model allows us to separate out the effect of patient area deprivation from the effect of hospital location and any other hospital characteristics correlated with patient area deprivation. In contrast, the random effects model combines the two effects. So in what follows we focus on the results from OLS fixed effects model 2, which yields similar results and is more amenable to standardization than the non-linear GLM model.

In fixed effects model 2, after controlling for patient characteristics (age, sex, number and type of diagnoses, uncemented procedure or not) and hospital fixed effects, patients from the least deprived tenth of areas on average stay 0.9 days less than patients attending the same hospital from the most deprived tenth of areas in 2001/2. This is smaller than the corresponding 1.5 day unadjusted gap between most and least deprived decile groups in Table 3. Since we control for hospital heterogeneity, this gap can be interpreted as the within hospital difference in length of stay as opposed to the global difference within the population reported in Table 3.

The gap in length of stay between most and least deprived decile groups rises slightly to 1.0 days in random effects model 1. Estimates from model 1 are influenced by variation between hospitals, as well as variation between patients, and so this suggests that Hospital Trusts with above-average lengths of stay tend to admit a slightly above-average proportion of income deprived patients – an issue explored further below.

Age group and diagnosis group remain substantially more powerful determinants of length of stay after adjusting for other factors. In fixed effects model 2, the adjusted length of stay gap between patients aged 85 and over and patients aged 45-54 in 2001/2 is 7.74 days (slightly lower

than the unadjusted gap of 8.39 days), and the adjusted gap between patients with 7 or more diagnoses and one diagnosis is 7.18 days (slightly higher than the unadjusted gap of 7.00 days).

In sensitivity analysis, there were no significant, substantial or systematic interactions between age and deprivation or between diagnosis group and deprivation.

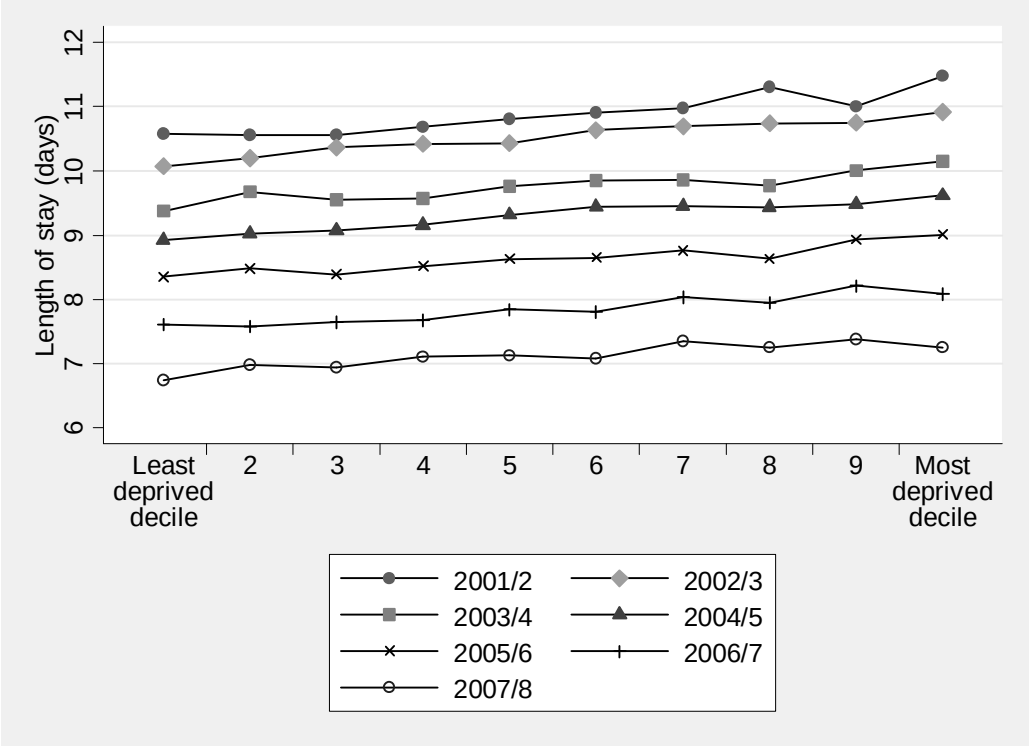

Figure 2: Adjusted mean length of stay by small area income deprivation decile group by financial year from 2001/2 to 2007/8 (standardised for other patient covariates and hospital fixed effects using model 2 stratified by year)

Figure 2 shows mean length of stay by deprivation group and year after adjusting for age, number and type of diagnoses, procedure type, and hospital level factors using fixed effects model 2 stratified by year from 2001/2 to 2007/8. The lines show a shallow adjusted gradient in length of stay from first to tenth income deprivation groups, for each of the years. The lines also

illustrate the persistent year-on-year falls in length of stay throughout the period, each one of which is larger than the corresponding year's length of stay gap between most and least deprived decile groups. That is, for any given year, the average difference in length of stay between most and least deprived decile groups is smaller than the average difference in length of stay between this year and next.

Table 7: Adjusted length of stay differentials by year (standardised for other patient covariates and hospital fixed effects using model 2 stratified by year)

	2001	2002	2003	2004	2005	2006	2007
(1) Most deprived decile	11.43	10.90	10.15	9.61	9.01	8.08	7.25
(2) Others	10.81	10.46	9.70	9.24	8.58	7.79	7.13
Gap: (1)-(2)	0.62	0.44	0.45	0.37	0.43	0.29	0.13
Ratio: (1)/(2)	1.06	1.04	1.05	1.04	1.05	1.04	1.02
(1) age 85 and over	16.62	15.62	14.87	14.88	13.82	12.45	11.81
(2) Others	10.56	10.25	9.50	9.01	8.33	7.55	6.89
Gap: (1)-(2)	6.06	5.37	5.37	5.87	5.48	4.89	4.92
Ratio: (1)/(2)	1.57	1.52	1.56	1.65	1.66	1.65	1.71
(1) 7 diagnoses or more	16.96	17.36	15.98	14.15	14.01	12.55	11.91
(2) Others	10.73	10.33	9.56	9.09	8.39	7.57	6.88
Gap: (1)-(2)	6.23	7.02	6.42	5.06	5.62	4.99	5.03
Ratio: (1)/(2)	1.58	1.68	1.67	1.56	1.67	1.66	1.73

Table 7 shows adjusted length of stay differentials by year, for deprivation, age and co-morbidity using fixed effects model 2. Unlike the figures in Tables 3, 4 and 5, these adjusted figures allow for correlations between deprivation, age, co-morbidity and systematic differences between hospitals. For example, deprivation differentials in Table 7 show the gap in average length of stay between the most deprived decile and others after purging heterogeneity in age, sex, number and type of diagnoses and hospital of admission across the two groups. This is the difference in length of stay that one would observe had all the other differences due to confounding characteristics (i.e. age, sex, number and type of diagnoses and hospital of admission) been

removed. So, for example, trends in Table 7 allow for the fact that deprived and elderly people may also tend to have more diagnoses – and attempt to identify a "purer" association purged of the influence of these other factors.

These adjusted figures show that patients in the most deprived decile group stay about 6% longer than other patients in 2001/2, falling to 2% longer by 2007/8. Whereas patients aged 85 or over stay 57% longer than patients aged 45-54 in 2001/2, rising to 71% longer in 2007/8. And patients with seven or more diagnoses stayed 58% longer in 2001/2, rising to 73% longer by 2007/8. In each case, of course, the absolute length of stay differentials fell over time in line with the general year-on-year fall in length of stay.

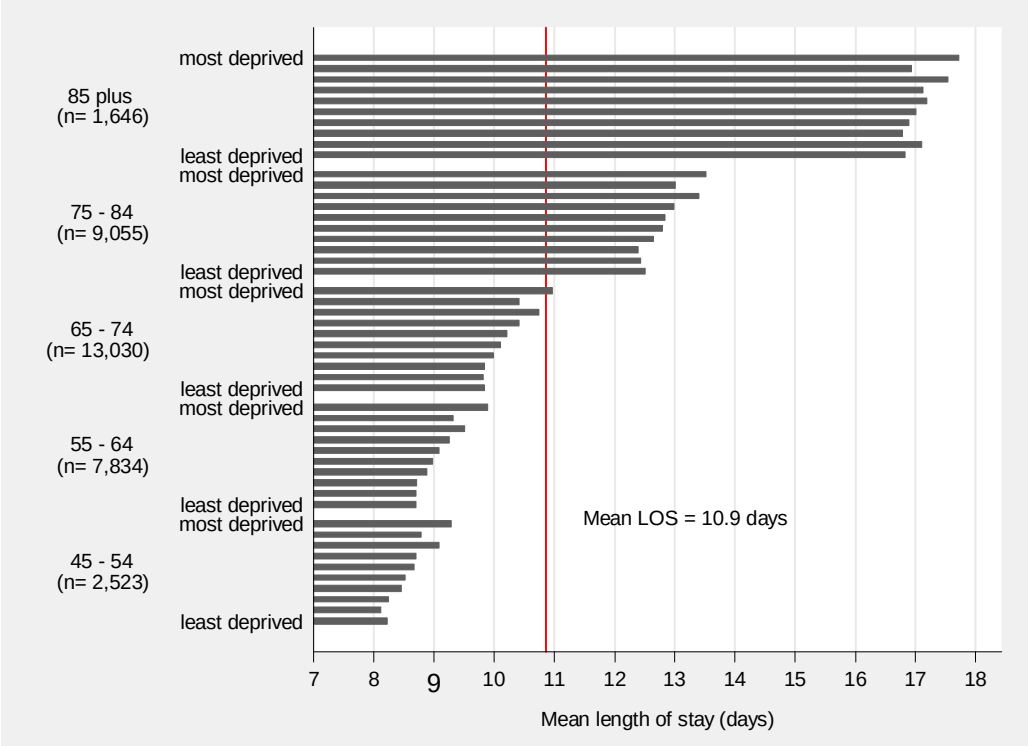

Figure 3: Predicted mean length of stay by age group and deprivation decile in 2001/2 (predictions from model 2)

Figures 3 and 4 present predictions from fixed effects model 2 in 2001/2. Figure 3 shows the relationships between length of stay, age group and income deprivation decile. Although there is a deprivation gradient in length of stay within each age group, this gradient is dwarfed by the larger differences between age groups.

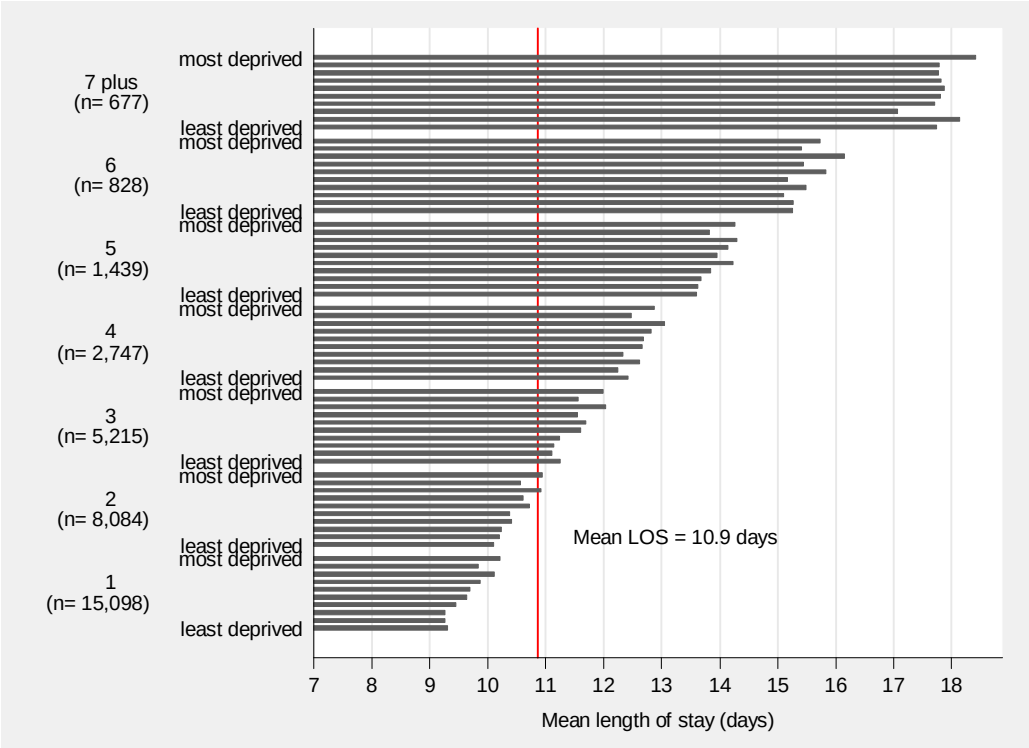

Figure 4: Predicted mean length of stay by number of diagnoses and deprivation decile (predictions from model 2)

Figure 4 shows the predicted relationships between length of stay, number of diagnoses and deprivation decile group. Again, the deprivation gradient within each diagnosis group is dwarfed by the larger differences between diagnoses groups.

Table 8: Patient level versus hospital level variance in length of stay

	2001	2002	2003	2004	2005	2006	2007
Model without patient characteristics							
Proportion of variance at hospital level	5.2%	4.2%	5.2%	4.8%	4.3%	4.0%	4.1%
Patient level (within hospitals) variance	33.14	34.04	30.78	33.01	30.99	26.31	24.81
Hospital level (between hospitals) variance	1.83	1.50	1.70	1.66	1.39	1.10	1.05
Model with patient characteristics							
Proportion of variance at hospital level	4.8%	4.8%	5.8%	5.1%	4.8%	4.2%	4.5%
Patient level (within hospitals) variance	27.39	28.15	25.55	27.56	25.72	21.66	20.22
Hospital level (between hospitals) variance	1.39	1.42	1.57	1.49	1.29	0.95	0.96
Note 1: Estimates were obtained from the RE OLS model described in Table 6. The model was estimated separately each year on a balanced panel of 129 hospitals which were not involved in mergers during 2001-2007.							
Note 2: LR test rejects the null hypothesis that the between hospitals variance is zero.							

Table 8 presents a decomposition of the total variation in length of stay into within and between hospital variance. This table contains predictions from model 1 estimated over a subgroup of 129 hospitals which do not change over the period considered (i.e. a balanced panel of hospitals not affected by mergers or reconfigurations). Focusing on a balanced panel allows us to provide consistent figures for the variance partition over time. Table 8 shows that the proportion of the variance at hospital level is small (i.e. from 5.2% in 2001/2 to 4.1% in 2007/8), before and after controlling for patient characteristics. This suggests that a large part of the variation in length of stay is due to the characteristics of the patients treated rather than the characteristics of the hospitals where they are treated. Table 8 also shows a modest but progressive decrease in the hospital level variation in length of stay over time. The hospital level variance gives an indication of the size of the differences in length of stay attributable to hospital level variation, which can be compared with the differences attributed to patient level covariates such as area deprivation, age and co-morbidity. After controlling for patient covariates, the hospital level

variance in 2001 is 1.39 days, which implies a hospital level standard deviation of about 1.18 days (the square root of 1.39).

Hospital level variance seems to be affected by the inclusion of patient level characteristics in the model. This can be considered as further evidence that some of the patient level and hospital level characteristics are correlated resulting in misspecification of the random effects model if such hospital level characteristics are not included in the model.

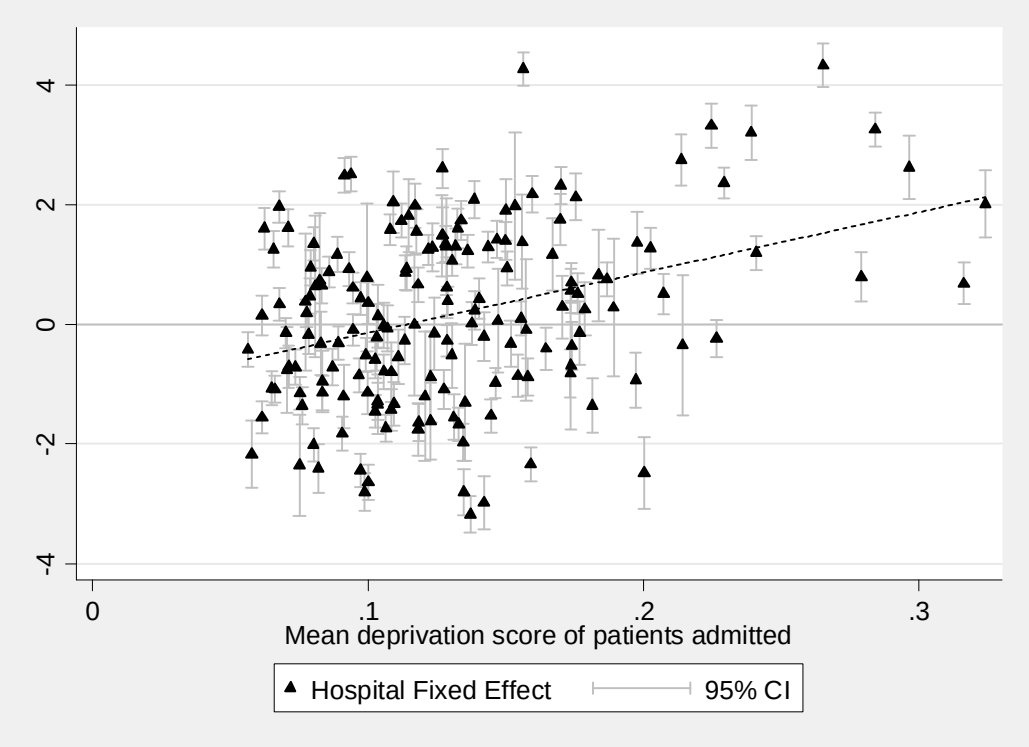

Figure 5: Residual association between hospital level mean length of stay and mean deprivation score of patients after controlling for patient characteristics (predictions from model 2)

Finally, figure 5 presents a scatterplot of the hospital fixed effects estimated from model 2 against the mean deprivation score of patients treated by each hospital. In this case, we assign a fixed intercept to each hospital and exclude the constant term from the model. The fixed effects

can be interpreted as hospital level differences in mean length of stay from the population average length of stay in 2001 after controlling for deprivation and other patient characteristics. There is evidence of a positive hospital level association, suggesting that hospitals treating more deprived patient populations tend to have longer lengths of stay, even after allowing for the composition of their patient populations.

Discussion

On average, NHS elective hip replacement patients living in more income deprived areas of England do stay slightly longer in hospital than patients living in less income deprived areas. However, this association is small. Age and co-morbidity are considerably more powerful determinants of length of stay for elective total hip replacement than small area deprivation.

This is clearly illustrated in Table 7, which compares patients with the relevant "high risk" characteristic (i.e. age over 85, seven or more diagnoses, and the most deprived tenth) with all other patients, after purging the influence of other patient and hospital factors. This is perhaps the most appropriate comparison for an unscrupulous hospital manager interested to know how large a saving in length of stay could be made by selecting against (or "dumping") patients with that particular "high risk" characteristic and instead treating other patients. After purging the influence of other factors, patients over 85 stayed 6.06 days longer than other patients in 2001/2 – i.e. 57% longer. Patients with seven or more diagnoses stayed 6.23 days longer than other patients in 2001/2 – i.e. 58% longer. Whereas patients from the most deprived decile group of small areas only stayed 0.62 days longer than other patients – i.e. 6% longer.

Table 7 also shows that the absolute differentials fell during the period 2001/2 to 2007/8, in line with general year-on-year reductions in length of stay. The relative differential fell to 2% by 2007/8 in the case of deprivation, whereas the relative differentials for age and co-morbidity grew during this period (to 71% and 73% respectively). This suggests that NHS hospitals have been relatively successful in reducing length of stay for long staying patients such as the elderly and those with severe, multiple co-morbidities. It also means that in relative terms age and co-morbidity are even more important determinants of length of stay in 2007/8 than they were in 2001/2, and small area deprivation is even less important.

For readers sceptical of regression modelling and adjusted figures, the unadjusted descriptive statistics in Tables 3, 4 and 5 show a similar pattern of results – i.e. that area deprivation is a much less powerful determinant of length of stay than age and co-morbidity. One interesting difference, however, is that the deprivation effect on length of stay is slightly larger in the unadjusted figures than in the figures adjusted for patient covariates and hospital fixed effects. For example, the unadjusted figures in Table 2 show that in 2001 patients from the most deprived decile group of small areas stayed 1.11 days (or 10%) longer than other patients, compared with 0.62 days (or 6%) longer in the adjusted figures in Table 7. Part of this difference is explained by heterogeneity in patient level confounders across these two groups, such us average age and number of co-morbidities, and part is due to a residual positive hospital level association between average hospital deprivation and average hospital length of stay, over and above the patient level association between average patient deprivation and average patient length of stay. The cause of this residual hospital level association is not known. One possibility is a negative "spill over" effect on hospital efficiency of treating a high proportion of deprived

patients; another possibility is self-selection of less deprived patients into hospitals with high quality orthopaedic departments that minimise length of stay; and there may be other possible explanations. However, the magnitude and causes of residual length of stay differentials between hospitals is not of direct concern to our unscrupulous hospital manager looking for ways to reduce mean length of stay within his own hospital by selecting against high risk patients.

One reason that people from deprived areas stay slightly longer in hospital on average than others is that they may have more co-morbidity – such as obesity, heart conditions, and other health problems – and hence take longer to recover. Our regression analysis partly allows for this, by purging the influence on length of stay of the number and type of diagnoses. However, we do not allow for the severity of co-morbidity. Other possible reasons are that patients from deprived areas may have less pleasant and supportive household environments to return to, and socio-cultural factors relating to patient and professional behaviour, such as the quality of communication and diagnosis and patient adherence to medication and recovery regimes.

Our main conclusion is that deprivation differentials in length of stay are small compared with differentials associated with age and co-morbidity. There may be incentives for NHS hospitals under pressure to cut waiting times to avoid offering elective hip replacements to very elderly patients and patients with substantial co-morbidity. However, any incentives to avoid offering elective hip replacements to patients from deprived areas appear negligibly small. In the case of elective hip replacement, the poor cost a bit more – but not much more.

Our data only tell us about the size of potential incentives to increase selection behaviour as the Blair/Brown reforms were introduced. We have not measured actual selection behaviour in this paper, either before or after the Blair/Brown reforms, and so cannot draw definitive conclusions about actual selection behaviour by NHS hospitals during this period. For what they are worth, however, our speculations are as follows. First, we suspect that there was probably not any important selection of hip replacement patients by socio-economic status prior to 2001/2, given (i) the relatively weak financial and managerial incentives to reduce waiting times and length of stay prior to the Blair/Brown reforms and (ii) the relatively strong ethical prohibitions and reputational risks associated with socio-economic discrimination in the context of a publicly funded universal health system. Second, we suspect that there probably was not any important increase in selection of hip replacement patients by socio-economic status after 2001/2, given that (i) the proportions of patients from more deprived areas remained approximately constant from 2001/2 through to 2007/8, and (ii) the incentives for selecting against patients from deprived areas were so small in terms of potential reductions in length of stay.

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