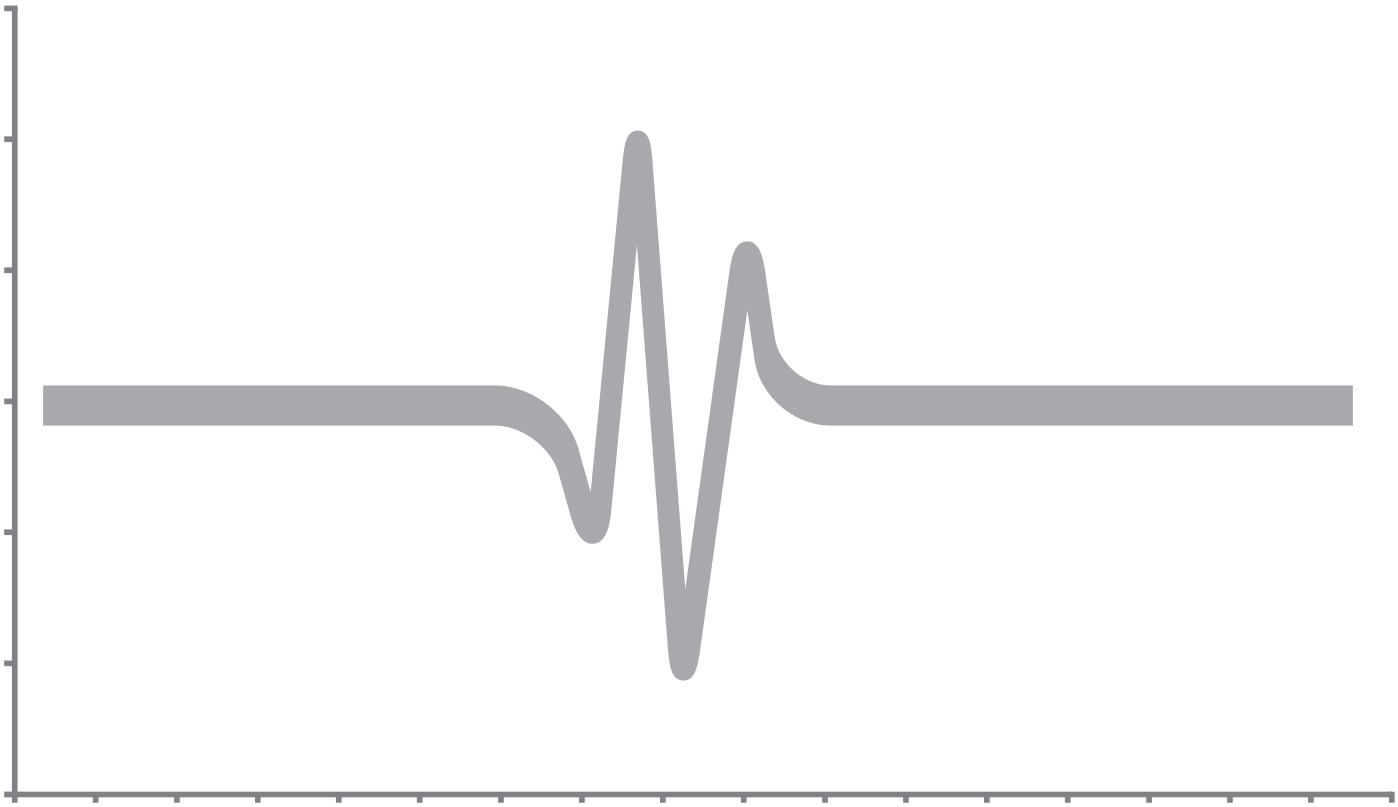
The Health Foundation
Inspiring Improvement

Hospital finances and productivity: in a critical condition?

Technical appendix



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The appendix was produced as part of the work by the Health Foundation on the report *Hospital finances and productivity: in a critical condition?*

For more details, see **www.health.org.uk/publication/hospital-finances-and-productivity-critical-condition**

Technical appendix

1. Introduction

In April 2015, the Health Foundation published *NHS hospital finances and productivity: in a critical condition?*[*] In the report we modelled the productivity of NHS hospitals from 2009/10 to 2013/14 using reference cost data and annual accounts to assess annual change in crude productivity. We also assessed hospital technical efficiency during that period.

We assessed productivity using two methods:

- *Crude productivity analysis*, using an output/input ratio to estimate annual change.
- *Technical efficiency analysis*, using a random effect model to isolate the contribution of efficiency to cost.

We used data from 2009/10 to 2013/14 from the reference cost at provider level to estimate crude productivity. We used data on hospital characteristics from providers' annual accounts to isolate the effect of efficiency in our random effect model.

This technical appendix is aimed at readers with an interest in the technical aspects of health data and econometric modelling. It provides additional details of the methods used for the report. The appendix covers the technical aspects of the complex process we used to assess productivity and technical efficiency in the health care sector.

[*] Lafond S, Charlesworth A, Roberts A. *Hospital finances and productivity: in a critical condition?*. Health Foundation, 2015. www.health.org.uk/publication/hospital-finances-and-productivity-critical-condition

2. Overview of methods

We conducted a short literature review to review productivity analysis that has already been done. We also examined the different methods used to assess productivity and technical efficiency in the health care sector.

We decided to estimate the crude productivity of the acute sector using an output/input ratio to assess annual change in hospital productivity. This approach is similar to methods used by the Office for National Statistics (ONS) to assess healthcare productivity.* See section 3 for details.

We assessed the technical efficiency of hospitals using a random effect model. When analysing panel datasets such as individual hospital cost over time, the most common statistical estimation models are either fixed effects or random effects model. We decided to use a random effects model as it allowed us to estimate the effect of time in-variate explanatory variables. This was of interest in the work on efficiency as we were analysing panel datasets where multiple providers were observed over several years. This is similar to the approach used by Deloitte in their work for Monitor and NHS England.† See section 4 for details.

* ONS Public Service Productivity Estimates: Healthcare, 2012. www.ons.gov.uk/ons/rel/psa/public-sector-productivity-estimates--healthcare/2012/art-healthcare.html

† Deloitte Evidence for the 2015/16 national tariff efficiency factor. Final report 8 July 2014. www.gov.uk/government/consultations/nhs-national-tariff-paymentsystem-201516-engagement-document

3. Crude productivity model

3.1 Model specification

Hospital productivity is estimated by dividing the total amount of acute care activity (output) by the total cost of producing this activity (input).

Productivity = output/ input

Where

- Input = provider's cost adjusted for inflation* and market force factor (MFF)
- Output = provider's cost weighted activity

3.2 Data

We used data from NHS reference cost† at organisational and currency code level for 159 hospitals (acute trusts) where the data was available from 2009/10 to 2013/14.

Input

Acute care input consists of the cost of delivering health care services. The cost was adjusted for inflation using the HM treasury GDP deflator of January 2015 and for variation in the price due to geographical location using the market force factor (MFF). It was calculated by multiplying the unit cost by the volume of activity. The method is described step by step below.

Calculate total cost of provider

- $TC_j = UC * A$

Calculate provider's cost in real terms

- TCj, real terms= $TC * (D_{14/15}/ D_t)$

Calculate provider's cost deflated by MFF

- $C_{mff,\ ij} = TC_{ij} / MFF_j$

Where:

- *TC = Total cost*
- *UC = Unit cost*
- *A = unadjusted activity*
- *D = GDP deflator*
- $D_{14/15}$ *= value of GDP deflator in 14/15*
- *t = Nominal Year*
- $i = HRG_i$
- $j = Provider_j$
- C_{ij} = total cost incurred by provider *j* for HRG_i
- C_{mff} = total cost deflated by MFF

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* Adjusted for inflation using HM Treasury December 2015 GDP deflator www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-december-2014-quarterly-national-accounts

† NHS Reference costs. www.gov.uk/government/collections/nhs-reference-costs

Output

Acute care output consists of an estimate of volume of activity for each hospital. The quantity of delivered health care is cost weighted.

Weight the activity by cost

- $CWA_j = \sum w_i A_{ij}$

Where:

- w = weight
- CWA = Activity weighted by cost
- A= unadjusted activity

Due issue of comparability across years, we decided to select data on acute care activity distinguished by HRG chapters as this data was comparable across the five years studied (2009/10 to 2013/14). Outpatient data was excluded because changes in commissioner reporting affected the measure of outpatient activity in 2011/12 in the reference cost dataset. Input and output of acute care therefore referred to the following hospital activities:

- Elective inpatients
- non-elective inpatients
- A&E
- Day case

Follow-up work on this productivity model will aim to include outpatient data from the Hospital Episode Statistics (HES) dataset.

4. Technical efficiency model

Many factors can affect the cost of providing health care; therefore, to account for cost drivers and isolate variations in cost attributable to efficiency, we ran a random effect model using SAS 7.1 statistical software.

4.1 Model specification

- $\text{Log}(\text{TC}_{ij,\ real\ terms}) = \alpha + \beta_1 \text{Log}(\text{CWA}_{ij}) + \Sigma\beta_2 H + \Sigma\beta_3 P + \Sigma\beta_4 Q$

Where:

- *H:* hospital characteristics
- *P:* patient characteristics
- *Q:* Quality of service

4.2 Data

Dependent variable

The dependent variable of this model is the total acute care cost of the 159 hospitals. The total cost of each provider was calculated using the same technique as for our crude productivity model and was also deflated for MFF and adjusted for inflation.

Independent variables

Variations between hospitals in the cost of providing acute care can be attributed to different characteristics, including providers' characteristics, demographic characteristics and the quality of service provided. We therefore included data on these cost drivers in order to account for cost variations associated with these characteristics.

Hospital's characteristics (including workforce characteristics)

In order to account for variation in cost that account to for the provider's **geographic location** we include the strategic health authority (SHA) code of the provider Factors associated with location, such as price, competition and population density, could account for variation in cost.

We also accounted for the **size and type** of the trusts. Bigger trusts may face diseconomies of scale as they tend to have more complex structures. We categorised the trusts into small, medium, large using the categories provided from the annual accounts.* We also accounted for the emergency activity by including the proportion of total admission for emergency care. Teaching and specialist hospitals were identified using a dummy variable as they may encounter different costs associated with their activity. For example, specialist trusts are thought to have higher cost and treat more complex or severe patients while teaching trusts are likely to spend more on training staff and this extra spend is not reflected in their output.

The **skill mix** of the hospitals was also taken into account. The proportion of medical and dental staff, nurses and supporting staff was observed. Previous studies have found a positive association between labour productivity and medical workforce.

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* Trusts size categories are based on National Reporting and Learning System definitions and are based on the number of beds

We also wanted to see if the proportion of total operating cost that accounts for the finance cost of private finance initiative **(PFI)** had an impact of efficiency so we included this variable in our model. The finance cost associated with PFI payments may constrain trusts financially and hinder productivity. We also wanted to test whether the use of temporary staff was a cost driver as **temporary staff** tends to increase the pay bill so we included the percentage of total staff that is not permanent in our model.

Demographic characteristics

In order to capture difference in patient's characteristics, we included data on age, gender and disease prevalence. It is well evidenced that health care costs rise with age.* **Gender** was also accounted for as female patients may require different type of care which in turn can impact cost. The disease prevalence of the demography where the hospital is located was also accounted for as higher prevalence rate of **morbidity** level would impact efficiency. Data on the prevalence of 14 diseases was obtained from Quality and Outcomes Framework (QOF) (see table below).

QOF disease prevalence	
Stroke	Hypertension
Hyper tension	Epilepsy
Hyperthyroid	Cancer
Mental Health	Heart Failure
Dementia	Chronic Kidney disease
Arterial disease	Learning disease
Cardiovascular disease	Chronic Obstructive Pulmonary Disease (COPD)

Since the disease prevalence data is only available at commissioner level, we mapped the data to acute providers. We calculated a weight equal to the proportion of funding received by the providers from the commissioner and then applied that weight to the commissioner prevalence data to compute provider- specific prevalence rates.

- $F_{cj}/F_j = w$
- $wDP_c = DP_j$

Where

- c = Commissioner
- j = provider
- F_{cj} = funding from commissioner c to provider j
- Fj = total funding that provider j received from commissioners
- w = weight
- DP = Disease prevalence

* Roberts A, Marhall L, Charlesworth A. *A decade of austerity? The funding pressures facing the NHS from 2010/11 to 2021/22*. The Nuffield Trust, 2012. www.nuffieldtrust.org.uk/publications/decade-austerity-funding-pressures-facing-nhs

Proxies for quality of service

Mortality rate is often used as an indicator of quality of service. However, due to lack of data on standardised mortality rate at provider level in 2009/10, we didn't use this as a proxy for quality. Mortality rates can help explain variations between trusts but they are unlikely to change significantly annually at a national level.

We used the patient recorded outcomes measures (**PROMS**) to estimate quality of care outcome. We gathered data on health gains from hip replacement at a provider level for the years studied. This measure estimates the improvement in health status of a patient.

Staff engagement tends to have a positive association with productivity. We wanted to test whether **staff satisfaction** had an effect on productivity so we used the results from NHS staff survey to test for association between efficiency and staff satisfaction. We calculated the proportion of staff who agree or strongly agree with the following two statements of the survey:

- If a friend or relative needed treatment I would be happy with the standard of care provided by this organisation
- I would recommend my organisation as a place to work

Activity

The cost weighted activity was also included in this model as an independent variable. In both models (crude productivity model and random effect model) the activity was cost weighted using the method detailed in section 3 and included the same acute care activities

Table A summarises the data, and sources, that we collected at provider level and tested in our technical efficiency model.

Table A: cost drivers tested in the analysis of hospitals' efficiency

Factor	Data Used
Geographic location	Dummy variables (1 for trusts located in strategic health authority; 0 otherwise) for each strategic health authority
Case mix adjusted activity	Activity weighted based on national average HGR unit cost
Size /type of trusts	Dummy variables (1 for small, medium, large, specialist or teaching; 0 otherwise) for each acute trust type
Gender	Proportion of total admissions for female patients from Hospital Episode Statistics (HES online)
Age	Proportion of finished consultant episodes for patient aged under 14 (HES online)
	Proportion of finished consultant episodes for patient aged over 65 (HES online)
Emergency Admissions	Proportion of total admissions for emergency care (HES online)
Skill mix	Administration staff as a proportion of total staff numbers
	Medical and dental staff as a proportion of total staff numbers
	Nursing, midwifery and health visiting staff as a proportion of total staff numbers
	Health care assistants and other support staff as a proportion of total staff numbers
Percentage of temporary staff	Temporary staff as a proportion of total number of staff
PFI	PFI finance cost as a proportion of total operating cost
Staff satisfaction	Proportion of NHS Staff who strongly agree or agree with the following statement: 'I would recommend my organisation as a place to work' (NHS Staff Survey)
	Proportion of staff who strongly agree / agree with Q12d: 'If a friend or relative needed treatment, I would be happy with the standard of care provided by this organisation' (NHS Staff survey)
Proxy of quality of elective care	Health gains from hip replacement, Patient Reported Outcomes Measures (PROMs)
Disease Prevalence	14 QOF indicators weighted at provider level (prevalence of stroke, hypertension, diabetes, COPD, epilepsy, hyperthyroid, cancer, mental health, heart failure, dementia, chronic kidney disease, arterial disease, leaning disability, cardiovascular disease)

We gathered the data on skill mix, percentage of temporary staff, proportion of total operating cost on PFI, size/ type of the trusts, location based on strategic health authority from provider annual accounts.

Our random effect model only included the factors that were statistically significant at a 95% confidence level. Table B below shows the results of our analysis.

Table B: Summary statistics of variables tested in the analysis of hospitals' efficiency

Variable name	Estimate	Standard Error	t Value
Intercept	16.818	7.218	2.33
Time (average annual change)	-0.004	0.004	-1.04
log of case mix activity	0.885	0.015	58.76
Percentage of female admissions	-0.023	0.001	-22.95
Percentage of patients aged over 75	-0.011	0.001	-10.62
Proportion of staff who are medical or dental staff	0.165	0.291	0.57
Percentage of staff who are health care assistants and other support staff	0.556	0.106	5.24
Emergency admissions as a proportion of total admissions	-0.006	0.001	-8.67
Percentage of nurses who are qualified nurses	1.047	0.115	9.1
Staff survey friends and family question	-0.33	0.115	-2.87
London	0.049	0.021	2.38
South West	-0.043	0.02	-2.2
Yorkshire and the Humber	-0.03	0.02	-1.51
East Midlands	0.037	0.025	1.46
West Midlands	0.029	0.019	1.53
East of England	-0.01	0.021	-0.48
South East	0.034	0.022	1.53
South Central	0.038	0.025	1.52
Large Acute trusts	0.072	0.019	3.71
Medium acute trusts	0.032	0.016	2.05
Acute teaching hospitals	0.159	0.024	6.74

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