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Does Hospital Competition Improve Efficiency?
The Effect of the Patient Choice Reform in England

Francesco Longo[a,*] Luigi Siciliani[a,b] Giuseppe Moscelli[c] Hugh Gravelle[a]

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

[*] Correspondence to: Department of Economics and Related Studies, University of York, Heslington, York, YO10 5DD, UK. E-mail: francesco.longo@york.ac.uk

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Abstract

We use the 2006 relaxation of constraints on patient choice of hospital in the English NHS to investigate the effect of hospital competition on dimensions of efficiency including indicators of resource management (admissions per bed, bed occupancy rate, proportion of day cases, and cancelled elective operations) and costs (reference cost index for overall and elective activity, cleaning services costs, laundry and linen costs). We employ a *quasi* differences-in-differences approach and estimate seemingly unrelated regressions and unconditional quantile regressions with data on hospital trusts from 2002/03 to 2010/11. Our findings suggest that increased competition had mixed effects on efficiency. An additional equivalent rival increased admissions per bed by 1.1%, admissions per doctor by 0.9% and the proportion of day cases by 0.38 percentage points, but it also increased the number of cancelled elective operations by 2.5%.

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1. INTRODUCTION

The efficiency of health care systems is a key goal for policy makers across OECD countries. Some of these, such as Australia, England, and Nordic countries, pursue greater efficiency by stimulating hospital competition through policies that give individuals the right to choose among hospitals (Cookson and Dawson, 2012, Propper, 2012, Palangkaraya and Yong, 2013).

In this study, we use the 2006 English National Health Service (NHS) relaxation of constraints on patient choice of hospital to investigate whether there was any effect of the exposure to greater competition on hospital efficiency. The aim of the reform was to induce hospitals to compete on quality and to enhance efficiency. Theory suggests that, under a DRG-type payment system, patient choice could increase or reduce efficiency. Increases in patient choice which induce higher quality may lead to a greater volume of patients and this increases incentives to improve efficiency by containing costs to increase the profit margin on each extra patient (Ma, 1994). But making an additional effort to increase quality may divert effort from cost-containment effort (Brekke et al., 2012).

The previous empirical literature (reviewed briefly in Section 1.2) focuses on unit costs and length of stay (e.g Cooper et al., 2012, Gaynor et al., 2013). We examine a wider subset of efficiency dimensions. Hospitals may increase efficiency by treating more patients for a given mix of inputs. We therefore examine admissions per bed, admissions per doctor, and admissions per nurse. Hospitals may also increase bed occupancy, reduce cancelled elective operations, and increase the proportion of day cases. We also consider unit costs, which we measure through the reference cost index (RCI), which compares a hospital’s total costs with the national average total costs for the same mix of services and is used by policy makers to assess hospital efficiency (Department of Health, 2014c). Since hospitals may also become more efficient via better management of amenities, we also analyse costs for cleaning services, linen and laundry, and the percentage of untouched meals. Section 1.3 provides a short analytical framework to place our set of efficiency indicators in context.

We analyse public hospitals for financial years 2002/03 to 2010/11. Like Cooper et al. (2012) and Gaynor et al. (2013), we use the ‘Patient Choice’ reform as a natural experiment and use a *quasi* differences-in-differences approach. This empirical strategy exploits the variation in market structure facing different hospitals, under the plausible argument that hospitals in more competitive areas are more likely to change their behaviour after the relaxation of constraints on patient choice of provider. Unlike previous efficiency studies, we estimate the *quasi* differences-in-differences regressions for our eleven efficiency indicators simultaneously through Seemingly Unrelated Regressions or SUR (Zellner, 1962, 1963) to improve the precision of the estimates, since hospital efficiency outcomes are potentially correlated. We also use the Unconditional Quantile Regression (UQR) approach suggested by Firpo et al. (2009) to investigate whether the effect of competition varies for more or less efficient hospitals. Competition is measured through the ‘equivalent’ number of rivals which is calculated as the inverse of Herfindahl-Hirschman index (HHI).

Our findings suggest that competition has mixed effects on efficiency. Post Choice policy, one more equivalent rival increases efficiency as measured by admissions per bed by 1.1%, admissions per doctor by 0.9%, and the proportion of day cases increases by 0.38 percentage points, while it decreases the proportion of untouched meals by 0.35 percentage points. We estimate that these effects produce cost savings of £2.2m for the average hospital, which is about 1% of total hospital costs. But offsetting this, the policy change increased the number of cancelled elective operations by 2.5%. We found no statistically significant effects on the other five efficiency indicators (bed occupancy, cleaning services costs, laundry and linen costs, and RCI for all admissions and for elective admissions).

SUR had better explanatory power than OLS and standard errors are smaller in most cases.

The UQR results indicate a mixed relationship between the level of efficiency and the effect of the choice reform. For instance, one more equivalent rival increases admissions per bed by 2.2% for hospitals with fewer admissions per bed (25th quantile), and there is no statistically significant effect for hospitals with more admissions per bed (50th, 75th, or 90th quantile). But one more equivalent rival increases admissions per doctor by 1.8% for hospitals with more admissions per doctor (75th quantile), but it has no statistical effect on hospitals with fewer admissions per doctor (10th or 25th quantile).

The next three sections briefly describe the related literature, the institutional background in the English NHS, and the analytical framework. Section 2 explains the econometric strategy. Section 3 describes the data, and Section 4 provides the results. Section 5 concludes.

1.1. Related studies

A number of empirical studies investigate the effect of competition on efficiency in the US (Gaynor and Town, 2011). Early studies suggest that hospital competition leads to an inefficient use of resources under a retrospective payment system (e.g. Joskow, 1980, Robinson and Luft, 1985).[1] Later studies find evidence of lower hospital costs in more competitive areas after the introduction of prospective payment system and managed care (Zwanziger and Melnick, 1988, Bamezai et al., 1999).[2] For example, Kessler and McClellan (2000) and Kessler and Geppert (2005), find that hospital competition has a welfare-enhancing effect by reducing costs and increasing quality for patients who had a heart attack.

For the UK, Söderlund et al. (1997) find no association between competition and unit cost after the introduction of the NHS internal market.[3] Gaynor et al. (2013) focus on a more recent

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[1] A retrospective payment system reimburses hospitals for the actual costs incurred for each patient.

[2] In 1982, hospitals in California were paid a fixed price for each patient treated, and new pro-competition laws allowed insurance companies to offer patients health care plans after negotiating the price with providers.

[3] The NHS internal market reform was introduced in 1991 and it stimulated competition by separating the roles of financier and supplier of health care services. Suppliers (hospitals trusts) had to compete to secure contracts, and therefore income, offered by the purchaser. The internal market was abolished in 1997.

reform that aimed at stimulating competition among hospitals through the relaxation of constraints on patient choice of hospital. The authors implement a *quasi* differences-in-differences estimator and find that competition reduced length of stay but did not change expenditure per admission.[4] Cooper et al. (2012) also exploit the Patient Choice reform and find that it reduced the pre-surgery length of stay of elective procedures such as hip and knee replacement, hernia repair, and arthroscopy more in competitive areas. Similarly, Bloom et al. (2015) use an instrumental variables strategy on a cross-section of hospitals in 2006 and find that competition reduces average length of stay.

Our study contributes to this literature in three ways. First, we use a wider set of efficiency indicators. We include measures of resource management (such as admissions per bed, per doctor and per nurse, bed occupancy rate, cancelled operations, proportion of day cases and untouched meals), and measures of cost (such as cleaning services costs and laundry and linen costs, and the RCI as an alternative indicator). Second, we estimate the regressions for our indicators simultaneously to account for correlations across the error terms. Third, we test whether the effect of competition on efficiency varies at different quantiles of the efficiency distribution using the UQR estimator of Firpo et al. (2009).

1.2. Institutional background

The English 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 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

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[4] Gaynor et al. (2013) study other aspect of hospital performance such as total number of admissions, total number and share of elective admissions, and total expenditure. They also investigate the effect of competition on quality as measured by heart attack and overall mortality.

conditions or client groups. Private hospitals are small, with no more than 50 beds, and overall provide about 6.5% of hospital beds (Boyle, 2011).

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. HRGs are groups of patients who are homogeneous with respect to 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, 2013b).

Hospital competition has been encouraged by relaxing restrictions on patients' choice of hospital for elective care. Before 2006, elective patients were mainly restricted to the set of hospitals in contract with their local health authority. In 2006, patients were given the right to be offered a choice of at least four hospitals 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 some aspects of hospital performance (e.g. mortality, waiting times).

1.3. Analytical framework

The production function of a hospital is $Y = f(K,L,e)$, where Y is the number of admissions, K is capital, L is labour, and e is managerial effort. Simple productivity measures are capital or labour productivity, given respectively by Y/K or Y/L. We can proxy Y/K with admissions per bed, and Y/L with admissions per doctor or per nurse. Ceteris paribus increases in managerial effort e will increase both productivity measures.

Managerial effort e can be proxied by the proportion of day cases and bed occupancy rates. For example, managers can encourage doctors to discharge the patient on the same day by ensuring suitable patients are admitted early in the morning and care is provided within the day. Managers may improve also admission and discharge procedures through better planning to ensure beds are not left unoccupied and elective operations are not cancelled.

If r and w are the unit costs of capital and labour, the cost is $C = rK+wL$. If input use increases proportionately with output, the cost function can be written as $C(Y) = c(r,w,e)Y$, where $c(\cdot)$ is the unit cost of treatment. Therefore, costs will also be a function of managerial effort. We measure costs at aggregate level and for specific services such as cleaning services and laundry and linen services, which are plausibly unaffected by factors that drive the costs of providing medical care such as the volumes of doctors and nurses.

There may be negative spillover effects across efficiency dimensions and from efficiency to quality. For example, higher bed occupancy rates may lead to more cancelled elective operations. In addition to improving productivity and reducing costs, managerial effort may also have an impact on quality of services and allocative efficiency. For example, managers may better monitor patients' preferences on meals to reduce wastes.[5] It is therefore useful to examine the effects of competition and choice policy on a wide range of efficiency and cost measures.

A theory model on the effect of competition on efficiency (Appendix A3) shows that competition could either increase or reduce efficiency. Hospital markets are oligopolistic with typically only a limited number of providers in each local market. More competition increases demand responsiveness to quality so that hospitals have a stronger incentive to attract patients based on clinical and non-clinical aspects of qualities (e.g. amenities). A change in the volume of patients induced by patient choice may also affect efficiency because some managerial

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[5] If hospitals reduce untouched meals by providing food of higher quality, then costs may increase but patient satisfaction will increase as well which, in turn, may stimulate demand. The reduction of untouched meals and improving standard of foods and drinks in NHS hospitals are policy targets (Department of Health, 2005, 2014a). A recent cost-benefit analysis commissioned by the Department of Health (Department of Health, 2014b) suggests that improved practices in the management of hospital food (e.g. use of menu planning software, implementation of waste policy and audit) may produce savings through enhanced catering efficiency and reduced patient length of stay.

efforts, say to improve purchasing procedures, will yield bigger returns on a larger pool of patients.

2. METHODS

To assess the impact of the Patient Choice reform on efficiency, we estimate the baseline Model I:

$$y_{kt} = \mu + \beta \bar{M}_k d_{t\geq 2006/07} + X_{kt}\theta + \lambda_t + \alpha_k + \varepsilon_{kt} \qquad (1)$$

where y_{kt} is an efficiency indicator for hospital k=1,...,N in year t=2002/03,…,2010/11; μ is the intercept; $\bar{M}_k = \left(1/T_k^{pre}\right)\sum_{t=2002/03}^{2005/06} M_{kt}$ measures the average pre-reform market structure of hospital k, with M_{kt} being the market structure of hospital k in year t and T_k^{pre} the number of pre-reform years for hospital k; $d_{t\geq 2006/07}$ is a dummy equal to one from year 2006/07 onwards, when the policy was introduced; X_{kt} is a vector of hospital-level control variables (e.g. percentage of male patients, patient age); λ_t are year dummies to account for time trends (e.g. of technical progress); α_k are hospital fixed effects to allow for time-invariant unobserved factors, and ε_{kt} is an idiosyncratic error term. We use $\bar{M}_k$ instead of M_{kt} to avoid potential endogeneity due to, for example, a hospital's quality and efficiency affecting the entry of rivals after the reform.

Model I is a *quasi* differences-in-differences regression because it uses a variable with differing *treatment intensity* rather than a treatment or control group (Angrist and Pischke, 2008, p. 175). The idea is that the patient choice policy has a greater effect in areas with more providers (i.e. more competitive areas). The English NHS fits this empirical strategy because of the high geographical variation in the English hospital market structure.[6]

The coefficient β in Model I is our differences-in-differences estimator indicating whether

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[6] For instance, hospitals in London generally compete with more than ten rivals within a radius of 30 km but some hospitals in the North East of England do not face any rival within the same radius.

the effect of the relaxation of patient choice constraints on efficiency varies with competition. If β>0 then hospitals in more competitive areas experience a greater increase in the efficiency indicator compared to hospitals in less competitive areas. β is identified under the common trend assumption (i.e. efficiency in both more competitive and less competitive areas follow the same trend in the absence of the reform).

We estimate Model I for eleven efficiency indicators. These outcomes are likely to be influenced by common unobservable factors (e.g. unmeasured patient characteristics) and to respond to exogenous shocks (e.g. introduction of a new medical technology). As a result, the error terms across the eleven regressions may be correlated. The single-equation OLS estimator neglects such correlations. We therefore also estimate Model I jointly for all the efficiency indicators as a SUR model.

SUR and OLS are equivalent if there is no correlation between error terms (Zellner, 1962). Even when errors are correlated, SUR and OLS are equivalent if the covariates exhibit greater collinearity across regressions than within regressions. If covariate collinearity within regressions is greater than across regressions, SUR will still provide more efficient estimates (Baltagi, 2011, p. 245). This latter condition is likely to be met in our study because, although using mostly the same covariates across regressions, the inclusion of hospital dummies (i.e. the hospital fixed effects) may induce some collinearity within regressors, and also because of the heterogeneity of the different efficiency indicators we use.[7] We estimate SUR by maximum likelihood and we cluster standard errors within hospitals to allow for the serial correlation of errors. We test the validity of SUR against OLS using a Breusch-Pagan (1979) test for correlation between error terms.

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[7] Intuitively, by using a lot of different efficiency indicators, the conditional mean function of each indicator is likely to be affected differently by covariates, choice policy and hospital fixed-effects, thus reducing the potential of collinearity across regression on different outcomes.

As in Kessler and McClellan (2000), we test whether the effect of the market structure on efficiency is non-linear using Model II:

$$y_{kt} = \mu + Q_k d_{t \geq 2006/07} \beta + X_{kt}\theta + \lambda_t + \alpha_k + \varepsilon_{kt}, \tag{2}$$

where Q_k is a vector of three dummies constructed on the quartile of the pre-reform market structure ($\bar{M}_k$) distribution. The first quartile (hospitals subject to the lowest competition) is the reference category.

We also estimate Model III which allows for time-varying market structure:

$$y_{kt} = \mu + \beta M_{kt} d_{t \geq 2006/07} + \delta M_{kt} + X_{kt}\theta + \lambda_t + \alpha_k + \varepsilon_{kt}. \tag{3}$$

The coefficient β in equation (3) has the same interpretation as in Model I, while δ captures the effect of competition in the pre-reform period.

As an additional robustness check, we implement Model IV, a more flexible version of Model III, which allows β to vary in each period as follows:

$$y_{kt} = \mu + P_t M_{kt} \beta + \rho M_{kt} + X_{kt}\theta + \lambda_t + \alpha_k + \varepsilon_{kt}, \tag{4}$$

where P_t is a vector of year dummies, excluding year 2005/06. This model provides information on the evolution of the effect of competition on efficiency in each pre- and post-reform year. We expect a greater effect of competition on efficiency in the post-reform years than in the pre-reform years.

All the above models focus on the effect of competition on *average* efficiency. But there may be more scope for competition to affect efficiency when efficiency is low. To investigate this, we implement in Model V the UQR approach suggested by Firpo et al. (2009):

$$R_\tau\left(y_{kt}\right) = \mu_\tau + \beta_\tau \bar{M}_k d_{t \geq 2006/07} + X_{kt}\theta_\tau + \lambda_t + \alpha_k + \varepsilon_{kt}, \tag{5}$$

where $R_\tau(y_{kt})$ is the τ^{th} unconditional quantile of the efficiency indicator distribution.[8] Estimates

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[8] More formally, $R_\tau(y_{kt})$ is the Recentered Influence Function (RIF) calculated as $RIF(y_{kt};q_\tau)=q_\tau+(\tau-1[y_{kt}\leq q_\tau])/f_y(q_\tau)$, where q_τ is the τ^{th} quantile of y_{kt}, $1[y_{kt}\leq q_\tau]$ is a dummy equal to one when y_{kt} is below q_τ, and $f_y(q_\tau)$ is the estimated

from this approach have an interpretation similar to model I: $\beta_\tau > 0$ indicates that, as a result of the choice policy, hospitals in the τ^{th} unconditional quantile of the efficiency indicator distribution and located in more competitive areas experience a greater increase in the efficiency indicator compared to similar hospitals located in less competitive areas.[9] We focus on the 10th, 25th, 50th, 75th, and 90th unconditional quantiles and we bootstrap clustered standard errors using 1,000 replications.[10]

3. DATA

3.1. Efficiency indicators

We have eleven efficiency indicators from 2002/03 to 2010/11 (See Appendix Table A4 for sources). As measures of resource management we use the number of *admissions per bed, admissions per doctor*, and *admissions per nurse*. Other indicators of resource management are *bed occupancy rate* and number of *cancelled elective operations* for non-clinical reasons, and *proportion of day cases* and *proportion of untouched meals*. We also use cost indicators including the overall *reference cost index* (*RCI*) and the *elective RCI, cleaning services costs* and *laundry and linen costs*.

3.2. Measure of hospital market structure

We measure market structure as the *equivalent number of rival hospitals*, including both

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density function at q_τ. The density function is estimated assuming a Gaussian kernel and using the optimal bandwidth that minimises the mean integrated squared error.

[9] Using UQRs to evaluate the effect of a change in policy provides several advantages compared to the alternative approach of conditional quantile regressions (CQR) introduced by Koenker and Bassett (1978). In CQRs, the covariates have the effect of redefining the quantiles of the dependent variable distribution (Borah and Basu, 2013): a hospital in the top of the efficiency indicator distribution may end up in the bottom of the conditional distribution. Hence, we cannot conclude whether explanatories have bigger or smaller effects on hospitals in particular quantiles. A further limitation of the conditional quantile approach concerns fixed effects, which must be treated as pure location shifters that remain constant across quantiles (e.g. Canay, 2011). This might be a strong assumption in empirical applications. In our case, for example, fixed effects are likely to capture unobserved case-mix, which needs to yield the same effect on the outcome for all hospitals, regardless of their *conditional* efficiency.

[10] We perform all estimations in Stata. We fit SUR through the command `gsem`. The unconditional quantile regression is implemented using `xtrifreg` (Borgen, 2016).

public and private providers. We calculate the HHI for hospital *k* as:

$$HHI_k = \sum_o S_{ko} HHI_o = \sum_o S_{ko} \sum_k \left(S_{ok} \right)^2 \tag{6}$$

where S_{ko} is the predicted market share of hospital *k*'s patients living in neighbourhood *o* within 30 km; and HHI_o is the concentration of patients across neighbourhoods, calculated through the predicted share of patients living in neighbourhood *o* admitted to hospital *k* (S_{ok}).[11] The hospital HHI (HHI_k) can be interpreted as a weighted average of the neighbourhood HHI (HHI_o), which helps to identify each hospital's market.[12] The inverse of hospital HHI (HHI_k^{-1}) is the number of equal sized rivals which would produce the same HHI. The equivalent number of rivals is constructed from HHIs using data from Hospital Episode Statistics (Gravelle et al., 2014) to predict patient choice of provider with models in which choice of provider is not affected by provider quality, as in Kessler and McClellan (2000).[13]

3.3. Control variables

We include as control variables: the percentage of male patients, percentage of patients between 15 and 59, 60 and 74, and older than 74 years (the reference category is the age range between 0 and 14), and percentage of emergency admissions. We also use a dummy for Foundation Trusts. In addition, we control for exogenous variation in input prices (e.g. nurses, buildings) through the market forces factor (MFF) index collected from the reference cost database. We also add the number of beds to the regressions for cancelled elective operations,

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[11] The patient share S_{ok} is the ratio between the number of hospital *k*'s patients living in neighbourhood *o* (I_{ko}) and the number of patients living in neighbourhood *o* (I_o), while S_{ko} is computed by dividing I_{ko} by the number of hospital *k*'s patients (I_k).

[12] The neighbourhood is a small geographical area with on average 1,500 inhabitants.

[13] Predicted patient flows are from a Poisson choice model for each year: $E\left(I_{ko} \mid distance_{ko}, z_k, Q_o\right) = \exp\left(\phi_1 distance_{ko} + \phi_2 distance_{ko}^2 + \phi_3' z_k + \chi' \boldsymbol{Q}_o\right)$ where I_{ko} is the number of hospital *k*'s patients living in neighbourhood *o*, $distance_{ko}$ is the distance between small area *o*'s centroid and hospital *k* located within 30 km, z_k is a vector of hospital type dummies, and Q_o is a vector of small area dummies.

cleaning services costs, and laundry and linen costs.

3.4. Descriptive statistics

Table 1 provides descriptive statistics. The sample includes between 143 (laundry and linen costs) and 173 (RCI) hospital trusts observed on average for just under 9 years. In each year, there are on average 110 admissions per bed, 185 admissions per doctor, and 69 admissions per nurse. The bed occupancy rate is 86%. 30.7% of patients are on average admitted as day cases, and hospitals cancel on average 359 elective operations in a year. On average, 7.6% of meals served to patients remain untouched, the cleaning services and the laundry and linen costs are respectively £2,842 thousands and £807 thousands. The reference cost indexes are 100 by construction: a RCI greater than 100 indicates that a hospital's total costs are greater than the national average total costs for the same HRG groups.[14] Correlations amongst the efficiency indicators are generally low and mostly below 30% in absolute value (Appendix Table A1).

Figure 1 shows the trend in some efficiency indicators from 2002/03 to 2010/11. Admissions per bed, admissions per nurse, cleaning services costs, and laundry and linen costs trended upward over the period whilst admissions per doctor and percentage of untouched meals fell. Bed occupancy rate, rate of day cases, and cancelled elective operations increased after 2006/07.

Table 1 also has descriptive statistics on explanatories and shows that there is considerable variation in the key number of equivalent rivals.

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[14] Appendix Table A2 provides the unconditional quantiles of the efficiency indicators.

4. RESULTS

4.1. Model results

Table 2 has the SUR results for Model I.[15] The key coefficient in the first row indicates whether the effect of competition on efficiency changed after the policy. Efficiency increased according to nine of the 11 indicators and fell for two (cancelled operations, cleaning service costs). The increases in efficiency are statistically significant at the 5% level for four indicators: post policy one more equivalent rival increases admissions per bed by 1%, admissions per doctor by 0.9%, and the proportion of day cases by 0.38 percentage points, and reduces the proportion of untouched meals by 0.35 percentage points. One of the reductions in efficiency (cancelled operations) is also statistically significant: one more equivalent rival increases cancelled elective operations by 2.5%.

Table 3 shows that an additional equivalent rival increases admissions by 0.6% and decreases the numbers of beds and doctors by 0.5% and 0.4%, although the effects are not statistically significant.[16] These results support those on admissions per bed and admissions per doctor in Table 2 since an increase in admissions and a reduction in the number of beds or doctors imply increases in admission per bed and per doctor.

Table 4 has the key results for Model II, in which the policy break dummy is interacted with three dummies for the three upper quartiles of the equivalent number of rivals. The estimates suggest that the choice policy has a greater effect on efficiency for hospitals in the two higher quartiles of competition.

Table 5 reports results for Model III and IV. Model III estimates the effect of market

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[15] The p-value for the Breusch-Pagan test for correlation among the error terms across regressions suggests that SUR yields more precise estimates than OLS for Model I and for Models II, III, and IV.

[16] Appendix Table A3 provides the results on admissions, beds, doctors, and nurses for Model III and IV. We observe higher statistical significance in model IV for the effect of competition on beds: an additional equivalent rival significantly reduces beds by 0.6% in 2007/08, 0.8% in 2008/09, and 1.2% in 2010/11.

structure before and after change in choice policy. Compared to Model I, the key coefficient is unchanged for admissions per bed and proportion of day cases, but it is no longer significant at 5% level for admissions per doctor, cancelled elective operations and proportion of untouched meals. The association between competition and efficiency before the reform (δ) is never statistically significant at 5% level. The association between competition and efficiency after the reform ($\beta+\delta$) is significant only for the admissions per bed and admissions per doctor: an additional equivalent rival increases admissions per bed by 1.5% (0.9%+0.6%) and admissions per doctor by 1.2% after the reform.

Model IV allows the effect of competition on efficiency to vary by year. Considering the proportion of day cases, for example, the estimated coefficient on the interaction term is negative and insignificant in the pre-reform periods, and increasingly positive and significant in the post-reform periods. Such estimates clearly indicate a persistent effect of the reform on efficiency as captured by the proportion of day cases.

Table 6 has the UQR results. There is a mixed relationship between the effect of the choice policy change and whether the hospital was more or less efficient. Less efficient hospitals tend to have greater increases in efficiency in the case of admissions per bed, the percentage of day cases and, to a lesser extent, admissions per nurse and percentage of untouched meals. But in the cases of admissions per doctor and admissions per nurse it is the more efficient hospitals which respond more.

4.2. Economic impacts

We provide some back of the envelope calculations of the economic impacts of the patient choice policy on a subset of our efficiency indicators (Appendix A1 has details and explanations of why we do not attempt to estimate cost savings for all our efficiency indicators). From Model I in equation (1), the average effect of patient choice on a given efficiency indicator is $\beta\bar{M}$, where $\bar{M} = 3.7$ is the mean equivalent number of rivals in the pre-policy period (Table 1).

Patient choice increased *admissions per doctor* by 3.3% (0.009×3.7). Since patient choice did not affect admissions (in Table 3 the effect on admissions is statistically insignificant), hospitals increase admissions per doctor by employing fewer doctors. Patient choice reduced the number of *doctors* by 1.5% (0.004×3.7; see Table 3). The average hospital has 420 doctors, and doctor average salary is £58,700 in the first quarter of 2011, so that the average hospital spends £24.654m on doctors. The average hospital annual cost savings from the reduction in the number of doctors are therefore £0.370m (1.5%×£24.654m).

Patient choice increased the proportion of *day cases* by 1.4 percentage points (0.0038×3.7). On average, hospitals treat 73,651 patients each year. Since patient choice did not affect admissions, it increased the number of day cases by 1,031 (0.014×73,651). In 2010/11, the average cost of day cases was £670, and the average cost of elective patients with at least one overnight stay was £2,435. The savings from treating an elective patient as a day case is therefore £1,765 (£2,435−£670). Hence, the annual cost savings per hospital as a result of an increase in day cases are £1.820m (1,031×£1,765).

Patient choice reduced the proportion of *untouched meals* by 1.3 percentage points (0.35×3.7). The average daily cost of feeding a patient is £8.29. Every day patients are served three meals and, therefore, the average cost of a meal is £2.76 (£8.29÷3). The average hospital has 686 beds, which are occupied 86% of the time (see Table 1). The total annual number of meals for the average hospital is 646,006 (686×0.86×3×365). Patient choice therefore reduced the number of untouched meals by 8,398 (646,006×0.013). Assuming that for each untouched meal hospitals serve a replacement meal of a similar cost that better fits patient's preferences, the annual savings from patient choice that arise from a reduction in the proportion of untouched meals is £0.023m (8,398×£2.76).

The annual total cost saving, from these three efficiency improvements is around £2.2m per hospital trust or £378m in total, around 1% of total hospital costs in 2010/11. This is not an estimate of the overall cost change from the change in patient choice policy since we only consider a subset of possible dimensions of efficiency. Moreover, data limitations prevent a full costing of all the effects on the changes in our subset of efficiency indicators, some of which implied reductions in efficiency and an increase in costs. However, our back of the envelope calculations for the indicators which we can cost suggest that, whilst the cost effects of changes in specific efficiency dimensions are relatively small as a proportion of total NHS costs, the overall efficiency effects of the choice policy change may be large enough to be of policy significance.

5. DISCUSSION

We investigated whether competition improves some dimensions of hospital efficiency in England using the exogenous variation generated by the 2006 patient choice reform and the geographical variation in market structure. We find that greater competition led to improvements in four efficiency indicators (admissions per bed, admissions per doctor, proportion of day cases, and the proportion of untouched meals) but increased cancelled elective operations. The effect of the choice reform was larger for hospitals facing more rivals but there was no consistent relationship between the effect of the reform and initial hospital efficiency.

Our results generally support the findings from other studies on English hospitals, which indicates a beneficial effect of competition on efficiency (e.g. Cooper et al., 2012). Our findings on admissions per bed and per doctor may help explain the reduction of beds and doctors in

NHS hospitals (Hosken, 2016, Matthews-King, 2018). The increase in the proportion of day cases after the choice reform is also largely coherent with the reduction in pre-surgery and overall length of stay on specific elective procedures found by Cooper et al. (2012).

The reductions in beds and doctors per admission may have also brought hospitals closer to their full capacity. This may explain the increase in cancelled elective operations. Since NHS hospitals cannot refuse emergency patients, cancelling elective operations is an obvious way to react when demand exceeds capacity. Hospitals could also allow waiting times to increase but this route would have costs for managers because of the enforcement of strict waiting times targets (Propper et al., 2008).

Under a relatively weak set of structural and distributional assumptions (i.e. the usual assumptions implicit in the SUR framework and differences-in-differences approach) our reduced form specification yields an unbiased estimate of the effects of competition on the specific efficiency measures. An alternative structural approach would enable us to examine the inter-relationships amongst the efficiency indicators, for example, between bed occupancy and cancelled operations. Such an approach, however, would require considerably stronger a-priori assumptions or a large number of instrumental variables for the identification of the causal effects.

Our analysis is based on an interesting but incomplete set of efficiency indicators and there may be reductions or increases in costs from changes in other indicators. A full cost-benefit analysis of the choice policy would also take account of the value of the change in quality it induced. Studies to date suggest that quality has improved for some conditions (Cooper et al., 2011, Gaynor et al., 2013, Gravelle et al., 2014, Moscelli et al., 2018), but may have fallen for others (Moscelli et al., 2016, Skellern, 2017). Account must also be taken of the direct costs of implementing the policy change, such as some proportion of the £280m spent by the NHS up to 2012 to set-up and run the electronic “Choose and Book” system to facilitate patients’ participation in their hospital referrals (Department of Health, 2013a, Dusheiko and Gravelle, 2018). There are also other potentially welfare increasing policy tools available, such as direct financial incentives for providers (Meacock et al., 2014), regulation, targets (Propper et al., 2008), and organisational and budgetary changes (Mason et al., 2015, Siciliani et al., 2017) which can be used as substitutes or complements to changes in competition amongst providers.

TABLES AND FIGURES

Table 1 – Descriptive statistics.

Variable	Def	Obs	Trust	Year	Mean	SD			Min	Max
						Overall	Between	Within		
Efficiency indicator										
Admissions per bed	E	1,498	171	8.76	110	31	25	18	38	319
Admissions per doctor	E	1,499	172	8.72	185	52	47	21	46	463
Admissions per nurse	E	1,499	172	8.72	69	16	14	7	20	119
Bed occupancy rate (%)	E	1,503	172	8.74	86.0	6.3	5.3	3.5	50.5	99.2
Proportion of day cases (%)	E	1,477	169	8.74	30.8	8.6	7.9	3.5	4.6	90.5
Cancelled elective operations	I	1,477	170	8.69	360	288	250	142	6	2426
Reference cost index	I	1,516	173	8.76	100.8	12.9	11.5	5.8	66.0	195.8
Elective reference cost index	I	1,498	171	8.76	100.2	16.5	13.6	9.3	60.5	197.3
Cleaning services costs (£1,000)	I	1,381	159	8.69	2,842	1,823	1,580	901	69	12,941
Laundry and linen costs (£1,000)	I	1,215	143	8.5	807	488	459	160	40	2,864
Proportion of untouched meals (%)	I	1,382	160	8.64	7.6	5.4	3.7	4.0	0.0	49.0
Measure of market structure										
Equivalent number of rivals (HHI^{-1})					3.7	2.5	2.4	0.7	1.0	13.6
Control variable										
Percentage of male patients (%)					44.1	4.8	4.7	0.9	14.8	65.3
Percentage of patients between 0 and 14 years (%)					13.5	13.1	12.9	1.2	0.0	94.2
Percentage of patients between 15 and 59 years (%)					44.4	8.0	7.8	1.6	5.8	74.3
Percentage of patients between 60 and 74 years (%)					21.0	5.9	5.7	1.1	0.0	47.0
Percentage of patients older than 74 years (%)					20.8	6.2	6.1	1.3	0.0	42.8
Percentage of emergency admissions (%)					35.2	9.6	9.1	2.7	0.2	61.8
Number of beds					686	382	374	65	31	2,523
Foundation trust					0.287	0.453	0.301	0.339	0	1
Market forces factor					1.003	0.074	0.074	0.014	0.886	1.323

E=positive indicator of efficiency, I=negative indicator of efficiency

Descriptive statistics for competition measure and control variables are calculated on the admissions per bed's sample.

Table 2 – Competition and efficiency: Model I.

Regressor	Log of admissions per bed	Log of admissions per doctor	Log of admissions per nurse	Bed occupancy rate	Proportion of day cases	Log of cancelled operations	Reference cost index	Elective reference cost index	Log of cleaning services costs	Log of laundry and linen costs	Proportion of untouched meals
Policy break 2006-07*Pre-reform HHI^{-1}	0.010	0.009	0.003	0.050	0.377	0.025	-0.306	-0.514	0.0010	-0.005	-0.345
	(0.004)**	(0.004)**	(0.004)	(0.120)	(0.119)***	(0.013)**	(0.275)	(0.392)	(0.007)	(0.008)	(0.171)**
Proportion of male patients	-0.002	-0.012	-0.008	-0.042	0.318	-0.036	-0.053	0.109	0.000	-0.002	-0.011
	(0.004)	(0.006)**	(0.006)	(0.152)	(0.146)**	(0.017)**	(0.257)	(0.417)	(0.009)	(0.009)	(0.240)
Proportion of patients between 15 and 59	0.018	0.015	0.022	-0.047	0.022	-0.017	-0.509	-0.445	0.017	0.005	-0.190
	(0.004)***	(0.004)***	(0.005)***	(0.143)	(0.120)	(0.014)	(0.283)*	(0.420)	(0.010)*	(0.007)	(0.169)
Proportion of patients between 60 and 74	0.012	0.013	0.016	-0.190	1.084	0.011	-0.424	-0.853	0.010	-0.002	-0.271
	(0.006)**	(0.007)*	(0.007)**	(0.205)	(0.172)***	(0.021)	(0.361)	(0.637)	(0.011)	(0.012)	(0.236)
Proportion of patients beyond 74	-0.001	0.013	0.011	0.129	-0.299	0.017	-0.200	0.270	0.005	0.021	-0.107
	(0.005)	(0.006)**	(0.005)**	(0.173)	(0.144)**	(0.019)	(0.309)	(0.568)	(0.012)	(0.010)**	(0.243)
Proportion of emergency patients	-0.007	-0.005	-0.007	-0.036	-0.643	-0.020	0.006	0.336	0.004	0.000	-0.107
	(0.002)***	(0.002)**	(0.003)***	(0.055)	(0.055)***	(0.006)***	(0.119)	(0.178)*	(0.003)	(0.003)	(0.068)
Log of beds						-0.134			0.124	0.319	
						(0.236)			(0.112)	(0.083)***	
Foundation trust	-0.032	0.005	-0.018	-1.030	-0.509	0.084	-1.691	-29.202	0.014	0.028	-0.274
	(0.012)***	(0.013)	(0.011)	(0.442)**	(0.329)	(0.053)	(20.431)	(27.211)	(0.024)	(0.029)	(0.540)
Market forces factor	0.411	0.148	0.337	7.588	-16.464	-0.132	0.309	1.141	-0.335	0.139	-26.864
	(0.278)	(0.272)	(0.288)	(8.876)	(9.176)*	(1.053)	(0.801)	(1.438)	(0.569)	(0.533)	(12.628)**
Constant	3.674	4.390	3.093	86.820	42.867	8.842	137.249	143.006	6.178	3.530	53.140
	(0.473)***	(0.519)***	(0.577)***	(15.364)***	(13.897)***	(2.246)***	(29.858)***	(47.606)***	(1.310)***	(0.989)***	(17.972)***

SUR estimation. All regressions control for hospital and year fixed effects.

Breusch-Pagan test for diagonal variance-covariance matrix: p-value=0.000

Clustered standard errors in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table 3 – Competition and admissions, beds, doctors, and nurses: Model I.

Regressor	Log of admissions	Log of beds	Log of doctors	Log of nurses
Policy break 2006/07*Pre-reform HHI^{-1}	0.002	-0.005	-0.004	0.003
	(0.005)	(0.003)	(0.003)	(0.003)
Proportion of male patients	-0.012	-0.009	0.002	-0.002
	(0.006)**	(0.004)**	(0.004)	(0.004)
Proportion of patients between 15 and 59	0.029	0.004	0.004	-0.002
	(0.009)***	(0.003)	(0.003)*	(0.003)
Proportion of patients between 60 and 74	0.022	0.004	0.000	-0.003
	(0.010)**	(0.005)	(0.004)	(0.004)
Proportion of patients beyond 74	0.009	0.014	-0.003	0.000
	(0.005)	(0.005)***	(0.004)	(0.004)
Proportion of emergency patients	-0.006	0.002	0.000	0.001
	(0.002)***	(0.001)	(0.001)	(0.001)
Foundation trust	0.012	0.040	0.004	0.027
	(0.011)	(0.012)***	(0.012)	(0.009)***
Market forces factor	-0.031	-0.430	-0.150	-0.332
	(0.256)	(0.214)**	(0.216)	(0.216)
Constant	9.852	6.589	5.755	7.348
	(0.586)***	(0.316)***	(0.307)***	(0.335)***
Observations	1,498	1,498	1,499	1,499
Number of trusts	171	171	172	172
Average	73,651	686	420	1,093

OLS estimation of Model I. All regressions control for hospital and year fixed effects.

Clustered standard errors in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table 4 – Competition quartiles and efficiency: Model II.

Efficiency indicator	2nd quartile	3rd quartile	4th quartile
Log of admissions per bed	0.010	0.025	0.053
	(0.021)	(0.021)	(0.023)**
Log of admissions per doctor	0.017	0.058	0.049
	(0.019)	(0.019)***	(0.026)*
Log of admissions per nurse	0.022	0.047	0.024
	(0.019)	(0.020)**	(0.026)
Bed occupancy rate	0.540	1.285	0.961
	(0.662)	(0.693)*	(0.814)
Proportion of day cases	0.796	1.073	2.108
	(0.626)	(0.501)**	(0.747)***
Log of cancelled elective operations	-0.024	0.085	0.113
	(0.079)	(0.080)	(0.084)
Reference cost index	-0.363	-2.691	-1.925
	(1.147)	(0.997)***	(1.493)
Elective reference cost index	2.491	-2.322	-3.354
	(1.940)	(1.983)	(1.971)*
Log of cleaning services costs	-0.037	-0.052	-0.021
	(0.038)	(0.047)	(0.045)
Log of laundry and linen costs	0.056	-0.008	0.019
	(0.054)	(0.046)	(0.046)
Proportion of untouched meals	-1.321	-1.819	-2.161
	(0.911)	(0.948)*	(1.038)**

SUR estimation. In addition to hospital and year fixed effects, all regressions control for gender, age categories, emergency admissions, foundation trusts, and market forces factor. The regressions for cancelled elective operations, cleaning services costs, and laundry and linen costs also control for beds.

Quartile dummies are constructed on the pre-reform HHI^{-1}: 2nd quartile=low-competition market, 3rd quartile=high-competition market, 4th quartile=very high-competition market; 1st quartile=very low-competition market (reference category).

Breusch-Pagan test for diagonal variance-covariance matrix: p-value=0.000

Clustered standard errors in parentheses.

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

Table 5 – Competition and efficiency: with time varying competition.

Regressor	Log of admissions per bed	Log of admissions per doctor	Log of admissions per nurse	Bed occupancy rate	Proportion of day cases	Log of cancelled operations	Reference cost index	Elective reference cost index	Log of cleaning services costs	Log of laundry and linen costs	Proportion of untouched meals
					Model III						
Policy break*HHI^{-1}	0.008	0.007	0.002	0.048	0.326	0.020	-0.186	-0.421	0.002	-0.0001	-0.255
	(0.004)**	(0.004)*	(0.004)	(0.110)	(0.106)***	(0.011)*	(0.220)	(0.339)	(0.006)	(0.007)	(0.156)
HHI^{-1}	0.006	0.005	0.008	0.028	-0.277	-0.002	-0.556	-0.385	-0.019	-0.013	-0.150
	(0.007)	(0.006)	(0.006)	(0.208)	(0.170)	(0.026)	(0.370)	(0.712)	(0.011)*	(0.015)	(0.306)
					Model IV						
Dummy 2002-03*HHI^{-1}	-0.003	-0.005	0.000	0.003	-0.245	-0.016	0.122	-0.532	0.024	0.012	0.569
	(0.006)	(0.006)	(0.006)	(0.214)	(0.178)	(0.034)	(0.460)	(0.713)	(0.015)	(0.012)	(0.317)*
Dummy 2003-04*HHI^{-1}	-0.002	-0.006	0.000	-0.025	-0.133	-0.018	-0.129	-0.268	-0.007	0.017	0.180
	(0.004)	(0.004)	(0.005)	(0.145)	(0.137)	(0.020)	(0.269)	(0.489)	(0.018)	(0.010)*	(0.225)
Dummy 2004-05*HHI^{-1}	-0.001	-0.006	-0.001	-0.039	-0.034	-0.024	-0.094	0.204	0.004	-0.007	0.348
	(0.003)	(0.003)*	(0.003)	(0.105)	(0.087)	(0.013)*	(0.190)	(0.383)	(0.007)	(0.009)	(0.192)*
Dummy 2006-07*HHI^{-1}	0.004	0.004	0.000	-0.220	0.159	0.009	0.014	-0.194	0.008	0.002	0.116
	(0.004)	(0.004)	(0.004)	(0.099)**	(0.087)*	(0.009)	(0.258)	(0.354)	(0.006)	(0.006)	(0.114)
Dummy 2007-08*HHI^{-1}	0.008	0.011	0.003	0.196	0.236	0.024	-0.603	-0.542	-0.004	0.000	0.077
	(0.004)**	(0.005)**	(0.004)	(0.170)	(0.139)*	(0.014)*	(0.255)**	(0.381)	(0.010)	(0.009)	(0.152)
Dummy 2008-09*HHI^{-1}	0.007	-0.001	0.000	0.206	0.289	0.023	-0.204	-0.529	0.007	0.001	-0.010
	(0.005)	(0.005)	(0.005)	(0.205)	(0.114)**	(0.015)	(0.250)	(0.446)	(0.006)	(0.009)	(0.253)
Dummy 2009-10*HHI^{-1}	0.008	0.001	0.002	0.000	0.347	-0.003	-0.189	-0.545	0.004	0.002	-0.372
	(0.005)	(0.005)	(0.004)	(0.161)	(0.127)***	(0.019)	(0.253)	(0.480)	(0.006)	(0.009)	(0.199)*
Dummy 2010-11*HHI^{-1}	0.013	0.002	0.004	0.153	0.418	-0.018	-0.356	-0.691	0.005	0.007	-0.352
	(0.005)***	(0.006)	(0.006)	(0.174)	(0.156)***	(0.018)	(0.279)	(0.489)	(0.007)	(0.009)	(0.193)*
HHI^{-1}	0.005	0.008	0.008	0.052	-0.359	0.014	-0.504	-0.554	-0.017	-0.009	-0.088
	(0.007)	(0.007)	(0.007)	(0.228)	(0.186)*	(0.028)	(0.401)	(0.737)	(0.013)	(0.016)	(0.334)

SUR estimation. In addition to hospital and year fixed effects, all regressions control for gender, age categories, emergency admissions, number of beds, foundation trusts, and market forces factor. The regressions for cancelled elective operations, cleaning services costs, and laundry and linen costs also control for beds.

Post-reform effect of market structure (p-value) in Model III ($\beta+\delta$). Log of admissions per bed: 0.015 (0.011); log of admissions per doctor: 0.012 (0.020); log of admissions per nurse: 0.010 (0.094); bed occupancy rate: 0.076 (0.726); proportion of day cases: 0.049 (0.771); log of cancelled operations: 0.018 (0.481); proportion of untouched meals: -0.405 (0.161); log of cleaning services costs: -0.017 (0.117); log of laundry and linen costs: -0.013 (0.357); reference cost index: -0.742 (0.101); elective reference cost index: -0.806 (0.215).

Breusch-Pagan test for diagonal variance-covariance matrix: p-value=0.000. Clustered standard errors in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table 6 – Effects of competition at different efficiency quantiles: Model V.

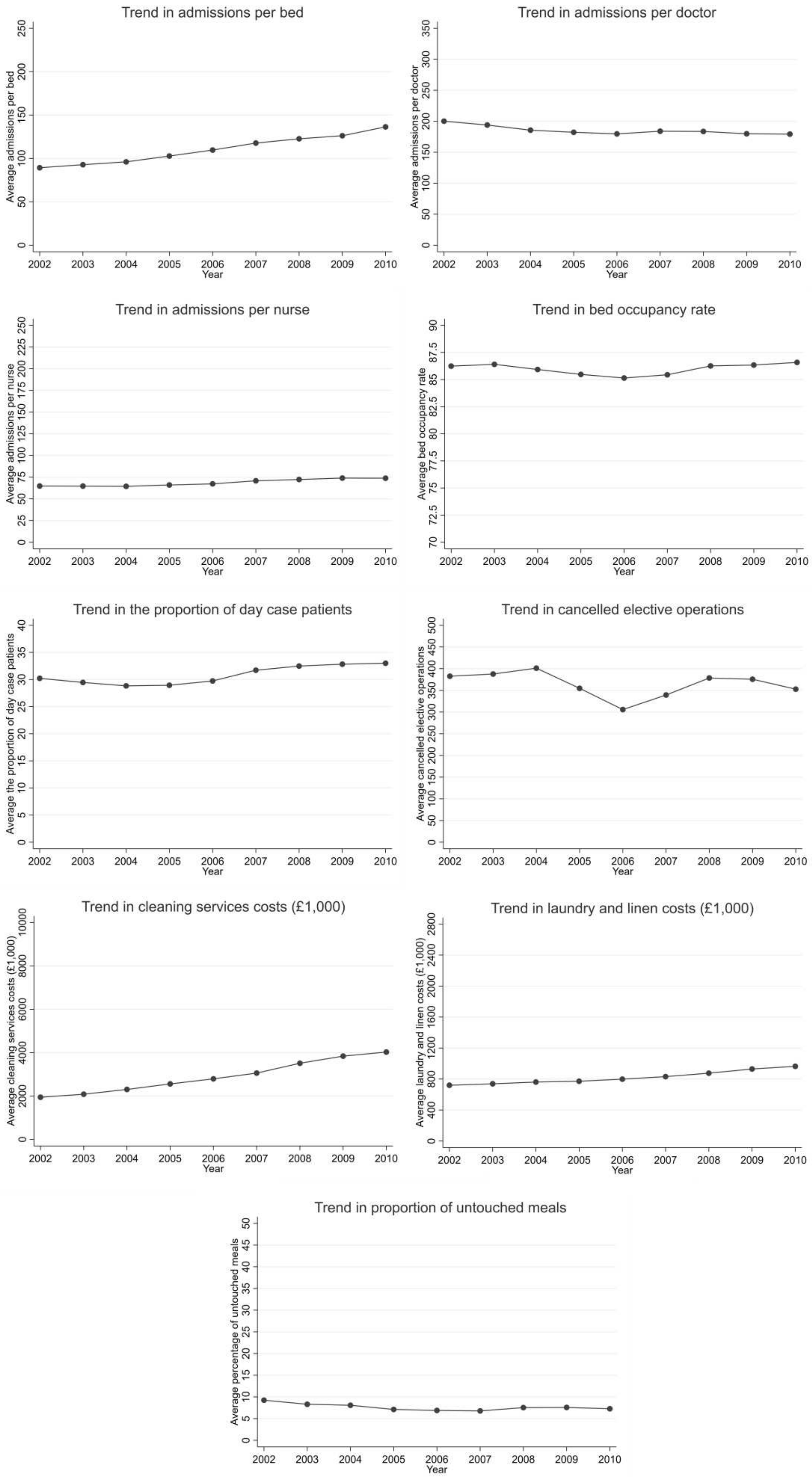
Efficiency indicator	10th	25th	50th	75th	90th
Log of admissions per bed	0.019	0.022	0.002	-0.010	-0.009
	(0.015)	(0.011)**	(0.008)	(0.008)	(0.010)
Log of admissions per doctor	-0.003	-0.004	0.013	0.018	0.016
	(0.017)	(0.010)	(0.005)**	(0.006)***	(0.007)**
Log of admissions per nurse	0.033	0.019	-0.005	-0.010	-0.009
	(0.024)	(0.011)*	(0.006)	(0.005)**	(0.007)
Bed occupancy rate	0.461	0.147	-0.079	-0.183	-0.211
	(0.408)	(0.190)	(0.148)	(0.191)	(0.252)
Proportion of day cases	0.914	0.396	0.220	0.101	0.277
	(0.372)**	(0.201)**	(0.202)	(0.255)	(0.377)
Log of cancelled elective operations	0.072	0.035	0.011	0.017	0.041
	(0.037)**	(0.023)	(0.022)	(0.022)	(0.026)
Reference cost index	-0.419	-0.319	-0.233	-0.532	0.062
	(0.281)	(0.248)	(0.250)	(0.424)	(1.068)
Elective reference cost index	0.295	-0.316	-0.395	-0.390	-1.934
	(0.501)	(0.386)	(0.487)	(0.742)	(1.592)
Log of cleaning services costs	0.018	-0.037	-0.031	-0.007	0.053
	(0.036)	(0.023)	(0.022)	(0.020)	(0.035)
Log of laundry and linen costs	-0.075	-0.021	0.010	-0.018	0.016
	(0.046)	(0.020)	(0.018)	(0.015)	(0.032)
Proportion of untouched meals	-0.076	-0.196	-0.168	-0.429	-0.627
	(0.160)	(0.128)	(0.144)	(0.245)*	(0.469)

Unconditional quantile regression. In addition to hospital and year fixed effects, all regressions control for gender, age categories, emergency admissions, number of beds, foundation trusts, and market forces factor. The regressions for cancelled elective operations, cleaning services costs, and laundry and linen costs also control for beds.

Bootstrapped clustered standard errors (using 1,000 replications) in parenthesis.

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

Figure 1 – Trend in the efficiency indicators from 2002/03 to 20010/11.



Trend in admissions per bed

Trend in admissions per doctor

Trend in admissions per nurse

Trend in bed occupancy rate

Trend in the proportion of day case patients

Trend in cancelled elective operations

Trend in cleaning services costs (£1,000)

Trend in laundry and linen costs (£1,000)

Trend in proportion of untouched meals

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APPENDIX

Table A1 – Pairwise correlations across efficiency indicators.

Efficiency indicator	Def	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Log of admissions per bed	E	1.0000										
(2) Log of admissions per doctor	E	0.2909*	1.0000									
(3) Log of admissions per nurse	E	0.5588*	0.7586*	1.0000								
(4) Bed occupancy rate	E	0.2018*	0.0595	0.2277*	1.0000							
(5) Proportion of day cases	E	0.1028*	-0.0501	0.1446*	-0.1041*	1.0000						
(6) Log of cancelled elective operations	I	-0.0181	0.0087	0.0946*	0.1674*	0.0551	1.0000					
(7) Reference cost index	I	-0.2197*	-0.6242*	-0.5829*	-0.1566*	0.0982*	-0.1022*	1.0000				
(8) Elective reference cost index	I	-0.2575*	-0.5555*	-0.5562*	-0.1590*	-0.045	-0.1227*	0.7412*	1.0000			
(9) Log of cleaning services costs	I	0.2821*	-0.0819	0.0714	0.2116*	-0.1088*	0.5955*	-0.055	-0.0904*	1.0000		
(10) Log of laundry and linen costs	I	0.1926*	0.1030*	0.1848*	0.3147*	-0.2760*	0.6670*	-0.1696*	-0.1776*	0.8133*	1.0000	
(11) Proportion of untouched meals	I	0.0405	-0.0234	-0.0542	0.0159	-0.0199	0.0134	-0.0121	-0.0267	-0.002	0.0185	1.0000

E=positive indicator of efficiency, I=negative indicator of efficiency

* = statistically significant at 5% level after Bonferroni adjustment

Table A2 – Unconditional quantiles of the efficiency indicators.

Efficiency indicator	10th	25th	50th	75th	90th
Admissions per bed	75	91	109	126	142
Admissions per doctor	115	151	190	218	243
Admissions per nurse	48	58	71	79	87
Bed occupancy rate	78.2	82.8	86.6	90.2	93.3
Proportion of day cases	22.1	26.4	30.0	34.6	39.1
Cancelled elective operations	86	154	284	475	763
Reference cost index	88.2	92.6	98.0	106.3	116.2
Elective reference cost index	82.2	88.9	97.2	108.6	122.6
Cleaning services costs	987	1,547	2,440	3,676	5,207
Laundry and linen costs	280	465	709	1,052	1,430
Proportion of untouched meals	2.4	4.2	6.4	9.6	14.5

Table A3 – Competition, admissions, beds, doctors, and nurses.

Regressor	Model	Log of admissions	Log of beds	Log of doctors	Log of nurses
Policy break 2006-07*HHI^{-1}	III	0.001	-0.004	-0.003	0.003
		(0.004)	(0.003)	(0.003)	(0.003)
HHI^{-1}		0.003	-0.007	-0.006	-0.009
		(0.007)	(0.004)*	(0.004)	(0.004)**
Dummy 2002-03*HHI^{-1}	IV	-0.008	-0.005	-0.003	-0.008
		(0.005)	(0.004)	(0.005)	(0.004)*
Dummy 2003-04*HHI^{-1}		0.005	-0.001	0.002	-0.004
		(0.010)	(0.003)	(0.003)	(0.003)
Dummy 2004-05*HHI^{-1}		-0.004	-0.003	0.003	-0.003
		(0.003)	(0.002)	(0.003)	(0.002)*
Dummy 2006-07*HHI^{-1}		0.002	0.000	-0.001	0.003
		(0.004)	(0.002)	(0.002)	(0.002)*
Dummy 2007-08*HHI^{-1}		0.002	-0.006	-0.007	0.001
		(0.004)	(0.003)**	(0.005)	(0.003)
Dummy 2008-09*HHI^{-1}		-0.003	-0.008	-0.001	-0.002
		(0.004)	(0.003)**	(0.004)	(0.003)
Dummy 2009-10*HHI^{-1}		-0.001	-0.007	-0.001	-0.002
		(0.004)	(0.004)*	(0.004)	(0.003)
Dummy 2010-11*HHI^{-1}		0.001	-0.012	0.001	-0.001
		(0.005)	(0.004)***	(0.004)	(0.004)
HHI^{-1}		0.002	-0.006	-0.009	-0.009
		(0.008)	(0.005)	(0.004)**	(0.004)**
Observations		1,498	1,498	1,499	1,499
Number of trusts		171	171	172	172
Average		73,651	686	420	1,093

OLS estimation. In addition to hospital and year fixed effects, all regressions control for gender, age categories, emergency admissions, foundation trusts, and market forces factor.

Clustered standard errors in parentheses, *** p-value<0.01, ** p-value<0.05, * p-value<0.1

Table A4 – Data sources.

	Source
Efficiency indicator	
Admissions, day cases	https://digital.nhs.uk/data-and-information/publications/statistical/hospital-admitted-patient-care-activity
Doctors	Data provided by NHS Digital until 2009/10. 2010/11 data available on: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-workforce-statistics-medical-and-dental-staff/nhs-staff-2000-2010-medical-and-dental. Doctors includes all medical staff such as consultants, associate specialists, specialty doctors, staff grade doctors, doctors in training, hospital practitioners/clinical assistants, and other doctors. Nurses comprise nurses, midwiferies, and health visiting staff.
Nurses	Data provided by NHS Digital until 2009/10. 2010/11 data available on: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-workforce-statistics-non-medical-staff/nhs-staff-2000-2010-non-medical. Nurses comprise nurses, midwiferies, and health visiting staff.
Beds, bed occupancy rate	https://www.england.nhs.uk/statistics/statistical-work-areas/bed-availability-and-occupancy/bed-data-overnight/
Cancelled elective operations	https://www.england.nhs.uk/statistics/statistical-work-areas/cancelled-elective-operations/cancelled-ops-data/
Reference cost index	http://webarchive.nationalarchives.gov.uk/+/http://www.dh.gov.uk/en/Managingyourorganisation/NHScostingmanual/DH_129310?PageOperation=email https://www.gov.uk/government/collections/nhs-reference-costs
Cleaning services costs, laundry and linen costs, proportion of untouched meals	http://hefs.hscic.gov.uk/DataFiles.asp. Cleaning services costs include all pay (e.g. salaries) and non-pay (e.g. equipment) costs for both in house or contracted out cleaning services. Laundry and linen costs are defined in a similar way
Covariate	
Patient gender, age, emergency admissions	https://digital.nhs.uk/data-and-information/publications/statistical/hospital-admitted-patient-care-activity
Foundation trusts	http://hefs.hscic.gov.uk/DataFiles.asp
Market forces factor	http://webarchive.nationalarchives.gov.uk/+/http://www.dh.gov.uk/en/Managingyourorganisation/NHScostingmanual/DH_129310?PageOperation=email https://www.gov.uk/government/collections/nhs-reference-costs

Table A5 – (i) Principal Component Analysis.

	Eigenvalue	Difference	Proportion explained variance	Cumulative
Principal Component 1 (PC 1)	3.38	1.05	0.31	0.31
Principal Component 2 (PC 2)	2.33	1.10	0.21	0.52
Principal Component 3 (PC 3)	1.23	0.18	0.11	0.63
Principal Component 4 (PC 4)	1.05	0.11	0.10	0.73
Principal Component 5 (PC 5)	0.93	0.20	0.09	0.81
Principal Component 6 (PC 6)	0.73	0.24	0.07	0.88
Principal Component 7 (PC 7)	0.49	0.17	0.04	0.92
Principal Component 8 (PC 8)	0.33	0.13	0.03	0.95
Principal Component 9 (PC 9)	0.20	0.03	0.02	0.97
Principal Component 10 (PC 10)	0.17	0.01	0.02	0.99
Principal Component 11 (PC 11)	0.16	-	0.01	1.00

Table A6 – (ii) Correlations Principal Component Analysis.

	Correlations										
Efficiency indicator	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10	PC 11
Log of admissions per bed	0.29	-0.03	0.54	0.12	0.10	0.59	-0.13	-0.42	0.01	0.23	-0.10
Log of admissions per doctor	0.42	-0.25	-0.20	-0.09	0.12	0.08	0.47	0.24	0.05	0.54	0.35
Log of admissions per nurse	0.47	-0.12	0.12	-0.06	0.01	0.18	0.30	0.28	0.07	-0.72	-0.13
Bed occupancy rate	0.14	0.12	0.18	0.42	-0.84	-0.12	0.15	0.02	0.00	0.07	0.12
Proportion of day cases	0.11	-0.01	0.70	-0.25	0.14	-0.59	0.00	0.19	-0.09	0.14	-0.05
Log of cancelled elective operations	0.18	0.49	-0.12	-0.10	0.12	-0.25	0.47	-0.62	-0.07	-0.10	0.03
Reference cost index	-0.45	0.15	0.26	-0.06	0.04	0.15	0.33	0.07	0.73	-0.03	0.19
Elective reference cost index	-0.44	0.14	0.18	0.00	0.01	0.31	0.45	0.24	-0.62	0.03	-0.10
Log of cleaning services costs	0.15	0.56	0.06	-0.04	0.10	0.15	-0.33	0.26	-0.13	-0.11	0.64
Log of laundry and linen costs	0.20	0.55	-0.14	-0.01	0.00	0.08	-0.04	0.36	0.20	0.28	-0.61
Proportion of untouched meals	0.00	0.01	0.03	0.85	0.47	-0.18	0.08	0.09	0.02	-0.04	0.01

A1. ECONOMIC IMPACT OF THE POLICY

Cost saving on cancelled elective operations. We find that patient choice increases *cancelled elective operations* and this may reflect lower efficiency in the management of the patients. An alternative interpretation is that this is the result of hospital managers implementing strategies to increase the utilisation of operating theatres by booking elective operations closer to full capacity. As a result, any delay in the duration of a surgery (e.g. due to complications) increases the probability that the surgery of other scheduled elective patients is cancelled. Moreover, after the introduction of the patient choice policy and until 2009/10, hospitals received a tariff payment even if the elective operation was cancelled (Cookson et al., 2017). We are however unable to quantify the effect on cancelled elective operations because of the lack of information on the utilisation of operating theatres. More cancelled elective operations may generate also a loss in patient benefits since elective patients will wait more after the cancellation of their operation. Also in this case, however, we have no information to evaluate such a loss.

Cost saving on doctors. The average doctors salary is calculated by averaging the total amount of basic pay over the total amount of worked full time equivalent units using the data available at:

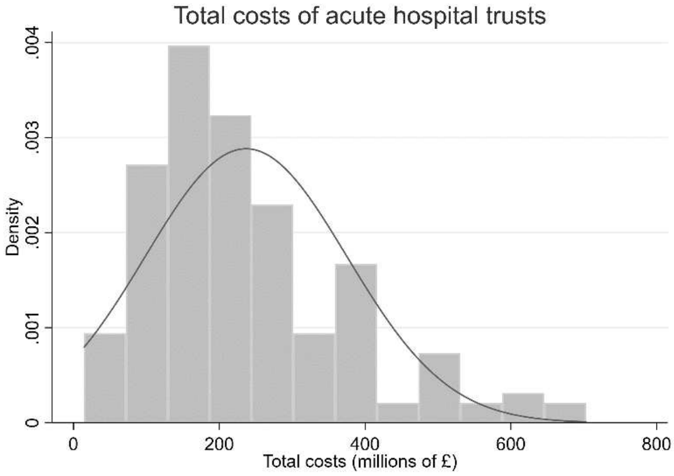
https://digital.nhs.uk/data-and-information/publications/statistical/nhs-staff-earnings-estimates/nhs-staff-earnings-estimates-january-march-2011.

Average cost of day case and elective patients. We calculate the average costs of elective and day case patients using 2010/11 reference costs data at HRG level. These averages are calculated on only those HRG codes that are used to classify both elective and day case patients within each hospital. The costs of elective patients and the number of elective patients averaged across 113,505 HRGs across all hospitals are £24,787 (standard deviation £118,286) and 10 (standard deviation 32), respectively. The costs of day cases and the number of day cases averaged across 118,285 HRGs across all hospitals are £26,027 (standard deviation £118,184) and 39 (standard deviation 175), respectively. The average costs of elective patients are calculated dividing the total costs of elective patients across all hospitals by the total number of elective patients across all hospitals. The total cost of elective patients across all hospitals amounts to £24.8bn and the total number of elective patients across all hospitals is 1.2 million, so the average costs of elective patients are equal to £2,435. Similarly, the average costs of day cases are calculated dividing the total costs of day cases across all hospitals by the total number of day cases across all hospitals. The total cost of day cases across all hospitals amounts to £3.1bn and the total number of elective patients across all hospitals is 4.6 million, so the average costs of day cases are equal to £670.

Cost savings on admissions per bed. We calculate the cost savings due to the effect of the choice policy on *admissions per bed* using the same approach of Section 4.2 (i.e. we calculate the effect at the sample mean using $\beta\bar{M}$, where $\bar{M} = 3.7$). Patient choice increases admissions per bed by 4.1% (0.011×3.7). Given that the choice policy does not affect the number of admissions, admissions per bed may increases because of a reduction in the number of beds. We estimate that patient choice reduces the number of beds by 1.9% (0.005×3.7). The average hospital has 686 beds and, therefore, the choice policy reduces its number of beds by 13 beds (1.9%×686). The cost of a hospital bed as £400 per day according the Department of Health (BBC news, 2017). If 13 beds are occupied in proportion to the average bed occupancy rate (86%) in each day of the year, then the cost saving effect of competition for the average hospital is £1.632m (£400×365×13×0.86). However, the reduction in beds is likely to be due precisely to the increase in the proportion of day cases discussed in Section 4.2. To avoid double counting, we therefore do not include the cost savings that arise from a reduction in beds.

Cost savings on percentage of untouched meals. We calculate the average daily cost of feeding a patient using the Hospital Estates and Facilities Statistics in 2010/11 (which can be found at http://hefs.hscic.gov.uk/DataFiles.asp). Across the 167 acute hospital trusts in 2010/11, such costs are on average £8.29 (standard deviation £2.76) with the lowest and highest cost being £2.57 and £17.46, respectively. In the calculation of cost savings in Section 4.2, we assume that for each untouched meal hospitals serve a replacement meal of a similar cost that better fits patient's preferences. This assumption is likely to hold true because hospitals want to feed patients to speed up their recovery (Jeffrey, 2014), and also to avoid potential greater costs due to compensations for those patients who decide to buy their preferred meal privately (Daily Mail Reporter, 2011).

Average total costs. We calculate the average total costs using reference costs data in 2010/11. Total costs include inpatient, outpatient, and emergency care activity, and the average is calculated across all existing 167 acute hospital trusts in 2010/11. The average of the total costs is £236.7m with a median of £203.7m, which indicates a right-skewed distribution as showed in the figure below. The total hospital costs amount to 39.534bn in 2010/11.



Average number of hospitals. We calculate the average number of hospitals using the Reference Cost Index data for all analysed years because they have the lowest number of missing observations. More precisely, there are 176 acute trusts in 2002/03, 173 from 2003/04 to 2005/06, 171 in 2006/07, 169 in 2007/08 and 2008/09, 166 in 2009/10, and 167 in 2010/11. Hence, there are on average 171 acute hospital trusts from 2002/03 to 2010/11.

A2. PRINCIPAL COMPONENT ANALYSIS

Appendix Table A5 of the Appendix shows the results of a Principal Component Analysis (PCA) on our eleven efficiency indicators. PCA is generally used as a dimensionality-reduction technique because it helps summarise variables that are strongly correlated to each other in a single or few components. The first of the principal components captures the highest proportion of variability across all variables while the last component captures the lowest proportion. PCA shows that the first principal component captures only a relatively small share, i.e. 31%, of the overall variation in the eleven efficiency indicators that we use. A large number of components (up to the first six components) needs to be used to capture 88% of the total variation. This finding is in line with Appendix Table A1 of the Appendix which shows that there exists from low to moderate correlation between our eleven efficiency indicators.

In addition, PCA allows us to further investigate which efficiency indicators may generate higher cost savings. We observe for example that the first component, i.e. the one capturing the largest variability, is moderately correlated with admissions per nurse (47%). This indicates a higher variability in this indicator compared to the other indicators. An increase in admissions per nurse might therefore generate relatively higher savings. Considering the indicators on which competition has a statistically significant effect, proportion of day cases is strongly correlated (70%) with the third principal component, proportion of untouched meals is strongly correlated (85%) with the fourth principal component, cancelled elective operations is correlated (47%) with the seventh principal component, and admissions per doctor is correlated (54%) with the tenth principal components. Hence, savings produced by an increase in proportion of day cases might be greater than those generated by a reduction in untouched meals, cancelled elective operations, and admissions per doctor. Such a result is in line with our evaluation of the cost savings.

A3. COMPETITION, QUALITY AND COST REDUCING EFFORT

Hospital managers choose quality q and effort e to maximise a quasi-altruistic utility function:

$$V(q,e;\theta,b) = u(y(q,e;\theta,b),e) + \alpha h(q)\,, \tag{7}$$

where the hospital's income is:

$$y(q,e;\theta,b) = b + \pi(q,e;\theta) = b + pD(q,\theta) - c(D(q,\theta),q,e)\,, \tag{8}$$

with $D_q>0$, $D_\theta<0$, $D_{q\theta}>0$ and $c_D>0$, $c_q>0$, $c_e<0$. θ is a measure of competition: more competition reduces demand (more rivals serve the same population) and increases the responsiveness of demand to quality. b is exogenous and could be interpreted as a direct grant from commissioners, a lump sum tax or subsidy (or we could get similar results by assuming the hospital is subject to a minimum profit constraint $\pi(q,e,\theta)\geq b$). $h(q)$ is intrinsic utility from quality and is increasing and concave in quality. $\alpha\geq 0$ is the degree of altruism. $u(y,e)$ is increasing in y, decreasing in e and concave and profit is concave in q and e. Additional effort reduces cost and the marginal cost of quality and output ($c_{qe}<0$, $c_{De}<0$).

This note investigates the effect of greater demand responsiveness to quality (θ), which we interpret, in line with the literature, as an increase in competition, on effort and we interpret an increase in e as an increase in efficiency.

First order conditions on quality and effort are:

$$V_q = u_y\pi_q + \alpha h_q = u_y[(p-c_D)D_q + c_q] + \alpha h_q = 0\,, \tag{9}$$

$$V_e = u_y\pi_e + u_e = u_y[-c_e] + u_e = 0\,, \tag{10}$$

and the responses of q and e to an increase in a parameter z ($z=\theta$ or b or p) satisfy:

$$\begin{bmatrix} V_{qq} & V_{qe} \\ V_{eq} & V_{ee} \end{bmatrix}\begin{bmatrix} \partial q/\partial z \\ \partial e/\partial z \end{bmatrix} = \begin{bmatrix} -V_{qz} \\ -V_{ez} \end{bmatrix}, \tag{11}$$

and so:

$$\begin{aligned} \partial e/\partial z &= \Delta^{-1}\left[V_{qz}V_{eq} - V_{ez}V_{qq}\right], \\ \partial q/\partial z &= \Delta^{-1}\left[V_{ez}V_{eq} - V_{qz}V_{ee}\right], \end{aligned} \tag{12}$$

where the determinant $\Delta = [V_{qq}V_{ee} - V_{eq}V_{qe}]>0$ by the concavity of V.

Solving for the effects of an income shock (b) an increase in competition (θ) we have (see table of derivatives overleaf):

$$\partial e/\partial b = \Delta^{-1}\left[V_{qb}V_{eq} - V_{eb}V_{qq}\right], \tag{13}$$

$$\begin{aligned}\partial e/\partial\theta &= \Delta^{-1}\left[V_{q\theta}V_{eq}-V_{e\theta}V_{qq}\right]=\Delta^{-1}\left[\left(V_{qb}\pi_{\theta}+u_{y}\pi_{q\theta}\right)V_{eq}-\left(V_{eb}\pi_{\theta}+u_{y}\pi_{e\theta}\right)V_{qq}\right]=\\ &=\Delta^{-1}\left[\left(V_{qb}V_{eq}-V_{eb}V_{qq}\right)\pi_{\theta}+u_{y}\left(\pi_{q\theta}V_{eq}-u_{y}\pi_{e\theta}V_{qq}\right)\right]= \qquad (14)\\ &=\left(\partial e/\partial b\right)\pi_{\theta}+u_{y}\Delta^{-1}\left[\left(\pi_{q\theta}V_{eq}-\pi_{e\theta}V_{qq}\right)\right].\end{aligned}$$

Thus the effect of greater competition can be decomposed as the sum of an income effect and a substitution effect due to the change in the marginal profitability of effort and quality. Making the usual assumptions that leisure is a normal good (effort is an inferior good) and remembering that $\pi_{\theta} = pD_{\theta}<0$, the income effect of greater competition is to increase effort.

The sign of the substitution effect due to the changes in marginal profitability is the sign of:

$$\pi_{q\theta}V_{eq}-\pi_{e\theta}V_{qq}=\pi_{q\theta}\left[\overset{-}{u_{yy}}\,\overset{+}{\pi_{e}}\,\overset{-}{\pi_{q}}+\overset{+}{u_{y}}\,\overset{+}{\pi_{qe}}+\overset{-}{u_{ye}}\,\overset{+}{\pi_{e}}\right]-\overset{-}{\pi_{e\theta}}\,\overset{-}{V_{qq}} \qquad (15)$$

Even if we assume that $\pi_{q\theta}>0$ so that, if effort is not a choice variable, a pure profit maximiser would increase quality when competition increases, this expression is ambiguously signed. If we assume utility is linear in income and additively separable in income and effort (so that the income effect is zero) the sign of the effect (only a substitution effect) of competition is:

$$\operatorname{sgn}\left(\partial e/\partial\theta\right)=\operatorname{sgn}\left(\pi_{q\theta}V_{eq}-\pi_{e\theta}V_{qq}\right)=\operatorname{sgn}\left(\overset{?}{\pi_{q\theta}}\,\overset{+}{\pi_{eq}}-\overset{+}{\pi_{e\theta}}\,\overset{-}{V_{qq}}\right) \qquad (16)$$

Hence if we assume $\pi_{q\theta} = (p-c_{D})D_{q\theta}-(c_{DD}+c_{qD})D_{\theta}>0$ (competition increases quality holding effort constant) then competition increases effort.

The objective of our model is to highlight the effects that arise from a higher demand responsiveness to quality, captured by the parameter (θ). In our simplified model we do not allow for strategic interaction between hospitals, nor for the entry or exit stimulated by changes in policy. Doing so would complicate the derivation of results (see, for example, Brekke et al., 2011, Gravelle et al., 2016) but would not alter the key insights from the simpler model: the effects policy changes depend on the preferences of providers, especially their degree of altruism, and the properties of their cost functions.

General case: $V = u(y,e)+\alpha h(q)$, $y = b+\pi(q,e)$	*Profit:* $\pi(q,e) = pD(q,\theta) - c(D(q,\theta),q,e)$
$V_{qe} = u_{yy}\pi_e\pi_q + u_y\pi_{qe} + u_{ye}\pi_e$	$\pi_q = (p-c_D)D_q - c_q \leq 0$, iff $\alpha \geq 0$
$V_{qb} = u_{yy}\pi_q \geq 0$ iff $\alpha \geq 0$	$\pi_e = -c_e > 0$
$V_{q\theta} = u_{yy}\pi_q\pi_\theta + u_y\pi_{q\theta} = V_{qb}\pi_\theta + u_y\pi_{q\theta}$	$\pi_{qe} = -c_{eD}D_q - c_{eq} > 0$
$V_{eb} = u_{yy}\pi_e + u_{ey}$	$\pi_\theta = pD_\theta < 0$
$V_{e\theta} = u_{yy}\pi_e\pi_\theta + u_{ey}\pi_\theta + u_y\pi_{e\theta} = V_{eb}\pi_\theta + u_y\pi_{e\theta}$	$\pi_{q\theta} = (p-c_D)D_{q\theta} - (c_{DD} + c_{qD})D_\theta$
	$\pi_{e\theta} = -c_{eD}D_\theta < 0$
Utility linear in income: $u(y,e) = y - f(e) + \alpha h(q)$	
$V_{qe} = \pi_{qe}$	
$V_{qb} = 0$	
$V_{q\theta} = \pi_{q\theta}$	
$V_{eb} = 0$	
$V_{e\theta} = \pi_{e\theta}$	