

A perfect storm: an impossible climate for NHS providers' finances?

Technical appendix



This appendix was produced as part of the work by the Health Foundation on the report
A perfect storm: an impossible climate for NHS providers' finances?



For more details, see www.health.org.uk/perfectstorm

1. Introduction

In March 2016, the Health Foundation published *A perfect storm: an impossible climate for NHS providers' finances?* In the report, we modelled the factors associated with financial performance of acute and specialist trusts in 2014/15. We identified these factors using a multivariate regression model and used data from providers' annual accounts and other publicly available sources.

This technical appendix is provided for those with an interest in the technical aspects of health data and econometric modelling. It provides additional details of the methods we used in the report.

2. Overview of methods

We examined factors associated with financial performance using a multivariate regression model.

We constructed the model to identify the variables that are statistically significant determinants of financial performance. The model was run using SAS 7.1 statistical software, using the stepwise function to select the final model.

Model specification

$$Y = \alpha + \sum \beta_1 H + \sum \beta_2 Q + \sum \beta_3 S + \sum \beta_4 E$$

Where:

Y: net adjusted deficit/total operating cost

H: hospital characteristics

Q: Quality and safety of care

S: Staff satisfaction

E: Effectiveness and best practice

Data

Dependent variable

The dependent variable of this model is the net adjusted deficit before impairments as a percentage of the total operating cost of 151 acute and specialist trusts. This is the variable used by both Monitor and NHS Trust Development Authority^{1*} to measure financial performance.

Independent variables

Trust characteristics

We examined variables that are specific to a trust to see if certain trusts' characteristics might be associated with the financial position of a provider.

* From 1 April 2016, both Monitor and NHS Trust Development Authority became part of NHS Improvement.

Acute and specialist trusts were distinguished using a dummy variable, as were trusts that have achieved foundation status. This was to account for difference in case mix, and heterogeneity in funding mechanisms. For example, specialist trusts are thought to have higher costs and different financial pressures than acute trusts as they treat more complex or severe patients and are often directly funded through NHS England.

Trust size, by number of sites, was taken from the patient-led assessments of the care environment (PLACE) data.² It was included in the model to test whether bigger trusts face diseconomies of scale due to their complex structure. We only included total number of hospital sites that had more than five beds.

We also examined the **cost profile** of each trust by including:

- total spend on agency staff as a proportion of total staff cost
- total spend on drugs as a percentage of total staff cost
- value of the reference cost index (an indicator of the cost of providing care)
- private financial initiative (PFI) cost.

To examine PFI cost we first ran the analysis using a continuous variable: PFI cost as a proportion of total operating cost. Not all trusts have PFI costs, so we also tested this as a dummy variable where 1 refers to trusts having a PFI cost.

We accounted for differences in **activity** by including the cost ratio between elective cost and non-elective cost and between inpatient and outpatient cost and the percentage of beds occupied. The cost ratio was calculated using HES data³ at provider level for 2013/14 as it is the latest year available. The percentage of occupied overnight beds for the period of January to March 2015 was used. The data are collected quarterly and we chose the quarter when hospital utilisation is usually the highest.

We also wanted to see if there was an association between the financial performance of commissioners and providers so we created a dummy variable and distinguished between providers with a CCG reporting a net deficit and those with a CCG reporting a net surplus.

We also examined whether having a permanent or temporary chief executive – and the length of stay of the chief executive – was associated with the financial performance of the trust by including variables on employment status of the chief executive. We included dummy variables for trusts with an interim chief executive and those with a chief executive in a permanent position for more than 1 year and less than 1 year.

Staff satisfaction

In order to identify association between financial performance and staff satisfaction, we used staff survey questions as indicators of staff satisfaction. Table A shows the questions from the NHS Staff Survey 2014⁴ that we considered. In each case we tested for an association between staff dissatisfaction, as described in Table A, and the financial position of a trust.

Table A: Questions in the NHS staff survey 2014

Question number	Question	Value used
Question 12.d	If a friend or relative needed treatment I would be happy with the standard of care provided by this organisation	% of employees strongly disagree or disagree
Question 9.a	Do the following statements apply to you and your job: I am satisfied with the quality of care I give to patients / service users	% of employees strongly disagree or disagree
Question 21	In the last 12 months how many times have you personally experienced harassment, bullying or abuse at work from... a) Patients / service users, their relatives or other members of the public b) Managers / team leaders or other colleagues	% of employees who answered yes to at least one statement
Question 16	During the last 12 months have you felt unwell as a result of work-related stress	% of employees who answered yes

Quality and safety of care

To assess whether quality and safety of care was associated with financial performance we used the Care Quality Commission (CQC) ratings as of May 2015 as proxies. The CQC inspect hospitals and give them a rating of ‘Outstanding’, ‘Good’, ‘Improvement required’ and ‘Inadequate’. We therefore created a dummy variable for each of these categories and one for trusts that had not yet been inspected.

We also assessed access to care by using referral-to-treatment waiting time and including the percentage of completed pathways admission within 18 weeks as of January 2015.⁵ We also used cancer waiting time by including the percentage of cancer patients treated within 62 days for quarter 3 of 2014/15.⁶ The data on the referral-to-treatment waiting time was missing for six trusts so we imputed the average. Similarly, we imputed the average cancer waiting time for five trusts in our dataset because the data was missing. None of these variables were found to be statistically significant in our model.

Effectiveness and best practice

Effectiveness and best practice was assessed using the better care better value (BCBV) indicators and the presence of an e-rostering system. BCBV indicators identify potential areas for improvement in efficiency. They include the following:⁷

- Managing first follow up (First follow up ratio)
- Reducing length of stay (Bed day saving %)
- Emergency readmission (14 day) (Emergency readmissions %)
- Outpatient appointment did not attend (DNA) (DNA %)
- Pre-procedure non-elective bed days (Pre-procedure bed day rate)
- Increasing day surgery rates (Daycase rate %)
- Pre-procedure elective bed days (Pre-procedure bed day rate)
- Sickness absence (FTEs lost to sickness absence %).

The value of the provider at the 50th percentile of each variable was used, except for length of stay and sickness absence variables where the value of the 25th percentile was used for data availability reasons. This provides estimates of potential savings that would be achieved if all providers operating below the 50th percentile (or the 25th percentile) improved to match that value. To avoid issue of multicollinearity we did not include all the BCBV variables in the final model; those excluded are discussed later. The data for quarter 4 of 2014/15 was used. Sickness absence was excluded from the analysis due to data availability issues.

We also tested the presence of an e-rostering system as it was associated with good practice after a review by Lord Carter of Coles of operational productivity in NHS acute providers.⁸ E-rostering systems are meant to improve efficiency by improving workforce planning and rostering. We created three categories to identify providers where there is an e-rostering system in place, where there is not and where the information is not available.

Table B (overleaf) provides a summary of all the variables tested, including those described above.

Table B: Summary of the variables used and the source of the data

Variables	Data used	Rationale
Specialist vs acute	Dummy variables (1 if specialist trust, else 0)	Specialist trust receive a higher share of income from direct commissioning that from CCGs compared to acute trusts
FT vs non-FT	Dummy variables (1 for FT, 0 for NHS/non-FT trusts)	Foundation trusts have different degree of independence from DH compares NHS trusts
Geographical size of trust	The total number of hospital sites was used as a proxy for the size of the trust	Control for regional differences due to different health economies.
Tariff income	Dummy variable for proportion of tariff income above mean	The national tariff has fallen in real terms in recent years, trusts who receive a greater share of their income from national tariff payments may therefore be more affected result in a worse financial position.
Agency staff	Agency staff cost as a proportion of total staff cost	Examine if hospitals spending more on agency staff paid at higher rate is associated with different financial performance
Drug cost	Drug cost as a percentage of total operating cost	Drug cost have increased rapidly in recent years examine if hospitals spending more on drug cost is associated with different financial performance
Private financial initiative (PFI) cost	Dummy variables (1 if the trusts have a PFI cost, else 0)	Test whether cost incurred by PFI is associated with financial performance
Reference Cost Index	value of the reference cost index	Test whether the complexity of activity provided by a trusts is associated with financial performance
Financial performance of commissioner	Dummy variables (1 if the trust's major CCG reported a net surplus, 0 if the trust's major CCG reported a net surplus)	Examine if trusts with CCG in deficit more likely to be in deficit

Variables	Data used	Rationale
Bed days occupied	Percentage of overnight beds occupied	Measure if capacity is associated with financial performance
Access to services	<ul style="list-style-type: none"> Percentage of referral to treatment within 18 weeks Percentage of cancer patients treated within 62 days 	Examine if performance on quality indicators associated with financial performance.
Staff satisfaction	<p>Staff survey questions:</p> <ul style="list-style-type: none"> During the last 12 months have you felt unwell as a result of work related stress In the last 12 months how many times have you personally experienced harassment, bullying or abuse at work from your manager If a friend or relative needed treatment I would be happy with the standard of care provided by this organisation 	Examine if financial performance is associated with more satisfied staff
Provider activity characteristics	<p>cost ratio between elective cost and non-elective cost</p> <p>cost ratio between inpatient cost and outpatient cost</p>	Test for relationship between different activity profiles and financial performance
Chief executive length of stay	<p>Dummy variables 1 if chief executive was there for less than a year</p> <p>Dummy variables 1 if chief executive is interim</p> <p>length of stay of chef executive as of March 31,2015</p>	Good leadership is often associated with better performance
Quality and safety of care provided	<p>dummy variables on CQC ratings:</p> <ul style="list-style-type: none"> if rated "outstanding" then 1 else 0 if rated "Good" then 1 else 0 if rated "Improvement" then 1 else 0 if rated "Inadequate" then 1 else 0 if "not inspected" then 1 else 0 	Is financial performance associated with quality of service provided?

Variables	Data used	Rationale
Providers' effectiveness and best practice	<p>Better Care better value (BCBV) indicators included:</p> <ul style="list-style-type: none"> • rate of pre-procedure elective bed day • percentage of bed day saving • percentage of DNA • percentage of day case <p>Delayed transfer of care as of January 2015</p> <p>e-rostering system : 3 categorical variable was created to assess is the trusts has a</p> <p>e-rostering system in place: e-rostering Yes, No and no data available</p>	<p>Are trusts performing better financially also performing better on BCBV indicators and have better practice?</p>

Multicollinearity diagnostics test

A common problem in the use of multivariate regression model is the presence of collinearity* between variables. Including many variables that are highly correlated can have adverse effect on the regression coefficient in the model. To mitigate this issue, we first identified pairwise correlations between variables and then ran a regression model using all predictors of net deficit, requesting a collinearity diagnostics in SAS. The results of the collinearity diagnostics are summarised in Table C.

We found correlation between BCBV indicators. We found collinearity between follow up and day surgery rates and between elective bed day rate and non-elective bed day rate. Since these variables were used to assess providers' efficiency, we removed one of the variables that were correlated. We chose to exclude follow up ratio and the non-elective bed day rate in the model.

Within staff survey we found correlation between questions on whether employees experience harassment/bullying/abuse at work from patients (question 21a) and colleagues (question 21b) and between the question on friends and family (question 12d) and work-related stress (question 16). We decided to only include questions 21b and 12d as all the staff survey questions were used to measure staff satisfaction. The question on providing the level of care that one aspires to (question 9c) was also excluded as it was correlated with question on work-related stress (question 16) and friends and family recommendation (question 12d).

We found a correlation between agency as a proportion of total staff cost and 'Inadequate' CQC rating, but decided to include both variables in the model as the effect between the two could not be distinguished. After running a collinearity diagnosis test we found that the tolerance value of 'Inadequate' rating equals 68%, which means that 68% of variation in rating is not explain by other variables in the model. The variance analysis shows a low value (below 5), meaning low collinearity between the two variables. Consequently, we decided to include both variables in the model.

* In statistics collinearity exist when two or more variables in a model can be linearly predicted from the others with a substantial degree of accuracy

Table C: Results of collinearity test

Parameter estimates							
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t 	Tolerance	Variance Inflation
Intercept	1	0.08033	0.07681	1.05	0.2977	.	0
NHS	1	0.00621	0.00754	0.82	0.4116	0.441	2.26757
Size	1	0.000231	8.4E-05	2.75	0.0069	0.77634	1.2881
Agency cost	1	-0.37252	0.09428	-3.95	0.0001	0.5371	1.86184
eRostering, yes	1	-0.00211	0.00647	-0.33	0.7443	0.63619	1.57187
eRostering, no	1	0.00216	0.01109	0.19	0.8459	0.63375	1.57792
Drug cost	1	-0.09457	0.06782	-1.39	0.1657	0.53775	1.8596
RCI	1	-0.00028	0.000329	-0.85	0.3971	0.54152	1.84667
Specialist	1	0.03229	0.01577	2.05	0.0427	0.20866	4.79239
Tariff income	1	-0.01284	0.00624	-2.06	0.0418	0.59745	1.67377
Percentage of beds occupied	1	0.03119	0.04437	0.7	0.4834	0.57424	1.74143
Waiting time target	1	-0.03405	0.0465	-0.73	0.4654	0.70156	1.42539
Cancer waiting time target	1	-0.02517	0.02693	-0.93	0.3518	0.788	1.26904
Staff Survey question 12	1	0.000967	0.00314	0.31	0.7586	0.63104	1.58469
Staff Survey question on friends and family	1	-0.00087	0.000539	-1.62	0.1086	0.5747	1.74003
Cost Ratio of elective and non-elective care	1	0.00344	0.00252	1.36	0.1753	0.54659	1.82951

Parameter estimates							
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t 	Tolerance	Variance Inflation
Inpatient outpatient cost ratio	1	-0.00615	0.00298	-2.07	0.0407	0.6542	1.5286
Chief executive in post for less than a year	1	-0.00377	0.0127	-0.3	0.7671	0.80068	1.24894
Chief executive in post for more than a year	1	0.01045	0.01023	1.02	0.3092	0.25434	3.93167
Interim chief executive	1	0.00455	0.01078	0.42	0.6735	0.34436	2.90398
Outstanding CQC rating	1	0.0101	0.03133	0.32	0.7476	0.88378	1.1315
Good CQC rating	1	0.00788	0.00895	0.88	0.3805	0.79588	1.25647
Improvement CQC rating	1	-0.00278	0.00648	-0.43	0.6693	0.68613	1.45744
Inadequate CQC rating	1	-0.01995	0.01313	-1.52	0.1313	0.65951	1.51628
Length stay (BCBV)	1	0.000315	0.00229	0.14	0.8908	0.67547	1.48044
Elective bed day rates (BCBV)	1	0.00931	0.01088	0.86	0.3937	0.82126	1.21764
Outpatient appointment (BCBV)	1	-1.1E-06	0.00102	0	0.9992	0.73314	1.36399
Day surgery rates (BCBV)	1	-0.00024	0.000251	-0.96	0.3412	0.55688	1.79572
Emergency readmission (BCBV)	1	0.00225	0.00207	1.09	0.2794	0.55315	1.80783

Table D provides the summary statistics of the variables included in the model.

Table D: Summary statistics of variables used in the model

Simple Statistics						
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
NHS	151	0.35099	0.47887	53	0	1
Size	151	41.50993	32.36497	6268	2	166
Agency cost	151	0.07162	0.03468	10.815	0.00883	0.18646
PFI	151	0.461	0.50009	70	0	1
eRoosting yes	151	0.68874	0.46455	104	0	1
eRoosting no	151	0.07947	0.27137	12	0	1
proportion of drug cost	151	0.04594	0.04819	6.93665	0	0.26393
RCI	151	99.83405	9.90058	15075	80.68587	145.02122
Specialist	151	0.12583	0.33276	19	0	1
tariff_mean	151	0.56954	0.49679	86	0	1
Percentage of bed occupied	151	0.87313	0.07128	131.8428	0.5771	0.998
Waiting time target	151	0.8862	0.06153	133.81608	0.63451	1
Cancer waiting time target	151	0.83447	0.10026	126.00433	0	1
Staff survey question 12	151	2.57971	0.96063	389.53665	0.5571	5.47445
Staff survey question on friends and family	151	15.19339	5.86409	2294	4.9505	35.96856
Cost Ratio of elective and non-elective care	151	0.54352	1.28451	82.07117	0.09371	14.07255

Simple Statistics						
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
Inpatient outpatient Cost Ratio	151	3.316	0.9957	500.71562	0.98815	7.40908
Chief executive in post for less than a year	151	0.04636	0.21096	7	0	1
Chief executive in post for more than a year	151	0.68874	0.46455	104	0	1
Interim chief executive	151	0.17219	0.3788	26	0	1
Outstanding CQC rating	151	0.00662	0.08138	1	0	1
Good CQC rating	151	0.09934	0.30011	15	0	1
Improvement CQC rating	151	0.27152	0.44623	41	0	1
Inadequate CQC rating	151	0.05298	0.22474	8	0	1
Length Stay (BCBV)	151	13.74771	1.2733	2076	9.18084	16.92383
Elective bed day rates (BCBV)	151	0.22981	0.24305	34.70149	0	2.43451
Outpatient appointment (BCBV)	151	7.96006	2.74328	1202	0	21.07103
Day Surgery Rates (BCBV)	151	78.50276	12.77045	11854	0	98.90678
EmerReadmin	151	5.324	1.55711	803.92475	0.60751	11.89731

After carefully selecting which variables to include in the model, a multivariate regression was run in SAS using the stepwise option to identify the variables that are statistically significant at a significance level of 0.10. Table E summarises the results of our model.

Table E: Results from the multivariate regression model of variable that were statically significant at a 95% confidence level

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	0.01794	0.01004	0.0026	3.2	0.0759
Specialist	0.02635	0.00788	0.00911	11.19	0.0011
Total parent sites	0.000268	7.58E-05	0.01022	12.55	0.0005
Agency cost	-0.37047	0.07524	0.01975	24.24	<.0001
Tariff income	-0.014	0.00496	0.0065	7.98	0.0054
If a friend or relative needed treatment I would NOT be happy with the standard of care provided by this organisation	-0.00098	0.000432	0.00422	5.19	0.0242
Inadequate COC rating	-0.02132	0.01129	0.0029	3.57	0.061

The stepwise option allowed us to identify variables associated with net deficit at a significance level of 0.10 and remove any insignificant variables from the model before adding a significant variable.⁹ Table F summarises the results of the stepwise selection process.

Table F: Summary of stepwise selection process

Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	Agency cost		1	0.2827	0.2827	33.7398	58.74	<.0001
2	Specialist		2	0.0577	0.3405	21.1946	12.95	0.0004
3	Parent sites		3	0.0498	0.3903	10.6481	12	0.0007
4	Tariff income		4	0.0275	0.4177	5.7203	6.89	0.0096
5	Staff survey		5	0.0286	0.4463	0.5213	7.48	0.007
6	Inadequate CQC rating		6	0.0134	0.4597	-0.8504	3.57	0.061

Figure A shows residual plots of the whole model. Figure B (shows the residual plots of the significant variables versus the predicted value (net deficit). It shows the distribution of the dependent variables and its relationship with the independent variable (net deficit). Overfitting can occur, especially in a small sample size. However, Figures A and B show that the data seems randomly dispersed around the horizontal axis.

Figure A: Residual plots of the dependent variables

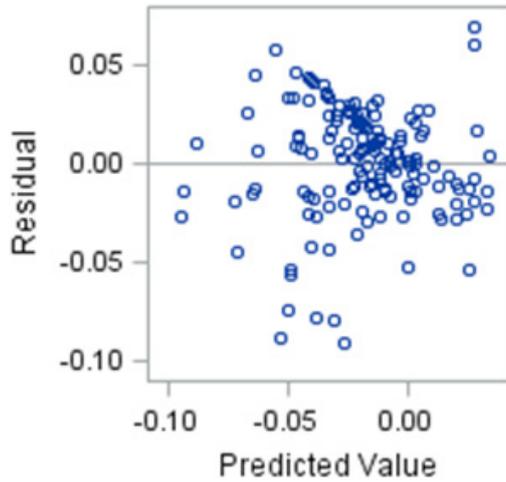
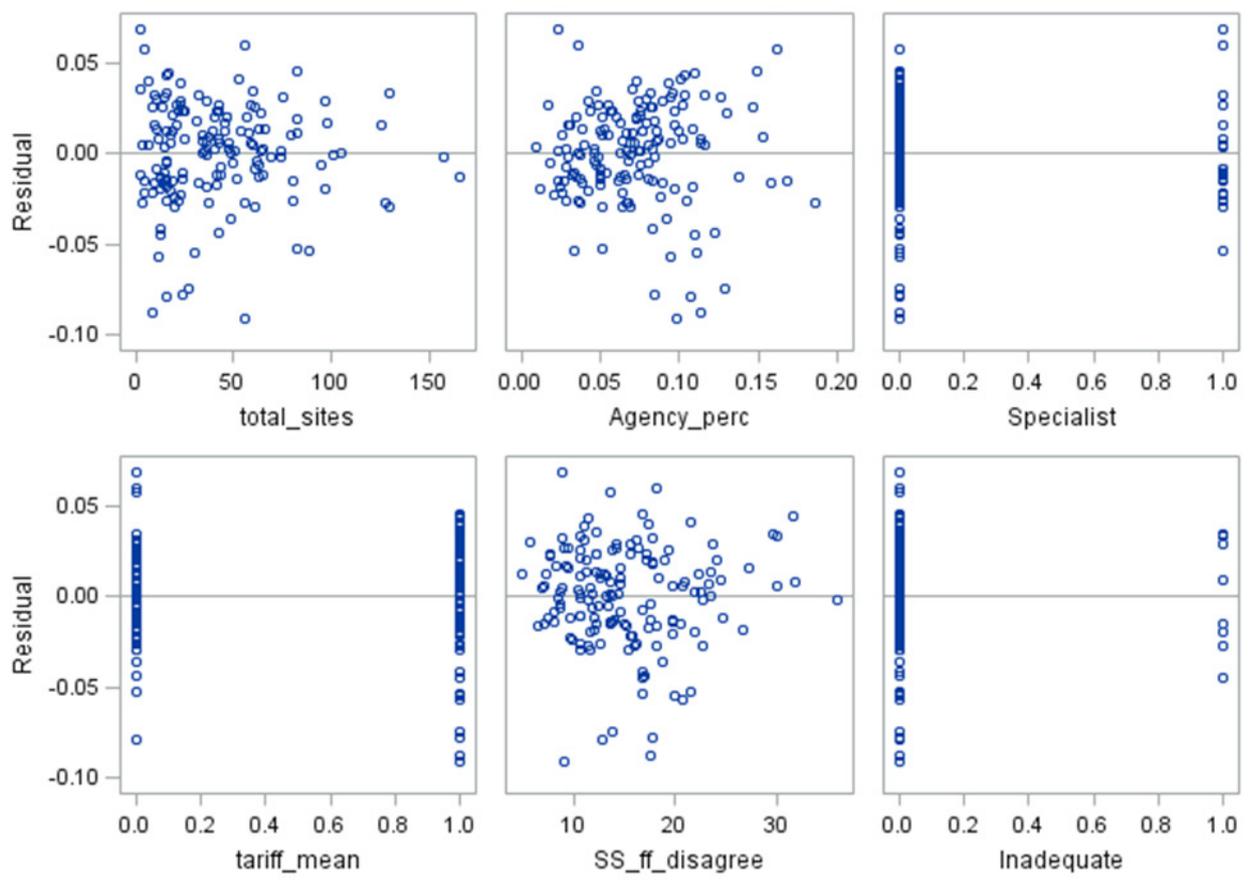


Figure B: Residual plots of significant variables



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