)*	(0.349)	(0.624)	(0.761)
Spatially lagged bed occupancy rate		0.180	0.024	0.106	0.021	-0.001	-0.039	-0.072	-0.095
		(0.352)	(0.590)	(0.212)	(0.362)	(0.371)	(0.312)	(0.080)*	(0.064)*
Spatially lagged reference cost index		0.160	-0.040	0.059	-0.036	-0.0005	-0.026	-0.081	-0.061
		(0.378)	(0.346)	(0.465)	(0.092)*	(0.367)	(0.550)	(0.084)*	(0.296)
Spatial lag	FE	0.170	-0.040	-0.060	0.065	-0.039	0.084	-0.069	-0.032
		(0.001)***	(0.468)	(0.279)	(0.233)	(0.505)	(0.113)	(0.218)	(0.552)
Spatially lagged bed occupancy rate		-0.051	0.004	-0.047	0.014	-0.001	-0.060	-0.027	-0.071
		(0.626)	(0.924)	(0.456)	(0.082)*	(0.225)	(0.109)	(0.347)	(0.089)*
Spatially lagged reference cost index		0.049	-0.008	-0.116	0.009	0.0003	-0.006	-0.020	0.021
		(0.563)	(0.816)	(0.028)**	(0.463)	(0.515)	(0.856)	(0.431)	(0.562)
Spatial lag	RE	0.181	-0.021	-0.057	0.114	-0.035	0.092	-0.045	-0.001
		(0.000)***	(0.710)	(0.316)	(0.028)**	(0.557)	(0.052)*	(0.382)	(0.986)
Spatially lagged bed occupancy rate		0.091	0.015	0.004	0.018	-0.001	-0.060	-0.043	-0.067
		(0.374)	(0.622)	(0.933)	(0.044)**	(0.093)*	(0.025)**	(0.083)*	(0.031)**
Spatially lagged reference cost index		0.051	-0.007	-0.070	0.004	-0.001	-0.032	-0.044	-0.035
		(0.544)	(0.791)	(0.116)	(0.713)	(0.092)*	(0.223)	(0.064)*	(0.251)

ML estimation. Control variables are identical to those in the main regression

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table A7 – Spatial lag model for the efficiency indicators allowing for spatially lagged quality.

Variable		Efficiency indicators					
		Bed occupancy	Cancelled operations	RCI	Elective RCI	Non-elect. RCI	Unit cost of hip repl.
Spatial lag	2010/11	-0.054	0.084	-0.029	0.016	-0.064	-0.122
		(0.619)	(0.424)	(0.806)	(0.886)	(0.572)	(0.292)
Spatially lagged SHMI		-0.021	-0.002	-0.256	-0.494	-0.615	0.00002
		(0.817)	(0.773)	(0.030)**	(0.032)**	(0.004)***	(0.548)
Spatially lagged overall patient satisfaction		-0.639	0.006	-0.573	-0.966	-1.582	0.0001
		(0.026)**	(0.785)	(0.090)*	(0.172)	(0.014)**	(0.221)
Spatial lag	2011/12	-0.114	-0.024	-0.038	0.034	-0.081	-0.230
		(0.333)	(0.839)	(0.742)	(0.757)	(0.468)	(0.039)**
Spatially lagged SHMI		-0.113	-0.005	-0.157	-0.540	-0.415	0.00003
		(0.248)	(0.415)	(0.169)	(0.006)***	(0.037)**	(0.239)
Spatially lagged overall patient satisfaction		-1.083	0.003	-0.185	-0.627	-0.512	0.00009
		(0.000)***	(0.866)	(0.566)	(0.261)	(0.357)	(0.215)
Spatial lag	2012/13	-0.097	0.125	-0.124	0.030	-0.145	-0.011
		(0.401)	(0.246)	(0.286)	(0.787)	(0.189)	(0.925)
Spatially lagged SHMI		0.037	-0.004	-0.088	-0.257	-0.367	0.00003
		(0.705)	(0.574)	(0.478)	(0.183)	(0.047)**	(0.199)
Spatially lagged overall patient satisfaction		-0.427	0.041	-0.259	-1.094	-0.714	-0.00010
		(0.242)	(0.120)	(0.579)	(0.131)	(0.308)	(0.325)
Spatial lag	20113/14	0.049	0.040	0.060	-0.049	-0.018	0.060
		(0.641)	(0.713)	(0.609)	(0.682)	(0.884)	(0.613)
Spatially lagged SHMI		-0.203	-0.009	-0.053	-0.274	-0.395	-0.00001
		(0.049)**	(0.209)	(0.717)	(0.248)	(0.075)*	(0.691)
Spatially lagged overall patient satisfaction		-0.290	-0.026	0.035	-0.112	-0.299	0.00004
		(0.331)	(0.199)	(0.933)	(0.872)	(0.635)	(0.591)
Spatial lag	FE	-0.090	0.018	0.029	0.046	-0.076	-0.095
		(0.136)	(0.736)	(0.607)	(0.430)	(0.179)	(0.091)*
Spatially lagged SHMI		0.003	0.010	0.077	-0.051	0.077	0.00003
		(0.954)	(0.017)**	(0.233)	(0.685)	(0.537)	(0.115)
Spatially lagged overall patient satisfaction		-0.280	-0.006	0.050	0.403	0.434	0.00003
		(0.064)*	(0.560)	(0.758)	(0.214)	(0.168)	(0.552)
Spatial lag	RE	-0.053	0.050	0.090	0.059	0.025	-0.069
		(0.367)	(0.353)	(0.103)	(0.297)	(0.647)	(0.220)
Spatially lagged SHMI		-0.031	0.003	0.024	-0.183	-0.171	0.00002
		(0.561)	(0.485)	(0.713)	(0.116)	(0.150)	(0.203)
Spatially lagged overall patient satisfaction		-0.512	-0.001	-0.144	-0.025	-0.364	0.00003
		(0.001)***	(0.929)	(0.403)	(0.937)	(0.257)	(0.522)

ML estimation. Control variables are identical to those in the main regression

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table A8 – First-stage estimates on the instrument and F statistic using quality indicators.

IV	Estimate		SHMI	Hip fract. mortality	Emerg. readm.	Overall satisf.	Satisf. on cleanliness	Satisf. on involvem.
W_{t-2}	I stage coefficient on the instrument	2012/13	0.610	0.499	0.778	0.587	0.830	0.707
			(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
	I stage F (Cragg-Donald) statistic		94.49	16.58	140.68	175.89	282.66	282.66
	I stage coefficient on the instrument	2013/14	0.560	0.489	0.875	0.621	0.940	0.794
			(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
	I stage F (Cragg-Donald) statistic		95.69	52.46	168.39	261.03	467.54	467.54
W_{t-3}	I stage coefficient on the instrument	2013/14	0.393	0.320	0.796	0.600	0.880	0.784
			(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
	I stage F (Cragg-Donald) statistic		39.70	14.30	101.60	159.30	234.30	145.80

Stock-Yogo 10% maximal IV size critical value = 16.38; Stock-Yogo 15% maximal IV size critical value = 8.96; Stock-Yogo 20% maximal IV size critical value = 6.66; Stock-Yogo 25% maximal IV size critical value = 5.53

Each regression controls for: population density, proportion of individuals aged 65 and over, proportion of individuals employed and looking for a job, proportion of individuals with a degree, proportion of owner occupier households, proportion of individuals with a degree, proportion of individuals in good and very good health, number of managers, proportion of junior doctors in training, proportion of consultants, number of beds, foundation trust, teaching hospital, specialist hospital. Control variables are included in the first stage of the 2SLS estimator.

In the regressions for SHMI, hip fracture, and stroke mortality, the specialist dummy is omitted because of the absence of specialist hospitals in these samples.

Data on the emergency readmission rate are currently available up to 2011/12. The estimate refers to the most recent available years (2010/11 and 2011/12).

For stroke mortality and average health change after hip replacement, estimates are omitted because of the absence of relevant instruments.

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table A9 – First-stage estimates on the instrument and F statistic using efficiency indicators.

IV	Estimate		Bed occupancy	Cancelled operations	RCI	Elective RCI	Non-elect. RCI	RCI for hip repl.
W_{t-2}	I stage coefficient on the instrument	2012/13	0.641	0.484	0.594	0.271	0.525	0.437
			(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
	I stage F (Cragg-Donald) statistic		85.14	30.46	87.65	16.29	60.16	44.49
	I stage coefficient on the instrument	2013/14	0.775	0.897	0.734	0.419	0.461	0.236
			(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
	I stage F (Cragg-Donald) statistic		135.99	105.08	206.49	56.77	59.51	13.39
W_{t-3}	I stage coefficient on the instrument	2013/14	0.616	0.480	0.704	0.380	0.483	0.291
			(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
	I stage F (Cragg-Donald) statistic		113.70	35.60	177.60	53.30	51.30	23.45

Stock-Yogo 10% maximal IV size critical value = 16.38; Stock-Yogo 15% maximal IV size critical value = 8.96; Stock-Yogo 20% maximal IV size critical value = 6.66; Stock-Yogo 25% maximal IV size critical value = 5.53

Each regression controls for: population density, proportion of individuals aged 65 and over, proportion of individuals employed and looking for a job, proportion of individuals with a degree, proportion of owner occupier households, proportion of individuals with a degree, proportion of individuals in good and very good health, number of managers, proportion of junior doctors in training, proportion of consultants, number of beds, foundation trust, teaching hospital, specialist hospital. Control variables are included in the first stage of the 2SLS estimator.

p-value in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1