DO HOSPITALS RESPOND TO NEIGHBOURS' QUALITY AND EFFICIENCY? A SPATIAL ECONOMETRICS APPROACH

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CONFLICT OF INTEREST

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ABSTRACT

We investigate whether hospitals in the English National Health Service increase their quality (mortality, emergency readmissions, patient reported outcome, and patient satisfaction) or efficiency (bed occupancy rate, cancelled operations, and cost indicators) in response to an increase in quality or efficiency of neighbouring hospitals. We estimate spatial cross-sectional and panel data models, including spatial cross-sectional instrumental variables. Hospitals generally do not respond to neighbours' quality and efficiency. This suggests the absence of spillovers across hospitals in quality and efficiency dimensions and has policy implications, for example, in relation to allowing hospital mergers.

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 policies may induce hospitals to compete on quality to attract patients, and to enhance efficiency (Gaynor, 2007).

A number of studies have investigated the effect of competition on quality and efficiency in the US, the United Kingdom, and other OECD countries with mixed results (section 1.1). The traditional approach involves relating quality and efficiency to a measure of market structure (e.g. Herfindahl index). In this study, we use an alternative approach and examine hospitals' strategic interactions. We investigate whether hospitals respond to changes in rivals' quality and efficiency, i.e. whether quality and efficiency are strategic complements or strategic substitutes in the sense that an increase in rivals' quality (efficiency) induces a hospital to increase or reduce its quality (efficiency).

The strategic relationship amongst neighbouring hospitals is important, for example, in relation to hospital mergers. Brekke et al. (2016) provide a theoretical analysis on hospital mergers and their effect on quality and efficiency. They show that if two hospitals merge these will reduce quality. The merger will also reduce quality in non-merging rival hospitals if qualities are complements. Merging hospitals, moreover, are likely to increase efficiency. Non-merging rival hospitals will increase efficiency if efficiencies are strategic complements.

We consider both clinical and non-clinical (e.g. amenities) dimensions of quality. Hospital level of clinical measures are increasingly available in the public domain (e.g. through websites) as part of patient choice policies. We measure clinical quality through risk-adjusted overall mortality and readmission rates, and mortality rates for high-volume conditions such as hip fracture and stroke. Mortality and readmissions rates do not however capture health gains for the vast majority of patients who do not die or are readmitted as an emergency. We therefore also measure health gains for hip replacement, a common elective procedure, based on patients-reported outcomes (PROMs). We capture non-clinical dimensions of patients' experience using patient satisfaction with 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.

We first test for spatial dependence across these quality and efficiency indicators by global Moran's I test. We find evidence of positive spatial dependence for several but not all quality and efficiency indicators. We then estimate for 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 estimate spatial panel models. Finally, we adopt two spatial cross-sectional instrumental variable (IV) approaches. In all models, our key coefficient of interest is the spatial lag of the dependent variable. A positive estimate implies strategic complementarity in quality or efficiency. Our key finding is that cross-sectional and panel data estimates of the spatial lag mostly suggest the absence of strategic interaction across rival hospitals in quality and efficiency.

Sections 1.1 and 1.2 review the literature and the institutional background. Section 2 sketches a 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 relates 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). Other studies focus on the impact of hospital competition on quality, providing mixed results. They find that competition improves (Kessler and McClellan, 2000, Kessler and Geppert, 2005), decreases (Gowrisankaran and Town, 2003) or is not associated (Mukamel et al., 2001) with clinical quality as measured by mortality.

Studies that analyse the effect of hospital competition on quality and efficiency in the UK also have mixed results. Some suggest that competition increases (Cooper et al., 2012, Gaynor et al., 2013) or is not associated with efficiency (Söderlund et al., 1997). Other studies find either negative (Propper et al., 2004, Propper et al., 2008), positive (Cooper et al., 2011, Gaynor et al., 2013, Bloom et al., 2015), or mixed impact of competition on quality (Gravelle et al., 2014a).

This study builds on the spatial approach proposed by Mobley (2003) and Mobley et al. (2009). These authors focus on strategic complementarity in prices, rather than quality, within the US context where hospital prices are not fixed. Similarly, Choné et al. (2014) study strategic complementarity of GPs’ prices in France using a spatial IV approach. Gravelle et al. (2014b) use a cross section of English data and find that seven out of sixteen clinical and patient-reported quality dimensions are strategic complements.

We improve on previous spatial econometric papers in three ways: first, we employ efficiency measures in addition to quality; second, we employ panel data to control for unobserved time-invariant heterogeneity through hospital fixed effects; third, we address potential endogeneity owing to other sources of unobserved factors through two IV approaches.

Our study contributes to the small literature on spatial econometrics applications in health economics. For instance, Moscone et al. (2007) study spatial spillovers in mental health expenditure in England and find that neighbouring mental health authorities interact in their expenditure decisions. Gaughan et al. (2015) test spillover effects on delayed discharges and find that more care home beds and younger patients in nearby local authorities reduce delayed discharge. Moscone and Tosetti (2014) provide a comprehensive review of spatial econometrics applications in health economics.

1.2. Institutional background

The English National Health Service (NHS) 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 health care 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).

Under such a fixed-price regime, hospital competition has been encouraged by allowing elective patients to choose where to be treated. The 2006 ‘Patient Choice’ reform initially allowed patients to choose amongst four or five providers, with the choice extended to any qualified provider from 2008 (Department of Health, 2009). Patients’ choice is facilitated through the website ‘NHS Choices’, which provides information on hospitals’ 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 and decreasing in the quality of hospital *j*. The objective function of hospital *i* is:

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

where *p* is the fixed price per treatment that the hospital receives from a third-party payer. $c_i\left(q_i,e_i\right)$ and $G_i\left(q_i,e_i\right)$ are variable and fixed treatment costs, respectively, which are increasing in quality and decreasing in cost-containment effort or efficiency e_i. We assume that quality and effort are substitutes in fixed costs, 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). The subscripts q_i and e_i indicate the partial derivative with respect to these choice variables.

Hospital *i* chooses quality and efficiency to satisfy:

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

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

where $D_{iq_i}>0$, $c_{iq_i}>0$, and $G_{iq_i}>0$. With strictly concave utility functions these 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 choice of 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 square bracketed term 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 test whether hospitals' quality or efficiency responds to the quality or efficiency of their rivals using the following function:

$$y_i = f_i\left(y_{-i}, X_i, \varepsilon_i\right) \tag{7}$$

where y_i is the quality or efficiency of hospital *i* ($=1,\ldots,I$); y_{-i} is the quality or efficiency of hospital *i*'s rivals; 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), and hospital type (e.g. foundation trusts, teaching hospitals); and ε_i is the error term.

From (7), we specify a cross-sectional spatial lag model:

$$y_i = \rho \sum\nolimits_j w_{ij} y_j + \beta' X_i + \varepsilon_i \tag{8}$$

where y_j is the quality or efficiency of hospital *i*'s rival *j* ($=1,\ldots,I \neq i$), w_{ij} is a weight related to the spatial relationship between hospital *i* and *j*, and X_i includes the intercept. In matrix form:

$$Y = \rho W Y + X\beta + \varepsilon \tag{9}$$

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

$$w_{ij} = \begin{cases} 0 & \text{if} \quad i = j \\ d_{ij}^{-1} & \text{if} \quad d_{ij} \leq 30 \text{ km and } i \neq j \\ 0 & \text{if} \quad d_{ij} > 30 \text{ km and } i \neq j \end{cases} \tag{10}$$

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., 2012, Bloom et al., 2015). Hospitals that are further within a 30 km radius are given a lower weight, and hospitals that are further than 30 km are given a weight of zero. 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 $\rho > 0$ quality (efficiency) increases in response to an increase in rivals' quality (efficiency). Spatial correlation can be due to strategic interactions between providers but also to two additional categories of factors. First, 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. Second, a hospital's quality may vary with characteristics, either observed or unobserved, of rival hospitals. For instance, a hospital's quality may increase if there is a high proportion of foundation trusts amongst its rivals which enhances competition. 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, which refers to the two possible sources of bias as respectively "*correlated effects*" and "*contextual effects*", and the general identification issue as the "*reflection problem*" (Manski, 1993).

To control for time-invariant unobserved factors, we estimate a spatial panel model:

$$y_{it} = \rho \sum_j w_{ij} y_{jt} + \beta' X_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \tag{11}$$

where $t = 1, ..., T$, α_i captures unobserved time-invariant hospital heterogeneity, and γ_t is a time fixed effect.

We conduct three separate sensitivity checks on regressions (8) and (11). First, we test whether disturbances are spatially correlated using a spatial autocorrelation (SAC) regression, which models spatial correlation in the error term ($\varepsilon_{i(t)} = \lambda \sum_j w_{ij} \varepsilon_{j(t)} + \xi_{i(t)}$). Second, 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. Finally, we re-estimate our primary regressions extending the radius within which hospitals compete to 60 km or 90 km.

We estimate spatial cross-sectional models by ML and spatial panel models by fixed effects (FE) and random effects (RE) ML.[1] The ML estimator is biased in the presence of unobserved *correlated* and *contextual effects*. Although controlling for unobserved time-invariant heterogeneity α_i may alleviate the problem, the key coefficient $\hat{\rho}$ may still not be identified if there are unobserved time-varying factors affecting the patient case-mix.

As a further sensitivity check, we estimate (8) through two spatial IV approaches. The first IV approach is a two-stage least squares (2SLS) estimator that instruments WY with its 3-year lagged value (WY_{t-3}).

The second IV approach consists of a 2SLS estimator that uses a spatially lagged covariate WZ to instrument WY, where Z is a single covariate in the matrix of covariates X. This approach is inspired by the generalised spatial two-stage least squares estimator (Kelejian and Prucha, 1998, 1999).

4. DATA

We have eight quality indicators and six efficiency indicators measured at hospital trust level.[2] All measures are from 2010-11 to 2013-14, except for the readmission rate which is from 2008-09 and 2011-12.

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

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[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).

[2] Detailed definitions of the quality and efficiency indicators are included in the appendix (Table A1 and Table A2).

deaths expected given the characteristics of patients. We also use risk-adjusted mortality rates for two emergency conditions (hip fracture and stroke), and risk-adjusted emergency readmissions for all conditions.

We collect risk-adjusted average health change for patients who had a hip replacement 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).[3]

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.

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 dividing the number of cancelled elective operations for non-clinical reasons by the number of elective admissions (Rumbold et al., 2015).

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[3] 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.

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. Explanatory variables

Our key regressor is the spatial lag of the dependent variable *WY*. Our control variables include demand and supply shifters. Demand shifters comprise: demographic variables such as *population density* and *proportion of elderly individuals* (65 and over), which we calculate using annual mid-year population estimates; economic deprivation measures such as *proportion of individuals employed or looking for a job*, *proportion of individuals with a degree*, and *proportion of households with property house*; and a measure of population health such as the *proportion of individuals in good or very good health*. Population deprivation and health measures are computed using 2011 Census data for all LSOAs within a 15 km radius.[4]

Supply shifters include: the *number of managers*, the *proportion of junior doctors in training*, the *proportion of consultants*, and the *number of beds*.[5] Information on hospital staff is collected from the HSCIC, whilst NHS statistics provide the number of beds.[6] Finally, we control for type of hospital**:** *foundation trust, teaching hospital*, and *specialist hospital*.

4.4. Instruments

The instrument for our first IV approach is WY_{t-3}. It is assumed to be exogenous because: rival hospitals' quality (efficiency) with a lag of three years is unlikely to be correlated with

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

[5] The proportion of junior doctors in training and consultants are computed as percentage of the clinical staff including doctors, nurses, and professional healthcare allied (e.g. therapists, healthcare scientists, technicians).

[6] 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 estimated by ML to allow comparability between cross-sectional and panel models. The same staff variables are instead included in the regressions for the emergency readmission rate estimated by IV to extend the set of possible instruments.

contemporaneous unobserved factors that may affect a hospital's quality (e.g. unmeasured comorbidities). It is relevant because persistence in hospital quality (efficiency) allows for correlation between past and current rival's quality (efficiency).

Valid instruments for the second IV approach are: the (spatially) *lagged proportion of consultants* for lagged SHMI; the *lagged proportion of junior doctors in training* for lagged emergency readmission rate, all *lagged patient satisfaction indicators*, *lagged RCI,* and *lagged elective* and *non-elective RCI.*; and the *lagged number of managers* for lagged bed occupancy rate and lagged rate of cancelled elective operations. Rivals' supply shifters are assumed to be uncorrelated with the error term. For example, the rivals' number of managers is unlikely to be correlated with a hospital's unobserved patient case-mix, and it is also unlikely to directly determine a hospital's quality.[7] In principle, we can expect lagged supply shifters to be also relevant (i.e. correlated with lagged quality) if supply shifters affect hospital quality. For example, if a hospital's proportion of consultants is associated with a hospital's quality we can expect some correlation between the rivals' proportion of consultants and rivals' quality.

4.5. Sample

Table I provides 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 excluded from the sample because, by construction, they do not compete. Considering the overall patient satisfaction's sample 13% of hospitals are monopolists. 23% are exposed to low competition with one or two rivals. 38% are located in

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[7] We exclude lagged demand shifters because they are constructed on catchment populations that are overlapping across rival hospitals.

areas with three to nine rivals, and 26% have more than nine rivals (up to a maximum of 25 rivals).

4.6. Descriptive statistics

The SHMI is on average 100 by construction. Mean hip fracture mortality rate is 7.2% and mean stroke mortality is 17.4%. The mean emergency readmission rate is 11.1%. On average, patients undergoing hip replacement have an average health gain of 0.413 QALYs. Patients express on average high overall satisfaction with a rating of 78.8. They are highly satisfied also with hospital cleanliness and involvement in treatment decisions with a rating of 88.1 and 72, respectively. The bed occupancy rate is 87% and the cancelled elective operations rate is 0.81%. The RCIs are standardised to 100 by definition.

Descriptive statistics of the regressors are for the overall patient satisfaction's sample. On average, the population density in the catchment area is 1,808 inhabitants per km^2, and 15.7% of individuals is older than 65 years. 70% of individuals are employed or looking for a job, 18.4% have a degree, 61.6% of households own a property house, and 81.5% of individuals are in good or very good health. Hospitals have on average 66 managers. Junior doctors in training and consultants represent respectively 2.6% and 6.3% of clinical staff. Hospitals have on average 631 beds. 83 hospitals (62.9%) are foundation trusts, 24 (18.4%) are teaching, and 14 (10.6%) are specialist.

5. RESULTS

Table II shows the results of the global Moran's I test for quality and efficiency indicators.[8] Spatial correlation is significant (at 5% level) and positive for two clinical (SHMI and emergency readmissions) and two patient-reported (patient satisfaction on overall experience

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[8] 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).

and hospital cleanliness) indicators. 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 from 0.150 (for RCI for hip replacement in 2011-12) and 0.483 (for RCI in 2013-14).[9]

5.1. ML results

Table III reports the estimated spatial lag coefficient ($\hat{\rho}$) for each quality and efficiency indicator using the ML estimator and after controlling for demand shifters, supply shifters, and type of hospital. In the cross-sectional model, SHMI is the only indicator with a positive and statistically significant estimated spatial lag. 10% lower SHMI (higher quality) in rival hospitals increases on average 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 RCI in 2010-11).[10] 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 A6 (Table A7) in the appendix provides the estimated coefficient for demand shifters, supply shifters, and hospital type in the regressions for the quality (efficiency) indicators. For instance, one more percentage point of elderly individuals increases on average the overall patient satisfaction rating by 0.3 points. An

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[9] Table A3 and Table A4 in the appendix display the local Moran's I test on quality and efficiency indicators in 2010-11 for hospitals which local spatial correlation is statistically significant at 5%. In general, there is some evidence of hospital clustering in the London area. 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.

[10] As a sensitivity check, we risk-adjust the bed occupancy rate and the RCI, which refer to overall hospital activity, by also controlling for proportion of male patients, patient age, and proportion of emergency admissions in equation (8) and (11). As shown in Table A5 in the appendix, results are similar to those reported in Table III.

additional manager decreases on average stroke mortality by 1.6 percentage points. Foundation trusts are associated with higher patient satisfaction. While teaching hospitals do not show statistically different quality or efficiency, specialist hospitals have better quality (e.g. lower readmission rates) but lower efficiency (e.g. greater RCIs).

Table III also has estimates of the spatial lag coefficient after controlling for unobserved time-invariant heterogeneity using FE and RE ML. We observe a positive and statistically significant spatial lag for SHMI (0.172) and overall patient satisfaction (0.110).[11] In sum, cross-sectional and panel ML estimates show little statistical evidence in favour of spatial dependence in quality and efficiency. This suggests that hospitals may not respond to rivals in their quality and efficiency decisions.

5.2. Sensitivity analysis

As a robustness check, we estimate the spatial lag WY through the SAC model, which allows for spatial correlation in the error term. Also in this case, cross-sectional and panel estimates show weak statistical significance for the spatial lag of quality and efficiency indicators (Table IV).[12] We also test whether a hospital's quality (efficiency) responds to rivals' efficiency (quality).[13] Results in Table V are similar to those in Table III.[14] Finally, Table A12 and Table A13 in the appendix suggest that our key results are robust to competition areas with a larger

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[11] As showed in Table A8 in the appendix, 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.

[12] In Table A9 in the appendix, we show the results for the Likelihood Ratio test comparing spatial lag model and SAC model. The test suggests that SAC is the correct model only for the rate of cancelled elective operations.

[13] 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.

[14] In line with our theoretical predictions, we do not generally observe an effect of rivals' efficiency on a hospital's quality (Table A10). Unlike our theoretical model, however, we find weak evidence of rivals' quality affecting a hospital's efficiency (Table A11). For instance, higher rivals' quality, as measured by the SHMI, is significantly associated at 5% level with better efficiency, as measured by the elective RCI, in 2010-11, 2011-12, and 2012-13. Such an association is only weakly significant (at 10% level) in 2013-14 and disappears in the panel model.

radius (60 km or 90 km).[15]

5.3. IV results

Table VI shows IV estimates of the spatial lag coefficient $\hat{\rho}$ for some quality and efficiency indicators.[16] In the first IV approach, WY_{t-3} is valid for six quality indicators (except for stroke mortality and average health change after hip replacement) and for all efficiency indicators. The estimates consistently show no spatial correlation in quality and efficiency in 2013-14. In the second IV approach, a lagged supply shifter is a valid instrument for five quality indicators (except for the condition-specific outcomes) and five efficiency indicators (except for the RCI for hip replacement).[17] For both quality and efficiency indicators, the spatial lag estimates do not exhibit any statistical significance at 5% level (except for SHMI in 2010-11). On the whole, similarly to ML estimates, IV estimates suggest the absence of spatial correlation in quality and efficiency.

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. The two studies have five indicators in common: three mortality indicators such as overall mortality, hip fracture and stroke mortality, and two patient satisfaction indicators such as satisfaction on hospital cleanliness and decision involvement.[18] Table A17 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

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[15] Table A12 and Table A13 in the appendix also show that the number of monopolist hospitals drops to one or zero when the radius is expanded to 60 km or 90 km, respectively.

[16] Table A14 and Table A15 in the appendix include first-stage estimate on the instrument and F statistic. As a rule of thumb, we assess the instrument as relevant if the first-stage F statistic is greater than 10 (Staiger and Stock, 1997).

[17] In Table A16, we empirically test the exclusion restriction on the chosen instrument. We reject this assumption only once (patient satisfaction on decision involvement in 2010-11).

[18] Gravelle et al. (2014b) explore spatial correlation 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 correlation 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.

2011-12 (the two closest years), the spatial lag is significant for overall mortality and it is insignificant for hip fracture mortality for both studies. Stroke mortality 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 they are insignificant in ours. For patient satisfaction on hospital cleanliness, this is due to the different years used in the analyses. For patient satisfaction on decision involvement, differences are due to the different analysed years and additional demand shifters in our analysis.[19]

6. CONCLUSIONS

This study investigates whether a hospital's quality or efficiency responds to an increase in quality or efficiency of its rivals. First, we test for spatial correlation by global Moran's I test and find evidence of a positive spatial correlation amongst some quality and efficiency indicators. Second, we estimate spatial cross-sectional models by ML and no longer observe a statistically significant spatial correlation in most indicators. Similarly, we observe little evidence of spatial correlation after controlling for unobserved time-invariant heterogeneity through a spatial panel model estimated by ML. Finally, our two spatial cross-sectional IV approaches further suggest the absence of spatial correlation for both quality and efficiency indicators. 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. These findings have important policy implications. They suggest that interventions incentivising quality or efficiency at local level may not affect other hospitals.

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[19] The additional demand shifters are: proportion of elderly individuals, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of households with property house, and proportion of individuals in good or very good health.

The results have implications for antitrust policies. Our study suggests that hospital mergers that might increase efficiency of merging hospitals (as a result of better scale economies) at the cost of reducing their quality (as a result of reduced competition) will not induce non-merging hospitals also to increase efficiency or reduce quality.

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TABLES AND FIGURES

Table I – Descriptive statistics.

Variable	Obs	Trusts	Monop	Mean	Std. dev.			Min	Max
					Ov	Betw	With		
Quality indicator									
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
Efficiency indicator									
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
Control variable									
Demand shifter									
Population density (1,000 indv/km^2)				1.808	2.032	2.037	0.041	0.124	7.859
Proportion of elderly individuals (%)				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 households with property house (%)				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 within a radius of 30 km.

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

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's ML estimates.

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	0.002[C]
	(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	-0.024[C]
	(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	-0.023[C]
	(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	0.044[C]
	(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	-0.039[C]
	(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)

Each cross-sectional regression controls for: population density, proportion of elderly individuals, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of households with property house, 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’s ML estimates after controlling for spatially correlated disturbances.

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

Each cross-sectional regression controls for: population density, proportion of elderly individuals, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of households with property house, 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 V – Spatial lag coefficient's ML estimates after controlling for rivals' 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)

Each cross-sectional regression controls for: population density, proportion of elderly individuals, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of households with property house, 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 VI – Spatial lag coefficient's IV estimates.

Indicator	IV 1	IV 2			
	2013-14	2010-11	2011-12	2012-13	2013-14
Quality					
Clinical					
Summary Hospital-level Mortality Indicator	0.519	0.889	0.638	0.272	0.534
	(0.090)*	(0.012)**	(0.061)*	(0.587)	(0.357)
Hip fracture mortality rate	-0.035				
	(0.939)				
Emergency readmission rate	0.307	0.350	0.524		
	(0.087)*	(0.156)	(0.093)*		
Patient reported					
Overall patient satisfaction	0.089	0.063	0.061	0.004	-0.079
	(0.467)	(0.600)	(0.606)	(0.976)	(0.585)
Patient satisfaction on hospital cleanliness	0.155	-0.174	-0.092	-0.072	0.068
	(0.218)	(0.358)	(0.630)	(0.696)	(0.711)
Patient satisfaction on decision involvement	0.266	-0.354	-0.170	-0.131	-0.075
	(0.081)*	(0.079)*	(0.362)	(0.479)	(0.697)
Efficiency					
Bed occupancy rate	0.0003	-0.169	0.016	-0.418	0.162
	(0.999)	(0.617)	(0.973)	(0.312)	(0.731)
Rate of cancelled elective operations	-0.074	-0.495	0.349	0.311	-0.463
	(0.792)	(0.788)	(0.734)	(0.469)	(0.234)
Reference cost index	-0.110	-0.408	-0.195	-0.230	-0.454
	(0.518)	(0.311)	(0.493)	(0.641)	(0.337)
Elective reference cost index	0.027	-0.982	-0.684	-0.686	-1.604
	(0.920)	(0.055)*	(0.074)*	(0.150)	(0.214)
Non-elective reference cost index	-0.339	-0.163	0.271	0.298	-0.305
	(0.272)	(0.635)	(0.294)	(0.528)	(0.623)
Reference cost index for hip replacement	0.625				
	-(0.109)				

IV 1 = IV strategy using the three-year lagged spatial lag of the dependent variable as instrument (WY_{t-3}).

IV 2 = IV strategy using a spatially lagged supply shifter as instrument (WZ). The instruments for the IV 2 strategy are: (spatially) lagged proportion of consultants for the lagged SHMI mortality rate; lagged proportion of junior doctors in training for lagged emergency readmission rate, lagged overall patient satisfaction, lagged patient satisfaction on hospital cleanliness, lagged patient satisfaction on decision involvement, lagged reference cost index, lagged elective and non-elective reference cost index; lagged number of managers for lagged bed occupancy rate and lagged rate of cancelled elective operations.

Each regression controls for: population density, proportion of elderly individuals, proportion of individuals employed or looking for a job, proportion of individuals with a degree, proportion of households with property house, 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.

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. For IV 1, the estimate refers to the latest available year (2011-12) and not to 2013-14. For IV 2, estimates in year 2012-13 and 2013-14 are omitted.

For stroke mortality and average health change after hip replacement, IV 1 and IV 2's estimates are omitted because of the absence of valid instruments. Similarly, IV 2's estimates are omitted for hip fracture mortality and RCI for hip replacement.

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