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Private healthcare market investigation

Comments on the Competition Commission's Price Concentration Analysis

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Section 1

Introduction

1.1 In the context of the Private healthcare market investigation the Competition Commission ("CC") has investigated the relationship between local prices for self-pay patients and local competition using an econometric model.[2] Based on this price concentration analysis ("PCA"), the CC states that *"initial analysis shows a statistically significant relationship between price and concentration, indicating that prices are expected to be, on average, higher in more concentrated local markets"*[3] and concludes that *"[CC's] current thinking is that some private hospital operators have market power in local areas"*.[4] The CC subsequently supplemented that PCA analysis with a working paper ("PCA working paper") on 28 March 2013.[5]

1.2 The CC organized a data room at its offices ("Data Room") to enable the parties' economic advisers to replicate the CC's economic analyses in the PCA working paper in order to test the robustness of the results. Compass Lexecon was instructed by BMI to consider the robustness of the CC's PCA results on the basis of the information provided in the Data Room and in the PCA working paper. This report provides the results of that activity.

Structure of this report

1.3 This report is organised as follows:

- In Section 2 we provide an executive summary of the paper and its conclusions.
- In Section 3 we describe the data, methodology and results of the CC's analysis.
- In Section 4 we comment on the CC's baseline specification from the PCA working paper. We show that it fails a standard econometric test for model misspecification known as the RESET test and find that it does not characterise the price-concentration relationship well.

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2 Competition Commission, "Annotated issues statement", dated 28 February 2013 ("Annotated IS"), paragraphs 68-69, and Appendix B, Annex 3.

3 Annotated IS, paragraph 68.

4 Annotated IS, paragraph 69.

5 Competition Commission, "Price-concentration analysis for self-pay patients", published on 28 March 2013.

- In Section 5 we discuss CC's robustness testing and we set out our additional robustness checks of the CC's results. In summary we find that the CC's results are not robust. In particular we find that the CC's baseline regression results appear to be wholly driven by the data from one hospital operator, Nuffield.
- In Section 6 we assess the CC's proposition that it has found a causal relationship between price and concentration. We find no convincing substantive discussion of this very significant question in either the Annotated Issues Statement or the PCA working paper.
- In Section 7 we show the results of the PCA using LOCI calculated based on data for self-pay patients rather than for insured patients. The results are in principle consistent with those we obtain using LOCI for insured patients. In particular, we find that the price-concentration relationship found by the CC, to the extent it exists, is driven wholly by one operator, Nuffield.
- In Section 8 we discuss the implications of the CC's analysis for an estimate of the total potential economic harm. Our analysis, while indicative, suggests that the CC's PCA analysis implies a magnitude of pricing effects that are at most considerably smaller than those implied by the CC's profitability analysis.

Section 2

Executive summary

2.1 In the PCA working paper, the CC reports at paragraph 74 that its findings are:

i) The CC's baseline specification characterises the relationship between price and concentration relatively well: *"In summary, the price-concentration relationship is thought to be **relatively well characterized** by the baseline specification."* (our emphasis)

ii) The relationship between price and concentration is ***robust***: *"This estimated relationship appears robust to various alternative specifications."*

iii) The relationship the CC is estimating is a ***causal*** relationship whereby concentration causes price changes: *"This indicates that reductions in local market concentration, as measured by LOCI, would likely **lead to** price reductions."* (our emphasis)

2.2 On the basis of our review of the evidence available in the Data Room and the PCA working paper, we consider that the CC has not substantiated these three key findings in the PCA paper. In particular, our review of the CC's analysis suggests that the CC's baseline model is not well specified, the finding of a market wide statistically significant relationship between price and concentration is not in fact robust and the CC has done little of the substantive work that would be required to convincingly come to a view that higher prices are actually caused by high concentration.

The CC's baseline results do not characterise the relationship between price and concentration relatively well at all

2.3 In terms of the CC's PCA finding that the price-concentration relationship is thought to be relatively well characterized by the baseline specification, we find that:

i) The CC's baseline specification **fails the standard econometric test for model misspecification** (known as Ramsey's RESET test).

ii) The CC's baseline specification is clearly rejected by a simple very mild generalisation of the CC's model and in the slightly expanded model none of the CC's findings are found to be robust. We discuss the precise form of that generalisation further below.

The CC's results are not robust

2.4 In terms of the CC's PCA findings that the relationship between price and concentration is robust, we find that:

- A reasonable interpretation of the CC's own robustness tests is that they demonstrate that the relationship between price and concentration is not robust. In particular:

  (1) Graphs of the raw data do not indicate any relationship between price and concentration.[6] The CC accepts this.

  (2) The CC's PCA analysis using fascia counts do not indicate any statistically significant relationship between price and concentration (Table 4 of the PCA working paper). The CC accepts this.

  (3) Tables 5 and 6 of the CC's PCA working paper suggest that the finding of a statistically significant correlation between price and concentration is not statistically robust across the CC's different focal treatments. Only a subset of treatments (just over half) reports a statistically significant relationship between price and concentration. And the magnitude of the CC's predicted effects of concentration on prices vary very significantly across treatments: in Table 6 of the PCA working paper the CC's estimated effect varies from plus 3.2 per cent to minus 41.4 per cent of the average episode price.

  (4) Table 10 of the CC's PCA working paper shows that the correlation is not statistically robust when examined on a hospital operator by hospital operator basis.

- Minor adjustments to the CC's baseline model or dataset clearly show that the CC's PCA results are not robust. In particular:

  (5) If we estimate exactly the CC's baseline model except that we exclude Nuffield's data, the results indicate no statistically significant relationship between price and concentration. Thus Nuffield's data appears to be wholly driving the CC's results in its baseline specification.

  (6) If we estimate a very slightly generalised version of the CC's baseline model allowing the LOCI coefficient to be hospital operator specific, we find that the CC's results are not robust. In contrast to the results reported in the CC's Table 10, such a specification can (i) be estimated on the full dataset and (ii) is clearly preferred by the data to the CC's baseline specification in Table 3. The results of such an exercise suggest that:

6 See Annotated IS, Appendix B, Annex 3 - Self-pay PCA, slides 21-25.

(a) There is no statistically significant relationship between price and concentration for any operator other than Nuffield.

(b) Consistent with the CC's hospital operator specific results in Table 10, the results suggest there is no statistically significant relationship between price and concentration for BMI hospitals in particular.

(c) Even if the CC were to decide (contrary to the conventional academic practice) to ignore statistical significance entirely, the predicted effect of concentration on price would be very significantly reduced.

2.5 In addition, while the CC has rightly been careful to use a technique known as 'clustering' (by hospital site) when calculating standard errors, we note that it seems likely that such adjustments will succeed in only partially reducing 'Moulton bias' since the observations across hospitals will presumably not in truth be wholly independent as is required by the resulting estimators of standard errors. As such estimated standard errors are likely be too small – and so will tend to indicate that relationships are statistically significant when in truth they are not.

No convincing substantive discussion of causality

2.6 In terms of the CC's third finding that the relationship is **causal** - we can find no convincing substantive discussion of this very significant question in either the PCA working paper or the Annotated Issues Statement.

2.1 In the Annotated Issues Statement the CC states (at slide 15): *"Depending on the interpretation of the regression, this correlation can imply causation—i.e., changes in concentration cause changes in price"*.[6] And then goes on (at slide 19): *"Causation: if the estimated differences in price are "causal", then they can be interpreted as the estimated price impact as a result of a change in concentration"*.[7] We agree – but the 'if' is hugely significant. The CC then subsequently simply asserts (at slide 32): "*Our current view is that these PCA results may approximate a causal relationship between price and concentration, but we are considering this further*". [8]

2.7 In the PCA working paper, the CC does assert at paragraph 12 of that paper that when its assumptions 1 and 2 hold *"then the parameter β can be interpreted as the causal effect of concentration on price."* But that discussion wholly abstracts from the realities of the dataset at hand, the available dataset (and likely omitted variables), the types of data variation available (across hospitals, across patients within a hospital etc) can hardly suffice for a

6 CC's Annotated Issues Statement, Appendix B, Annex 3- Self-pay PCA, slide 19.

7 CC's Annotated Issues Statement, Appendix B, Annex 3- Self-pay PCA, slide 19.

8 CC's Annotated Issues Statement, Appendix B, Annex 3- Self-pay PCA, slide 32.

serious investigation. As Davis and Garces (2010) describe:[9] *"It is important to stress that a regression equation does not distinguish correlation and causality and estimation will usually pick up correlations even if there is absolutely no causal relationship between the variables."* Relationships between price and concentration are known to arise for a variety of reasons – not all of which are associated with competition problems. For example, we may find a positive association between price and concentration when high quality hospitals recover their costs via high prices but also achieve significant market shares. The word 'causal' does not appear further in the PCA working paper.

2.8 The CC does provide some discussion of its assumptions 1 and 2 which it asserts are sufficient for establishing a causal relationship between price and concentration.

2.9 In terms of its discussion of assumption 1, the CC's tests of assumption 1 (functional form) amount to only examining two distinct specifications (i) linear versus taking logs of the variables and (ii) a division of the data by treatment. This constitutes a very limited test of functional form. For example, the CC provides no tests of whether it would be appropriate to include other variables in the specification (such as the distance to nearby hospitals for example) or for non-linearities other than logs. Moreover, the CC's test is an unconventional one in the sense that the CC does not test for departures from its baseline model using the full dataset – i.e. using all the information the CC has. Rather it divides the dataset into different parts and then uses the data part-by-part. More conventional functional form tests consider whether the model successfully fits the full dataset. This is not quite the same as asking whether we get the same relationship when we apply the model to a subset of the data. We have already mentioned that the CC's baseline model fails the conventionally applied RESET test of model specification. And also that when looking at subsets of its dataset, the CC does not consistently get the same answer as that provided by its baseline model. In Table 5 of the PCA working paper the CC finds only half of the LOCI coefficients (4 out of 8) are statistically significant while the other half are not. The results also show the R-squares fall significantly relative to the baseline model. In Table 6 the CC finds just over half (5 out of 8) are statistically significant while the others are not.

2.10 In terms of its discussion of assumption 2, the CC promptly dismisses conventional economic concerns around endogeneity at around paragraph 46 of the PCA. The authors of the academic paper to which the CC refers in terms of the LOCI measure argue: *"LOCI is likely endogenous, for the usual reasons. Market shares are not likely to be independent of unobserved factors that determine prices*".[10] However, the CC comes promptly to the view that "*any endogeneity bias is likely to be limited*" and that *"LOCI and the other covariates are likely to be exogenous.*" The CC's "*reasoning relates primarily to the use of regional dummy*

9 Davis, P. and E. Garcés. 2010. "Quantitative Techniques for Competition and Antitrust Analysis," Princeton University Press, page 89, Chapter 2.

10 Akosa Antwi, Y.O.D., Gaynor, M. and W.B. Vogt. 2006. "A competition index for differentiated products oligopoly with an application to hospital markets", unpublished manuscript, page 12.

variables", arguing that this will "*capture any differences in the average market conditions hospitals face in different regions – this will include, for example, differences in population*".

2.11 This argument is unconvincing since regions are not economic markets but contain groups of local markets which may have quite different characteristics. For instance some are big while others are small, and if the omitted variable were, say, local population then that would vary within any given region and so regional dummy variables would not properly control for it. Similarly, regional dummy variables do not obviously address concerns about say local hospital quality driving local high shares and also high local prices since hospital quality and hospital self-pay prices will vary within region. Indeed, the presence of regional dummy variables in the regression suggests that the CC's identification of the LOCI parameter will primarily be exactly from variation across price and concentration within the regions. Ultimately on this point the CC simply asserts without reasoning or justification that: "*These within-region factors are thought to be limited, and thus unlikely to induce substantial endogeneity bias*".[11]

2.12 There is no discussion of the role of measurement error of explanatory variables (except for one aspect of the measurement of LOCI) which may also introduce endogeneity bias.[12] Yet the same is likely to be true for a number of other included variables such as episode cost.

2.13 In any event, we further considered aspects of the CC's analysis where it appeared to at least recognise some of the issues that ordinarily need to be considered in a price-concentration analysis. Specifically, we considered the CC's estimates reported in Table 7 where the CC attempts to control for endogeneity bias – that is a situation where the CC's assumption 2 fails. As the reader will understand from the tone of our earlier remarks, we wholeheartedly agree with the CC that checking robustness to such possibilities is likely to be important. However, we do not agree with the CC's conclusions that its results in this regard are at all robust.

2.14 Specifically, we find that:

[11] PCA working paper, paragraph 46.

[12] See for example the discussion in Davis, P. and E. Garcés. 2010. "Quantitative Techniques for Competition and Antitrust Analysis," Princeton University Press, at section 2.1.4.4 on page 86.

i) *Exclusion of individual hospitals*: in the CC's preferred specification (Table 7, specification 10) in the PCA working paper we tested whether excluding the patient episode data from one hospital at a time would change the CC's conclusions. Specifically we considered hospitals with more than 300 patient episodes in the CC's dataset and dropped each hospital one at a time before repeating the CC's analysis. We found that the LOCI coefficient became statistically insignificant when excluding a variety of individual hospitals. **That is, significant elements of the CC's results appear to depend on the presence or absence of a single hospital from the dataset.** For illustration, these results suggest that not only does dropping all Nuffield data from the CC's analysis change the CC's conclusions (as shown in Section 4), so does removal of a **single** Nuffield hospital such as Nuffield Glasgow. The same can be said of Nuffield Exeter or Nuffield Bournemouth. Moreover, the statistical significance of the results also goes away when we remove Spire Cardiff or Spire Edinburgh or Spire Norwich, or indeed BMI Ross Hall or BMI Three Shires.

ii) *The benchmark Hotelling model suggests that the CC's instrumental variables are not likely to be valid*: In the Hotelling model of spatial competition, pricing and distance are interrelated and the optimal price a firm sets would ordinarily be related to the distance from its competitors. The Hotelling model would suggest that the distance to rival hospital should be accounted for in the pricing regression and therefore it could and should not simultaneously be used as an instrumental variable for concentration (LOCI).

iii) *First stage regression results*: When considering IV and 2SLS regression results (or indeed GMM regression results), standard practice involves reporting and examining first stage regression results. The CC's first stage regression results show that the driving distance to a hospital in the same network is found to have a statistically insignificant positive relationship with LOCI (specification 7, CC Table 7), while the drive-distance to a hospital in a competing network has a negative and statistically significant relationship with LOCI (specification 8, CC Table 7). It is only when both instruments are used (specifications 9 and 10, CC Table 7) that the own-distance instrument becomes statistically significant in the first stage regression. This finding of a relationship between the driving distance to own hospital and network LOCI is not robust -in the sense that it does not emerge in specification 7, a finding which begins to indicate that the conditional correlation between this instrument and LOCI is weak. Importantly, the instrument is found to contribute only a tiny amount to the extent to which the first stage regressors can collectively explain variation in the instrumented variable LOCI. This is consistent with the instrument 'driving distance to a hospital in the same network' being a potentially 'weak' instrument for LOCI.

iv) *Testing relevance of instruments*: The CC uses two instruments for LOCI: the distance to nearest hospital under common ownership and the distance to nearest rival hospital. The CC concludes that its endogeneity tests suggest that instrument

(1) 'may not be a relevant instrument' (paragraph 54, PCA) while instrument (2) 'is a relevant instrument'. The CC also finds that the null hypothesis that both instruments are jointly irrelevant is rejected in specifications (9) and (10) – i.e. specifications which include both instruments. The results in the CC's Table 7 are therefore indicating that only the addition of a wholly or largely irrelevant instrument is giving the CC its statistically significant results. A test that confirms both instruments are jointly relevant certainly does not logically imply that one of them is not irrelevant. In sum, overall the appropriate inference from the first stage regression results and the CC's statistical tests in Table 7 – specifically the test that the CC's 'instruments are irrelevant' - seems likely to be that specifications (9) and (10) should be rejected in favour of specification (8). We note in particular that the CC's specification (8) finds no statistically significant relationship between price and LOCI. Thus what appears to be happening is that the CC is adding a wholly or largely irrelevant instrument and doing so is significantly changing the statistical significance of the results the CC is obtaining in Table 7. Such a result is troubling as weak instruments are known to have a significant potential to both (i) cause significant bias in real-world samples and also (ii) magnify the bias caused by small violations of the assumptions required for an estimator to be a good one (exclusion restrictions).

v) *Interaction of operators with LOCI*: We consider separating the coefficients on LOCI by hospital operator. We find that there is no longer any statistically significant coefficient for the instrumented LOCI variable under any of the instrumental variable specifications estimated by the CC when we exclude Nuffield data from the dataset. The CC's results are again not robust to dropping the Nuffield data. Moreover, when we performed the analysis for Nuffield's data only, the instrumented LOCI variable is significant under CC's specifications (8) and (9). Such results are consistent with the results in the CC's Table 10 and our earlier conclusions that Nuffield's data is driving the CC's results in the full sample.

Using self-pay LOCI instead of a LOCI based on data for insured patients in the PCA

2.15 The CC has used the LOCI measure based on insured patients and adjusted for network effects in the PCA. We implemented another approach to calculating LOCI following the CC's methodology, but based on data for self-pay patients instead of insured patients.

2.16 We find again that Nuffield data is driving the finding of a significant price-concentration relationship and that once a differential relationship by operator is allowed for in the data, there is no indication of a statistically significant relationship between price and concentration for the other operators.

2.17 The statistical test results suggest that it is inappropriate to restrict the specification to require the LOCI parameter to be equal for all operators when estimating a price-concentration relationship using the self-pay LOCI concentration measure. The results are again consistent with proposition that the price-concentration relationship that the CC found is, to the extent it exists, driven wholly by Nuffield.

The inconsistency of the CC's PCA analysis with its estimate of excess profitability

2.18 We provide an initial calculation of the implied total overcharge based on the CC's baseline PCA specification results as well as the results of our robustness checks. In an effort to be ultra conservative in such an analysis, we use the CC's point estimates and we do not take into account whether the CC's estimates are statistically significant or not. For the avoidance of doubt, this is not in fact a reasonable basis for actually calculating such an overcharge – but it appears to potentially provide a 'worst case scenario' for the potential direct economic harm to consumers on the basis of the PCA evidence.

2.19 This worst case scenario would imply a total annual overcharge (i.e. transfer from consumers to BMI) is, at most, £[✂]. This is calculated on the basis that the prices paid by all BMI's inpatients (i.e., self-pay *and* insured) in a given year would be reduced by the amount implied by a reduction in LOCI of 0.2 in the CC's baseline specification. The equivalent figure for the total worst-case scenario implied overcharge for our robustness check specifications ranges from £[✂] per year.

2.20 Given these estimates we make a simple point. All of these estimates represent a small fraction of the CC's estimated 'excess profitability' emerging from the CC's profitability model. There appears to be a significant tension between the PCA results and the CC's profitability analysis about the magnitude of the CC's concern about pricing effects.

Section 3

CC's price concentration analysis: methodology, data and results

3.1 The CC summarises its PCA findings as follows:[13]

i) The CC's baseline specification characterises the relationship between price and concentration relatively well: *"In summary, the price-concentration relationship is thought to be **relatively well characterized** by the baseline specification."* (our emphasis)

ii) That the relationship between price and concentration is ***robust***: *"This estimated relationship appears robust to various alternative specifications."*

iii) That the relationship the CC is estimating is a ***causal*** relationship whereby concentration causes price changes: *"This indicates that reductions in local market concentration, as measured by LOCI, would likely **lead to** price reductions."* (our emphasis)

3.2 In this section we provide a summary of the methodology, data and results of the CC's price concentration analysis, as set out in the Annotated IS and subsequently the PCA working paper.

CC's methodology: initial analysis in the Annotated IS

3.3 The CC begins its analysis in the Annotated IS with a simple analysis considering the relationship between average price and concentration observed in graphs where prices are plotted against fascia counts and LOCI values.

3.4 The CC argues that it sees some indication of a price-concentration relationship in three cases which we discuss in turn:

- *Gallbladder removal (LOCI and fascia count).* Correlation coefficients of -0.23 (LOCI) and -0.24 (fascia count) are reported. It is not clear whether such correlations are statistically significant.

[13] PCA working paper, paragraph 74.

- *Rhinoplasty following trauma (fascia count).* The relationship is far from clear in the Rhinoplasty (fascia count) graph – since in particular (i) the highest prices are recorded in markets with the largest fascia count, and (ii) the correlation coefficient is reported to be of the 'wrong' sign at +0.01, indicating prices are higher where fascia count is higher (and concentration is therefore lower).
- *Gastric banding (LOCI).* The correlation coefficient is -0.4 and no indication of statistical significance is provided.

3.5 Overall the CC finds *"no clear overarching pattern across the graphs"*[14] and so turns to a regression analysis in an attempt to identify a *"more nuanced relationship"*. We note that the CC faces a significant challenge to find a nuanced relationship convincingly since there are likely to be important demand and cost-side variables that are not well observed and which are potentially correlated with the available measures of concentration. A further discussion of this point is provided below.

CC's methodology: PCA

3.6 The CC's aim for conducting the PCA was to *"evaluate the relationship between prices and market concentration in local markets"*.[15] The CC notes *that "[p]rices and concentration are typically expected to be related such that higher prices prevail in more concentrated markets; however, in any particular instance, there may be countervailing market features that offset the relationship"*.[16]

3.7 The CC focuses their PCA on eight 'focal treatments' that the CC considers are *"likely to reflect the overarching price-concentration relationship across the market as whole"*.[17]

3.8 Since the hospitals and the local markets differ in many dimensions which may affect prices charged, the CC used multiple regression analysis to estimate the price-concentration relationship.

3.9 More specifically, the CC estimates the following equation:[18]

$$\ln(price_{iht}) = \beta . concentration_h + \gamma . X_{iht} + \varepsilon_{iht}$$

where:

$price_{iht}$ is the price paid for private hospital services by patient *i* in hospital *h* in time

14 See Annotated IS, Appendix B, Annex 3, slide 21.

15 PCA working paper, paragraph 4.

16 PCA working paper, paragraph 4.

17 PCA working paper, paragraphs 23 and 24.

18 PCA working paper, paragraph 7.

period *t*;

$concentration_h$ is a measure of local market concentration faced by the hospital *h* that patient *i* visited;

X_{iht} contains control variables, i.e. other measurable factors specific to patient *i*'s visit in hospital *h* in time period *t*, which the CC expects to affect the price paid by patient *i*; and

ε_{iht} represents the unobserved factors affecting prices, i.e. factors not included in X_{iht}.

3.10 Since the CC uses the natural logarithm of price in its baseline regression analysis, the parameter β of the concentration variable can be interpreted as *"the (approximate) average percentage change in price following a one unit change in concentration"*.[19] We note that it is not necessary for the CC to use such an approximation since the exact price change can easily be computed and the CC should check – where it matters – that any predictions are not materially affected by the approximation. More significantly, we note that this will also only be true if the conditions required for the CC's regression technique to provide valid answers are satisfied. We discuss those conditions further in Section 6.

Range and selection of control variables

3.11 Obtaining and including in the analysis the relevant control variables (i.e. other factors influencing the analysed variable – in our case factors other than concentration which affect self-pay prices) is clearly an important part of the regression analysis. The CC has attempted to take into account various types of control variables.

3.12 The CC uses "basic" controls (dummy variables for year, hospital group, treatment), "patient" controls (age, gender, number of nights per episode), "supply-side" controls (hospital average direct cost), and "demand-side" controls (geographic location) in the regression analysis. However, some of these control variables are proxies which the CC uses to control for other variables for which data is not available.

3.13 For instance, the CC recognises it should attempt to control in the regression analysis for the episode cost. Since this cost data at the episode level is not available, the CC has used hospital average direct costs instead. Although such costs will reflect a part of the episode level costs (which is non-specific to the episode/treatment), it clearly does not include the information about the cost of the episode which one would ideally wish to control for in the regression analysis of self-pay prices.

3.14 Another example is the patient's length of stay which can be used as a patient control containing useful information related to episode costs (accommodation charges are a part of episode costs). However, we understand that most of the costs associated with a surgical procedure are incurred preparing for and during the procedure itself, so the length of stay is not likely to include all the relevant information about the complexity of the patient's medical condition, which can also be expected to be a very important determinant of episode costs and ultimately also the price.

[19] PCA working paper, paragraph 12.

3.15 Omitted variables (such as episode costs or medical condition complexity described above) can lead to regression model mis-specification and biased estimates of parameters on variables that are included.

3.16 We have previously pointed out such concerns in our analysis using BMI's pricing data submitted to the CC:[20]

> *"Our approach to the pricing evidence is to examine whether prices are lower in some markets than others. In doing so we should in principle control for exogenous demand and cost factors that may affect prices. For instance, one might expect that higher treatment costs for a given individual and/or hospital would result in higher observed episode prices. However, this is not an easy task. For example, we do not observe variables indicating the severity of a patient's condition in the data. These variables are an important determinant of the treatment specific costs and therefore of the treatment specific prices. Moreover, the market/hospital characteristics which we do observe are likely to be relatively poor proxies for the treatment specific characteristics that we would ideally like to take into account when analysing self-pay prices.*
>
> *In particular:*
>
> - *treatment costs, intensity of care required, use of drugs/hospital consumables, and other similar factors vary substantially across treatments and are likely to be poorly proxied by average hospital per bed costs; and*
> - *market size variables for a specific treatment may not be well proxied by general measures of market size such as population or age distribution. For example, the incidence of smoking related illnesses and obesity relate to the lifestyle of the local population as well as the number of people living near a hospital."*

3.17 The CC largely agrees that included control variables should *"include the factors that are expected to affect prices, as well as being correlated with the concentration measures"* and *"[f]actors that affect supply and demand conditions for private healthcare services are typical candidates for control variables"*.[21]

3.18 The data realities clearly suggest that in this instance the risks and consequences associated with omitted variables must be taken particularly seriously. We return to this topic in Section 6.

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20 See also Compass Lexecon analysis "Do private healthcare providers have market power in solus hospital markets?", dated 11 January 2013, paragraphs 68-69.

21 PCA working paper, paragraph 20.

Interpretation of the statistical significance of results

3.19 In the Annotated IS, the CC stated that *"[s]tatistically significant estimates can be interpreted as those that the model (more) reliably distinguishes from the general noise and variation in the data"*.[22]

3.20 We are not sure we understand what the CC means by 'more' in this statement. A conventional approach would suggest that statistically insignificant estimates mean that from the statistical point of view, the CC's analysis would be deemed to find no evidence of a relationship between price and concentration. On conventional application, the statistics from the regression analysis are telling us that the data cannot distinguish between the presence of an effect and the absence of an effect. More specifically, the lack of statistical significance is telling us that if there were in truth no relationship between price and concentration then if we drew random samples from the world of the size involved in the CC's analysis, we would find a negative coefficient on LOCI a significant fraction of the time. In extremis, we would find a negative coefficient on LOCI in half of the samples and a positive coefficient in the other half of the samples.

3.21 To illustrate the potential importance of such a distinction, consider that the CC argues that *"[the] estimated [price-concentration] relationship appears robust to various alternative specifications"*.[23] However, some of the CC's robustness checks indicate that the CC's results are not robust in the sense of maintaining the finding of a statistically significant relationship. In particular:

(a) the hospital operator specific regression results (Table 10, PCA working paper) indicate that only Nuffield is found to have a statistically significant relationship between price and concentration using the LOCI measure of concentration; and

(b) the treatment specific regression results (Tables 5 and 6, PCA working paper) show only a subset of treatments (just over half) report a statistically significant relationship between price and concentration. And the magnitude of the CC's predicted effects of concentration on prices vary very significantly across treatments: in Table 6 the CC's estimated effect varies from *plus* 3.2 per cent to *minus* 41.4 per cent of the average episode price.

3.22 If the CC were to start taking estimates seriously even though they are not statistically significant (which we do not advise), then BMI would presumably wish to note that for a variety of the specifications we estimate, the coefficient on BMI's LOCI is estimated to be positive but statistically insignificant. For example those in Annex B relating to CCSD codes E0260, M6530, T2000, W3712 and W4210. If the CC were to be consistent, then such

22 Annotated IS, Appendix B, Annex 3, slide 19.

23 PCA working paper, paragraph 74.

results would then need to be taken by the CC to indicate that BMI should be allowed to increase its ownership of hospitals in an effort to drive down self-pay prices.

Data used by the CC

Price

3.23 The CC used a database of prices relating to self-pay patients in the period from 2009 until 2012 for the five main hospital groups: BMI, HCA, Nuffield, Ramsay, and Spire. The CC's dataset includes episode prices for inpatient episodes (single hospital visits) at 147 hospital sites.[24]

3.24 The episode price is defined as the price paid by a self-pay patient for hospital services, excluding the cost of consultant fees and ancillary items.[25] In the PCA working paper, the CC considers that *"[t]here are minor differences in this definition across the data for each hospital group (eg for BMI data [the CC] could not exclude ancillary items) but such differences are expected to be minor"*.[26] In the CC's Annotated IS, the CC similarly acknowledges that the datasets for the five hospital groups have differences, but also says without going further into detail that it believes that *"any inconsistencies are expected to be minor and limited"*.[27]

3.25 In this regard we note that it is not clear from the paper why the CC expects this to be the case. So we are unable to comment on the appropriateness of this conclusion.

3.26 Among the potential inconsistencies mentioned by the CC,[28] we would expect that, in particular, the recording of multiple treatments per visit may potentially be a significant factor affecting the results of the analysis. The CC does not say how it ensured that episodes with multiple treatments are treated consistently across providers.

3.27 Another example of potential inconsistency is the recording of ancillary items which may be included for some operators' invoices, but excluded for others – as the CC notes on slide 7 of Annex 2 of the Annotated IS. It is not clear why the CC considers such effects to be of minor importance, again meaning that we are unable to comment on the appropriateness of this conclusion.

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24 PCA working paper, paragraph 15.

25 PCA working paper, paragraph 17.

26 PCA working paper, footnote 13.

27 Annotated IS, Appendix B, Annex 3, slide 5; see also PCA working paper, footnote 13.

28 See Annotated IS, Appendix B, Annex 3, slide 5.

3.28 Finally we note Nuffield's submission in response to the Annotated IS[29] that it may not be the case.

Concentration

3.29 The CC used the data on insured patients provided by Healthcode to construct the concentration measures. This database includes information on inpatient episodes at 173 hospital sites.[30]

3.30 The CC used two concentration measures for the PCA: the Logit Competition Index ("LOCI") and fascia counts. Both are based on insured patients as, according to the CC, *"[t]he Healthcode dataset represents the most consistent and complete picture of patient journeys that is available to [the CC]"*[31] for this purpose.

3.31 LOCI is equal to one minus a weighted average market share of a hospital. The CC uses the LOCI measure which is based on patient episodes (rather than revenues) and which incorporates an ad-hoc adjustment for network ownership of hospital groups.

3.32 Fascia counts have been calculated by the CC as *"the count of general private hospital and PPU fascia within three distance bands from the focal hospital: 0-9 miles, 9-17 miles and 17-26 miles"*.[32] These distances are based on the median catchment area for UK hospitals, which the CC estimates to be 17 miles.[33]

3.33 We do not repeat our detailed previous submission on the use of LOCI as a measure of concentration here, but we do encourage the CC to revisit them.[34] In sum, the model which would motivate the use of LOCI is unlikely to be a good model for approximating the process generating the data we observe. Such a conclusion provides a reason to believe that there are likely to be important omitted variables in the CC's PCA analysis – one further to our earlier observations on that point provided in paragraph 3.18 above.

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29 See paragraphs 5.11-5.14 Nuffield Health response to AIS available from http://www.competition-commission.org.uk/assets/competitioncommission/docs/2012/private-healthcare-market-investigation/130405_nuffield_health_annotated_issues_statement.pdf .

30 PCA working paper, paragraph 16.

31 PCA working paper, paragraph 18.

32 PCA working paper, paragraph 18.

33 PCA working paper, footnote 17.

34 See "Comments on CC's annotated issues statement: The CC's approach to measuring concentration", dated 17 April 2013.

CC's PCA results

3.34 The CC presents in the PCA working paper two sets of PCA results: (i) PCA results using LOCI as a measure of concentration, and (ii) PCA results using fascia counts as a measure of concentration.

3.35 For both sets of results, the CC includes three regression specifications:

- specification (1) which includes year, operator and treatment dummies as control variables;
- specification (2) which, in addition to control variables in (1), includes patient-level controls (age, gender, number of nights); and
- specification (3) which, in addition to control variables in (2), includes a cost variable and regional dummies.

Results using LOCI as a measure of concentration

3.36 The CC's PCA results using LOCI as a measure of concentration are set out in Table 3 of the PCA working paper and are also reproduced below.

Table 1: CC's price concentration analysis results using LOCI

	(1)		(2)		(3)	
	Coefficient	*Std error*	*Coefficient*	*Std error*	*Coefficient*	*Std error*
LOCI	–0.162*	0.068	–0.163*	0.068	–0.180***	0.053
Year dummy: =1 if 2010	–0.005	0.012	–0.005	0.012	–0.001	0.01
Year dummy: =1 if 2011	0.031**	0.011	0.033**	0.011	0.040***	0.01
Year dummy: =1 if 2012	0.043**	0.013	0.045**	0.014	0.052***	0.012
Operator dummy: =1 if HCA	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Operator dummy: =1 if Nuffield	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Operator dummy: =1 if Ramsay	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Operator dummy: =1 if Spire	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Treatment dummy: =1 if Cataract surgery	–1.902***	0.039	–1.888***	0.042	–1.888***	0.038
Treatment dummy: =1 if Rhinoplasty following trauma	–1.460***	0.059	–1.429***	0.061	–1.431***	0.061
Treatment dummy: =1 if Gastric banding	–0.725***	0.048	–0.698***	0.047	–0.706***	0.05
Treatment dummy: =1 if Removal of gallbladder	–0.878***	0.014	–0.858***	0.016	–0.867***	0.016
Treatment dummy: =1 if Prostate resection	–0.816***	0.014	–0.813***	0.014	–0.820***	0.015
Treatment dummy: =1 if Inguinal hernia surgery	–1.751***	0.015	–1.739***	0.017	–1.740***	0.018
Treatment dummy: =1 if Knee replacement	0.081***	0.01	0.080***	0.01	0.078***	0.01
Patient sex			–0.008	0.005	–0.008	0.004
Patient age			0.000	0.000	0.000	0.000
Episode number of patient nights			0.004	0.002	0.005*	0.002
ln(average direct cost)					–0.016	0.032
[Location dummies]					[Not shown]	[Not shown]
Constant	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
R-squared	0.91		0.91		0.917	
N	20720		20720		20720	

*Notes: Numbers may not sum due to rounding. Base categories for dummy variables are BMI, 2009 and hip replacement. Standard errors are clustered by hospital site. Blank entries indicate that the covariate is not included in the specification. ***/**/* indicates statistical significance at the 0.1%/1%/5% level.*

Source: CC analysis

3.37 The coefficients (β) on the LOCI variable are -0.162, -0.163 and -0.180 for CC specifications (1), (2) and (3) respectively, and all coefficients are reported as statistically significant at least at a 5% level. The CC refers to the specification (3) as the 'baseline specification'.[35]

35 PCA working paper, paragraph 20.

3.38 The CC's interpretation of results under the baseline specification (3), is that *"an increase in the LOCI of 0.5 (ie a 50 per cent decrease in the weighted average market share) will cause price reductions of around 9 per cent and an increase in LOCI of 0.2 (ie a 20 per cent decrease in the weighted average market share) is estimated to cause a price reduction of around 3.6 per cent"*.[36]

3.39 In the PCA working paper the CC carries out robustness checks of the baseline specification (3) and we consider these and other robustness checks in later sections.

Results using fascia counts as a measure of concentration

3.40 The CC notes in the PCA working paper that *"[n]one of the specifications using fascia count estimate statistically significant price-concentration relationships at the 5 per cent level"*.[37] The CC considers that *"[fascia count] is a less refined measure than the LOCI"* and *"[the CC] view the LOCI specifications, as compared with the fascia count specifications, as providing a better reflection of the price-concentration relationship"*.[38]

3.41 We note that it is far from obvious that the fascia counts approach would be a less reliable measure for measuring concentration, compared to LOCI.[39] As such at this stage of its analysis it is not at all clear that the CC should properly disregard its finding that there is no statistically significant relationship between price and concentration when using fascia counts as a concentration measure.

3.42 Since the CC's findings on the relationship between price and concentration when using fascia counts as a measure of concentration are not contentious for BMI (i.e. the CC is not alleging any statistically significant relationship between price and concentration), in the rest of this response we focus on the CC's analysis using LOCI as a concentration measure. We do note however that the CC should, in our view, pay proper regard to the fact that the fascia count results suggest no statistically significant relationship between price and concentration.

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36 PCA working paper, paragraph 30.

37 PCA working paper, paragraph 33.

38 PCA working paper, paragraph 35.

39 See also "Comments on CC's annotated issues statement: The CC's approach to measuring concentration", dated 17 April 2013.

Discrepancy between the results presented by the CC in the Data Room compared to the PCA working paper and our inability to examine the data cleaning done by the CC in the Data Room

3.43 We note that the CC results presented in the Data Room were slightly different from those included in the PCA working paper. The data used for the PCA in the Data Room has one extra observation for the treatment (CCSD code) E0260 (Rhinoplasty following trauma): there were 2,377 observations (episodes) in the CC dataset in the Data Room compared to 2,376 observations indicated in the PCA working paper.

3.44 The CC results presented to the advisors in the Data Room were thus slightly different compared to the results in the PCA working paper: under CC's baseline specification (3), the coefficient on the concentration variable changed from -0.180 (the PCA working paper) to -0.179 (CC's Data Room results). The statistical significance of this coefficient changed as well: while it was significant at 0.1% level in the PCA working paper, the Data Room set of results shows that the LOCI coefficient was statistically significant at 1% level. This level of statistical significance is, however, still conventionally considered high and therefore we note that the change in results (PCA working paper versus the results presented by the CC in the Data Room) does not affect the substance of the CC's statistical analysis.

3.45 While the appearance of one extra observation is not itself likely to be significant, its mysterious appearance without explanation may potentially be indicative of deeper issues. We would have preferred to have the opportunity to examine the CC's data cleaning process more closely but we were not given access to sufficient information to allow us to follow all of the steps from the raw data files submitted by the parties to the final dataset available to economists in the Data Room. Since the CC cleaning process results in reduction in the total number of observations (episodes) from almost 4 million to around 21,000, the cleaning and data selection process is potentially very important for a view on the reasonableness or otherwise of the CC's conclusions and we have not to date had a meaningful opportunity to comment upon it.[40]

3.46 For completeness, we include in **Error! Reference source not found.** the full results presented by the CC in the Data Room (i.e. with the one extra observation for CCSD code E0260 compared to the PCA working paper), including the results of the CC's robustness analysis analogous to tables 5 through 10 of the PCA working paper.

Summary

3.47 The CC's analysis indicates that:

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40 The CC did provide 'do files' in the Data Room, but without the data it was impossible to run these computer program files and therefore it was not possible to meaningfully examine the impact of each step of the data cleaning process being used by the CC on its PCA results.

(a) graphs of prices against concentration show no relationship between price and concentration;

(b) results from fascia counts show no relationship between price and concentration;

(c) the hospital operator specific regression results (Table 10, PCA working paper) indicate that only Nuffield is found to have a statistically significant relationship between price and concentration using the LOCI measure of concentration; and

(d) the treatment specific regression results (Tables 5 and 6, PCA working paper) show that only a subset of treatments (just over half) report a statistically significant relationship between price and concentration. And the magnitude of the CC's predicted effects of concentration on prices vary very significantly across treatments: in Table 6 the CC's estimated effect varies from *plus* 3.2 per cent to *minus* 41.4 per cent of the average episode price.

3.48 In addition we note that the following are likely to be significant issues:

(a) Measurement error. There appears likely to be a measurement error issue in (i) the price variable; (ii) in LOCI and in particular (iii) in other included variables such as episode cost.

(b) Omitted variables (such as episode costs or medical condition complexity described above) can lead to regression model mis-specification and biased estimates of parameters on variables that are included, and are in this case likely to raise significant issues since we do not have good information on a number of variables that are likely to be important for the analysis – for example good episode cost data. Moreover since LOCI is likely to be a poor proxy for the real indicators of market power, variables which are actual indicators of market power are also likely to be omitted.

3.49 Finally we note that the role of statistical significance is an important one. A conventional approach would suggest that statistically insignificant estimates mean that from the statistical point of view, the CC's analysis would be deemed to find no evidence of a relationship between price and concentration whenever the conventional levels of statistical significance cannot be established. The luck of the draw – chance – is a competing rival hypothesis for the limited and statistically imprecisely estimated degree of correlation we are observing between price and concentration. The statistics are telling us that it is a hypothesis that, on a number of significant occasions, the data cannot rule out.

Section 4

Comments on the CC's PCA results – baseline specification

4.1 In this section we provide our comments on the specification that the CC refers to as it 'baseline specification' - specification (3) in Table 3 of the PCA working paper.

4.2 In this chapter our analysis shows that:

- statistical tests confirm that the CC's baseline specification is rejected by the data in favour of a mildly more general specification which does not impose the restriction that the relationship between price and concentration is the same for all operators;
- the CC's finding of a relationship between price and concentration is being driven by the data from a single hospital operator (Nuffield);
- the other operators (excluding Nuffield) do not have a relationship between price and concentration (jointly or individually); and
- the CC's analysis in the PCA working paper (Table 10) confirms that provided in the Annotated IS (at slide 31, Annex 3 to Appendix B) that there is no relationship between price and concentration for BMI.

Statistical tests confirm that the CC should not require the price-concentration relationship to be identical for all operators and the CC's finding of a relationship between price and concentration is driven solely by the data for one hospital operator (Nuffield)

4.3 The CC's baseline specification includes a restriction requiring the LOCI coefficient to be equal for the five main operators in order to determine whether there is a relationship between price and market concentration. The single coefficient estimated for the LOCI concentration variable is effectively forcing – in a manner driven by the model specification, not the data – the relationship between price and concentration to be the same for all five operators.

4.4 We have relaxed this constraint in the CC's baseline model by "interacting" the LOCI variable with dummy variables for each of the five main operators. This generalises (in a very minor way) the CC's baseline specification and allows us to examine whether the individual operators' relationships between price and market concentration are the same. We can do so while controlling for the same covariates. These results are set out in Table 2 below.

Table 2: Regression results – CC's specifications (1) - (3) using interaction of LOCI and operator

LOCI coefficient by operator	(1)		(2)		(3)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
N	[✂]		[✂]		[✂]	

Source: Compass Lexecon analysis.

*Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications. ***/**/* indicates statistical significance at the 0.1%/1%/5% level.*

4.5 The results in Table 2 show that the LOCI coefficient for Nuffield for the CC's baseline specification (3) is [✂] and it is statistically significant at the [✂]% level, while the coefficients for the other operators are not statistically significant (and therefore statistically not different from zero).

4.6 Even putting statistical significance to one side, which the academic community typically considers is the wrong approach, the point estimate in column (3) for BMI is [✂] instead of [✂] in CC's baseline specification. The CC's experiment of a 20% decline in LOCI (when interpreting the results of the PCA analysis) would then be associated with a [✂]% price increase rather than a [✂]% price increase (estimated by the CC for all hospital operators under its baseline specification). This is a very significantly smaller effect. And, of course, at some point one has to recognize that the magnitude of the predicted price effects are too small to be measurable – we cannot learn about the 'nuanced relationship' that the CC seeks to explore. In short, the data may be telling us that any effect is too small or too nuanced to be measurable with precision – and that is what, for example, the standard errors on the BMI LOCI coefficient suggests. Indeed that is what the standard errors on all the hospital operator specific LOCI coefficients except Nuffield suggest.

4.7 This way of slightly generalizing the CC's baseline specification allows us to statistically test whether it is appropriate to restrict the model in the manner done by the CC in its baseline specification (i.e. restricting the LOCI coefficient to be equal for all operators). We test this restriction implicit in the CC model in a variety of ways. Here we report the results of performing an F-test of joint significance on all the LOCI coefficients for all five operators in a model allowing for interactions, and also an F-test of joint significance on the non-Nuffield LOCI coefficients (i.e. all operators except Nuffield). The results of these tests are set out in the table below.

Table 3: Test results for estimating one LOCI coefficient for all operators

Null hypothesis	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]
All except Nuffield = 0	[✂]	[✂]

Source: Compass Lexecon analysis.

4.8 These tests suggest that while it is appropriate to restrict the coefficient to be equal to each other and to zero for the non-Nuffield operators (as we cannot reject the null hypothesis that they are all equal to each other and zero), the results indicate that the same cannot be said for the data for all five operators. This suggests that the data for Nuffield estimates a significantly different price concentration relationship (measured by LOCI) from the other operators. Strikingly this result is robust across the various regressions estimated by the CC (see Section 5, Annex B and Annex C).

4.9 These statistical tests thus show that the CC should not artificially restrict the specification to require that the LOCI parameter is equal (and non-zero) for all operators. Indeed, the test results suggest that a better model statistically to the CC's baseline model is for the coefficient on LOCI to be zero on all operators other than Nuffield. The CC's conclusion in the Annotated IS that 'some' operators exhibit a relationship between price and concentration appears unsound on the basis of the CC's preferred baseline specification. Putting aside all other issues and concerns, the statistical test results clearly indicate that the CC should at most conclude on the basis of its baseline specification that one operator – Nuffield – exhibits a relationship between price and concentration in the CC's PCA analysis using LOCI.

There is no relationship between price and concentration for all other operators excluding Nuffield in the CC's baseline specification

4.10 As we have shown above, the relationship between price and concentration in the CC's dataset is fully driven by the data for one hospital operator - Nuffield. Considering the CC's baseline model specification, there is no statistically significant relationship between price and concentration for all other operators except Nuffield – and this holds whether we analyse each operator individually or all of them (except Nuffield) together.

4.11 In terms of the analysis for each operator individually, we have already shown above that with the LOCI-operator interactions approach, which shows the price-LOCI relationship separately for each operator, we find that there is no statistically significant price-concentration relationship for any hospital operators except Nuffield.

4.12 Next we turn to testing for the relationship between price and concentration when restricting the LOCI coefficient to be equal for all operators (except Nuffield). In Table 4 below, we set out the PCA results for regression using LOCI as a measure of concentration (corresponding to Table 3 in the PCA working paper), with the only adjustment being the exclusion of the data for Nuffield.

Table 4: PCA results excluding Nuffield using CC's specifications from Table 3 of the PCA working paper

	(1)		(2)		(3)	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
R-squared	[✂]		[✂]		[✂]	
N	[✂]		[✂]		[✂]	

Source: Compass Lexecon analysis

4.13 The table indicates that for all three of the CC's baseline specifications, there is no statistically significant relationship being reported between price and concentration, since none of the LOCI coefficients is statistically significant. Thus, when analysing together the data for all operators except Nuffield, we find there is no statistical relationship between price and concentration.

4.14 In addition, the LOCI coefficients are also very small in magnitude compared to the CC results presented in the PCA working paper. The coefficients are thus not only statistically insignificant but likely also economically small. According to CC's interpretation, these regression results suggest that an increase in LOCI of 0.2 (i.e. a 20 per cent decrease in the weighted average market share) would be estimated to be associated with a price reduction of around [✂] per cent.

4.15 Robustness checks (analogous to the ones the CC has performed in the PCA working paper tables 5 to 9) for this regression analysis excluding Nuffield are included in Section 5.

CC's analysis indicates that there is no relationship between price and concentration for BMI

4.16 Finally, we have carried out the CC's regression analysis only using BMI's data to explore the relationship between price and concentration in BMI's data under CC's model specifications. We summarise in the table below the results using CC's specification (1) – (3) from Table 3 in the PCA working paper.

Table 5: PCA results for BMI using CC's specifications from Table 3 of the PCA working paper

	(1)		(2)		(3)	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
R-squared	[✂]		[✂]		[✂]	
N	[✂]		[✂]		[✂]	

Source: Compass Lexecon analysis

4.17 Since none of the LOCI coefficients is statistically significant, the analysis indicates that there is no statistically significant relationship between price and concentration for BMI. This is consistent with CC's robustness check in Table 10 of the PCA working paper where the CC also finds that there is no statistically significant relationship between price and concentration for BMI. Indeed column (3) is exactly the specification reported for BMI in Table 10 of the PCA working paper.

4.18 We have also performed the robustness checks of these results using just the BMI data for the PCA analysis – they are included in Annex D. These robustness checks correspond to those the CC performed in Tables 5-9 of the PCA working paper but using only the CC's dataset for BMI. The results indicate that there is no statistically significant relationship between price and concentration for BMI under all specifications including the baseline specification, except for one coefficient in one table (Table 8 which tests excluding areas potentially affected by missing invoices).

Section 5

Comments on robustness testing of the CC's PCA results

5.1 The CC has sought to test the robustness of its estimated baseline regression model (CC's specification 3) – see Tables 5 to 9 in the PCA working paper.[41] We agree with the CC that it is appropriate to test for each of these concerns.

5.2 In particular, the CC has considered:

- the functional form and the dataset used to estimate the model (Tables 5 and 6 in the PCA working paper);
- exogeneity of the covariates (Table 7 in the PCA working paper);
- the effect of missing invoices on the LOCI (Table 8 in the PCA working paper); and
- other modifications relating to the data (Table 9 in the PCA working paper).

5.3 We set out our comments on each of the CC's robustness checks below.

5.4 Specifically:

i) *Functional form of the model*: We find that a conventional RESET test of the functional form of the CC's baseline model suggests it should be rejected for misspecification.

In our robustness check of the CC's treatment-by-treatment analysis (Tables 5 and 6 of the PCA working paper) where we allow the LOCI coefficient to differ by operator, most operators do not exhibit a robust and statistically significant relationship between price and concentration in all or most treatments. And none of the LOCI coefficients by treatment for BMI are statistically significant. (See paragraphs 5.12 to 5.26 below.)

41 In this section we do not address the CC's analysis in Table 10 of the PCA working paper (operator-by-operator analysis), since in Section 4 we implement LOCI-operator interactions to see the individual relationship between price and market concentration for each operator separately.

ii) *Exogeneity of the covariates*: When we separate the coefficients on LOCI by hospital operator and create separate instruments for each operator, the results (analogous to those provided in Table 7 of the CC's PCA working paper) suggest that Nuffield (and potentially HCA) has significantly different results from the other operators. In addition, when we exclude Nuffield data from the dataset, there is no longer any statistically significant coefficient for the instrumented LOCI variable under any of the instrumental variable specifications estimated by the CC. (See paragraphs 5.27 to 5.31 below.)

iii) *The effect of missing invoices on the LOCI*: When we test interacting the LOCI variable with hospital operator dummies to see the effect of the missing invoice problem (Table 8 of the CC's PCA working paper) on the LOCI coefficient for each operator, we find that the exclusion of hospitals most affected by the missing invoices leads to non-statistically significant LOCI coefficients for all operators except for Nuffield. (See paragraphs 5.32 to 5.38 below.)

iv) *Other modifications relating to the data*: The results of the robustness checks of CC's results in Table 9 of the PCA working paper follow the same pattern as in our previous robustness checks - i.e. Nuffield shows a statistically significant negative relationship between price and the LOCI concentration variable, while the other operators do not show significant relationships between price and concentration. (See paragraphs 5.39 to 5.44 below.)

Functional form of the model

5.5 The CC performed several robustness checks on their base specification. These checks include allowing for different price-concentration relationships for each treatment (Table 5 in the PCA working paper), and also allowing LOCI to be linear (rather than logarithmic) in prices by treatment (Table 6 in the PCA working paper).

5.6 In this section we first consider a more formal but wholly standard statistical test for functional form misspecification known as the RESET test. We find that the RESET test rejects the CC's baseline model on the grounds of functional form misspecification.

5.7 In Section 4 we reported the results of testing the robustness of the CC specifications by using operator specific LOCIs. The results indicated that the CC's baseline specification was not very robust. In this section, we secondly verify that that conclusion extends also to the results analogous to those provided by the CC in Tables 5 and 6 in the PCA working paper. We find that these too are not robust.

5.8 We set out the results of these checks below.

RESET test for functional form misspecification

5.9 We have implemented a test for functional form misspecification to test whether the CC's model is not misspecified. We used Ramsey's RESET test, which is commonly used for these purposes.

5.10 The RESET test was proposed by Ramsey as a way of testing for possible omissions of non-linear terms which may be significant in explaining variation in the dependent variable.[42] The test involves taking the fitted values of a regression and including the squared, cubed, and possibly higher order terms of these fitted values as additional control variables in a new regression. An F-test can be performed on the coefficients of these non-linear terms to determine whether there are possible non-linearities in the data which are not being accounted for in the original regression, i.e. whether the regression model is misspecified.

5.11 We have performed the RESET test for the baseline CC specification (3) taking into account the fitted values – see tests (1) to (4) in Table 6. For completeness we have also performed the RESET test taking the fitted values for all control variables except LOCI – see tests (5) and (6) in Table 6 below. In all instances the RESET test rejects the null hypothesis that the CC's baseline specification is correctly specified.

Table 6: RESET test results for CC's baseline specification (3)

Test	Null hypothesis	F/t-statistic	p-value	Result of the test applied to the CC's model
(1)	RESET using fitted values	[✂]	[✂]	×
(2)	RESET using powers of independent variables	[✂]	[✂]	×
(3)	Fitted values^2	[✂]	[✂]	×
(4)	Fitted values^2 and ^3	[✂]	[✂]	×
(5)	(Fitted values except LOCI)^2	[✂]	[✂]	×
(6)	(Fitted values except LOCI)^2 and ^3	[✂]	[✂]	×

Source: Compass Lexecon analysis.

Note: [1] Tests (1) and (2) have been performed using the estat ovtest command in Stata with clustered standard errors. Tests (3) through (6) were performed by manually regressing powers of the fitted values. [2] Tests (3) and (5) follow the student's t-distribution rather than the F distribution.

42 See Cameron and Trivedi. 2005. "Microeconometrics: Methods and Applications", pages 277-278.

Treatment by treatment analysis (CC's Table 5)

5.12 The CC has considered whether the relationship between price and concentration may differ by treatment. To this end, the CC has analysed separately this relationship by CCSD code for the eight focal treatments.

CC results

5.13 The results from the CC's treatment-by-treatment analysis are set out in the table below.

Table 7: CC's PCA results from the Data Room – Table 5 (treatment-by-treatment analysis)

	(3)	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]									
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
N	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: CC's PCA results from the Data Room

5.14 These results show that four of the focal treatments have LOCI coefficients which are negative and statistically significant at conventional levels. However, the results also provide four treatments that are not found to have a negative and statistically significant relationship between price and concentration. Thus it is not true that the CC's Table 5 results provide support for the finding that there is an across-the-board robust statistically significant relationship between price and LOCI when the analysis is performed at the treatment level. Rather the results indicate that, at most, such relationships are found for a particular subset of treatments.

Compass Lexecon robustness tests

5.15 We have conducted a robustness check of Table 5 by allowing the LOCI coefficient to differ by operator. This adjustment, i.e. implementing LOCI-operator interaction terms, is in line with the robustness check we have performed for the CC's baseline specification (3) in Section 4. We report the results in the following table.

Table 8: Regression results using interaction of LOCI and operator - Table 5 (treatment-by-treatment analysis)

LOCI by operator	(3)	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
BMI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

5.16 The results indicate that most operators do not exhibit a robust and statistically significant relationship between price and concentration across treatments. In particular, none of the LOCI coefficients by treatment for BMI are statistically significant and, in fact, more than half of the point estimates are positive. The Nuffield LOCI coefficient is consistent with a statistically significant relationship between price and concentration for the CCSD codes E0260, G3080, M6530 and W4210. However the Spire and Ramsay's results display negative and statistically significant relationships for just two and one treatment, respectively. (While the results for Spire also provide one coefficient which is reporting a positive association between LOCI and price.)

5.17 In Annex B, we show that the results indicate that there is no relationship between price and concentration for each focal treatment once we conduct the analysis for all operators excluding Nuffield.

5.18 Overall, this suggests that the CC's finding in Table 5 of the PCA working paper that there is a significant relationship between price and concentration for treatments E0260, G3080, J1830, and W4210 is not robust because statistical tests suggest that the CC's model should not be restricted to require the LOCI coefficients for all operators to be equal for these treatments. When applying the CC's specification restriction (that the LOCI coefficient has to be equal for operators) to just those operators which have the same price-concentration relationship for each treatment, there is no robust statistically significant relationship between price and concentration for more than one operator - ordinarily Nuffield.

Treatment by treatment analysis with no log transformation (CC's Table 6)

5.19 The CC next considered whether the relationship between the unadjusted linear price (without log transformation) and concentration may differ by treatment. In Table 6 of the PCA working paper, the CC analysed this relationship separately by CCSD code for the focal treatments.

CC results

5.20 The CC's results from the treatment-by-treatment analysis with no log transformation are set out in the table below.

Table 9: CC's PCA results from the Data Room – Table 6 (treatment-by-treatment analysis with no log transformation)

	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
N	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Average episode price	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
LOCI marginal effect as % of average episode price (%)	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: CC's PCA results from the Data Room.

5.21 The results show that some treatments (E0260, G3080, J1830, W3712 and W4210) exhibit a statistically significant relationship between price and concentration, while others (C7122, M6530 and T2000) do not. The results provide evidence of a statistically significant negative relationship between price and concentration in some treatment codes – but the result is far from universal. Two (out of eight) of the estimated effects are actually positive (but statistically insignificant).

Compass Lexecon robustness tests

5.22 We have conducted a robustness check of Table 6 by allowing the LOCI coefficient to differ by operator as well as treatment. This is analogous to our robustness check of Table 5 (above) and we present the results of this check in the table below.

Table 10: Regression results using interaction of LOCI and operator – Table 6 (treatment-by-treatment analysis with no log transformation)

LOCI by operator	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
BMI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

5.23 Similarly to the results with a log transformation (see paragraph 5.16 above), the results show that most operators do not exhibit a significant relationship between price and concentration across treatments. None of the LOCI coefficients by treatment for BMI are statistically significant. The test does report statistically significant relationships for Nuffield (for the CCSD codes E0260, G3080, M6530, W3712 and W4210), Spire (W3712 and W4210) and Ramsay (J1830).

5.24 The results suggest that for most operators and treatments, there is no significant relationship between price and concentration.

5.25 In Annex B, we show that there is no relationship between price and concentration for these focal treatments once we conduct the analysis for all operators excluding Nuffield.

5.26 Overall, this suggests that the CC's finding that there is a statistically significant and market-wide relationship between price and concentration for treatments E0260, G3080, J1830, W3712 and W4210 is not robust because statistical tests suggest that the CC's specification restriction which requires the LOCI parameter to be equal and non-zero for all operators is not appropriate for these treatments.

Exogeneity of the covariates

5.27 Next we consider separating the coefficients on LOCI by hospital operator (i.e. creating interaction variables between operator dummies and the LOCI variable) and also creating separate instruments for each operator for CC's specifications from Table 7 in the PCA working paper (endogeneity analysis). We set out our findings in the table below.

Table 11: Instrumental variable regression results (CC's Table 7) using LOCI-operator interaction

LOCI by operator	(7) Instrument – distance to own		(8) Instrument – distance to competitor		(9) Instrument – distance to own and competitor (2SLS)		(10) Instrument – distance to own and competitor (GMM)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: [1] The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. [2] The operator LOCI instruments have been created by multiplying the LOCI instrument by a dummy variable for each hospital operator. [3] All other variables follow the CC's specifications.

5.28 First we note the HCA results in column (10). These may be affected by the same concerns we express in Section 6 with regard to the use of both instruments. We note in particular the relatively small number of HCA observations in the dataset and the very significant variation in the estimated parameter values for HCA across the specifications. However, we also note that the results from column (8) indicate the HCA results are not solely driven by the use of both instruments.

5.29 Second we note that the results might potentially suggest that Nuffield has significantly different results from the other operators. To test this proposition further, we have used (i) the CC's standard IV specification restricting the LOCI coefficient to be equal for four operators (and excluding Nuffield), and also (ii) performed the analysis separately using only Nuffield data. We report the results in the table below.

Table 12: Instrumental variable regression results for all operators excluding Nuffield and separately for Nuffield

Specification	(7) Instrument – distance to own		(8) Instrument – distance to competitor		(9) Instrument – distance to own and competitor (2SLS)		(10) Instrument – distance to own and competitor (GMM)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Nuffield only	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
All except Nuffield	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The variables follow the CC's specifications. The GMM estimate is not provided because the weighting matrix was unable to be calculated for the selected subset of data. We have not had time to explore the reasons the regression package is dropping LOCI in this case, but note that it may indicate an identification problem.

5.30 Strikingly, these results indicate that there is no longer any statistically significant coefficient for the instrumented LOCI variable under any of the instrumental variable specifications estimated by the CC when we exclude Nuffield data from the dataset. The CC's results are again not robust to dropping the Nuffield data.

5.31 Moreover, when we consider Nuffield only, we find that the instrumented LOCI variable is significant in column (8) (and indeed in column (9)). These findings are consistent with our earlier results for CC's baseline specification (i.e. without considering endogeneity), where Nuffield is driving the CC's results showing a statistically significant relationship between price and concentration.

The effect of missing invoices on the LOCI

5.32 The CC considers the effect of hospitals with missing invoices when estimating the relationship between concentration and prices – see Table 8 in the PCA working paper.

5.33 There are 50 hospitals which have missing invoice data in the Healthcode database. It is possible that these hospitals may contribute towards biasing the weighted market shares (LOCI) in regions where these hospitals draw patients from and therefore the CC sought to test for this potential bias.

CC results

5.34 The CC identifies 66 hospitals which are most likely to be affected by the issue of hospitals with missing invoices in their local area, and the CC re-runs the analyses excluding these potentially affected hospitals. The CC's results for this robustness check are set out in the table below.

Table 13: CC's PCA results from the Data Room – Table 8 (removing affected hospitals)

	(3)	(11) Excluding potentially affected hospitals
	Coefficient	Coefficient
LOCI	[✂]	[✂]
[Other covariates not shown]		
R-squared	[✂]	[✂]
N	[✂]	[✂]

Source: CC's PCA results from the Data Room.

5.35 These results suggest that excluding hospitals potentially affected by the missing invoice problem leads to a statistically significant LOCI coefficient which is larger in magnitude. There is also a significant decrease in the number of observations – the sample size used for the regression drops from [✂] to [✂] – which indicates that the issue affects a significant proportion of the sample.

Compass Lexecon robustness check

5.36 As part of our robustness checks involving operator interaction terms, we have analysed the effect of excluding hospitals potentially affected by the missing invoice problem by operator. Specifically, by interacting the LOCI variable with hospital operator dummies we can see the effect of the missing invoice problem on the LOCI coefficient for each operator. The results are set out in the table below.

Table 14: Regression results using interaction of LOCI and operator – Table 8 (removing affected hospitals)

LOCI by operator	(3) Benchmark		(11) Excluding potentially affected hospitals	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

5.37 The results suggest that once again the exclusion of hospitals most affected by the missing invoices leads to non-statistically significant LOCI coefficients for all operators except for Nuffield, which shows a statistically significant and negative LOCI coefficient.

5.38 We note that all HCA hospitals are potentially affected by the missing invoices issue and they are therefore necessarily excluded them from this analysis in both the CC's and our own results.

Other modifications relating to the data

5.39 The CC has conducted additional robustness checks in Table 9 of the PCA working paper, labelled as "other modifications to the data". We summarise below the CC's results and show that under our further robustness checks, the effects identified by the CC do not hold and there is no relationship between price and concentration under these alternative specifications.

CC results

5.40 The CC has considered whether the following sensitivities would affect the finding of a relationship between price and concentration: (i) not excluding irregular episodes, (ii) including all treatments, and (iii) allowing for more disaggregated regional effects (NUTS3 regional dummies). The results of these robustness checks are set out in the table below.

Table 15: CC's PCA results from the Data Room – Table 9 (other modifications to the data)

	(3)	(12) No irregular episode exclusions	(13) All treatments	(14) NUTS3 regional dummies
LOCI	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]	[✂]	[✂]	[✂]	[✂]
R-squared	[✂]	[✂]	[✂]	[✂]
N	[✂]	[✂]	[✂]	[✂]

Source: CC's PCA results from the Data Room.

5.41 The CC's results suggest that there is a negative and significant relationship between the LOCI concentration measure and prices, when considering these other sensitivities for the PCA analysis.

Compass Lexecon robustness tests

5.42 We have considered whether these CC sensitivity checks results are robust. In particular, we considered whether the results change when we allow for different price-concentration relationships by hospital operator – see the results in the following table.

Table 16: Regression results using interaction of LOCI and operator – Table 9 (other modifications to the data)

LOCI by operator	(3)	(12) No irregular episode exclusions	(13) All treatments	(14) NUTS3 regional dummies
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

5.43 The results follow the same pattern as in our previous robustness checks – i.e. Nuffield shows a statistically significant negative relationship between price and the LOCI concentration variable, while the other operators do not show statistically significant relationships between price and concentration. This again indicates that the CC's results are being driven by the data for a single operator – Nuffield.

5.44 As we show in Annex C, there is no statistically significant relationship between price and concentration (whether in the baseline specification or under the CC's robustness checks corresponding to Tables 5-9 in the PCA working paper) once we exclude the data for Nuffield and analyse the data for just the other operators.

Conclusion

5.45 In summary, our mild generalisation of the CC's baseline specification (i.e. using CC's model with added interaction terms for LOCI by operator) appears to consistently indicate there is no relationship between price and concentration - except possibly for Nuffield - for the various model specifications and robustness checks considered by the CC.

Section 6

Assessing the CC's arguments on causality

6.1 In this chapter we consider the CC's third finding in the PCA working paper that the estimated price-concentration relationship is **causal** whereby concentration increases causes price increases. Specifically, the CC writes in paragraph 74 of the PCA: *"This indicates that reductions in local market concentration, as measured by LOCI, would likely **lead to** price reductions."* (our emphasis)

6.2 In summary, we do not find the discussion of this very significant question in either the PCA working paper or the Annotated Issues Statement convincing.

6.3 The CC effectively begins its discussion by asserting that the inclusion of regional dummy variables in the regression equation obviate concerns around causality. We do not find this a convincing argument since – for example – hospital quality may clearly (i) vary across hospitals within region and also (ii) be correlated with hospital market share and also prices.

6.4 We further considered the CC's estimates reported in Table 7 where the CC attempts to control for endogeneity bias – that is a situation where the CC's assumption 2 fails. We consider that checking robustness to such possibilities is likely to be important. However, we do not agree with the CC's conclusions that its results in this regard are at all robust.

6.5 Specifically, we find that:

i) *Exclusion of individual hospitals*: in the CC's preferred specification (Table 7, specification 10) in the PCA working paper we tested whether excluding the patient episode data from one hospital at a time would change the CC's conclusions. Specifically we considered hospitals with more than 300 patient episodes in the CC's dataset and dropped each hospital one at a time before repeating the CC's analysis. We found that the LOCI coefficient became statistically insignificant when excluding a variety of individual hospitals. **That is, significant elements of the CC's results appear to depend on the presence or absence of a single hospital from the dataset.** For illustration, these results suggest that not only does dropping all Nuffield data from the CC's analysis change the CC's conclusions (as shown in Section 4), so does removal of a **single** Nuffield hospital such as Nuffield Glasgow. The same can be said of Nuffield Exeter or Nuffield Bournemouth. Moreover, the

statistical significance of the results also goes away when we remove Spire Cardiff or Spire Edinburgh or Spire Norwich, or indeed BMI Ross Hall or BMI Three Shires.

ii) *The benchmark Hotelling model suggests that the CC's instrumental variables are not likely to be valid*: In the Hotelling model of spatial competition, pricing and distance are interrelated and the optimal price a firm sets would ordinarily be related to the distance from its competitors. The Hotelling model would suggest that the distance between rival hospital should be accounted for in the pricing regression and therefore it could and should not simultaneously be used as an instrumental variable for concentration (LOCI).

iii) *First stage regression results*: When considering IV and 2SLS regression results (or indeed GMM regression results), standard practice involves reporting and examining first stage regression results. The CC's first stage regression results show that the driving distance to a hospital in the same network is found to have a statistically insignificant positive relationship with LOCI (specification 7, CC Table 7), while the drive-distance to a hospital in a competing network has a negative and statistically significant relationship with LOCI (specification 8, CC Table 7). It is only when both instruments are used (specifications 9 and 10, CC Table 7) that the own-distance instrument becomes statistically significant in the first stage regression. This finding of a relationship between the driving distance to own hospital and network LOCI is not robust (in the sense that it does not emerge in specification 7) which begins to indicate that the correlation between this instrument and LOCI is weak. Importantly, the instrument is found to contribute only a tiny amount to the extent to which the first stage regressors can collectively explain variation in the instrumented variable LOCI. This is consistent with the instrument 'driving distance to a hospital in the same network' being a potentially 'weak' instrument for LOCI.

iv) *Testing relevance of instruments*: The CC uses two instruments for LOCI: the distance to nearest hospital under common ownership and the distance to nearest rival hospital. The CC concludes that its endogeneity tests suggest that instrument (1) 'may not be a relevant instrument' (paragraph 54, PCA) while instrument (2) 'is a relevant instrument'. The CC also finds that the null hypothesis that both instruments are jointly irrelevant is rejected in specifications (9) and (10) – i.e. specifications which include both instruments. The results in the CC's Table 7 are therefore indicating that only the addition of a wholly or largely irrelevant instrument is giving the CC its statistically significant results. A test that confirms both instruments are jointly relevant certainly does not logically imply that one of them is not irrelevant. In sum, overall the appropriate inference from the first stage regression results and the CC's statistical tests in Table 7 – specifically the test that the CC's 'instruments are irrelevant' - seems likely to be that specifications (9) and (10) should be rejected in favour of specification (8). We note in particular that the CC's specification (8) finds no statistically significant relationship between price and LOCI. Thus what appears

to be happening is that the CC is adding a wholly or largely irrelevant instrument and doing so is significantly changing the statistical significance of the results the CC is obtaining in Table 7. Such a result is troubling as weak instruments are known to have a significant potential to both (i) cause significant bias in real-world samples and also (ii) magnify the bias caused by small violations of the assumptions required for an estimator to be a good one (exclusion restrictions).

v) *Interaction of operators with LOCI*: We consider separating the coefficients on LOCI by hospital operator (see Table 11 in Section 5). We find that there is no longer any statistically significant coefficient for the instrumented LOCI variable under any of the instrumental variable specifications estimated by the CC when we exclude Nuffield data from the dataset. The CC's results are again not robust to dropping the Nuffield data. Moreover, when we performed the analysis for Nuffield's data only, the instrumented LOCI variable is significant under CC's specifications (8) and (9). Such results are consistent with the results in the CC's Table 10 and our earlier conclusions that Nuffield's data is driving the CC's results in the full sample.

Interpretation of the regression analysis - causation

6.6 First we note that the language on this point in the Annotated IS is considerably more measured than in the PCA working paper. Specifically, the CC rightly emphasises in the Annotated IS that it is important to distinguish between correlations and causal effects[43] although the CC also states that *"[d]epending on the interpretation of the regression, [the] correlation can imply causation – i.e., changes in concentration cause change in price"*.[44] If the emphasis in reading this statement is placed on the word 'can', then it is consistent with our own views. As Davis and Garces (2010) describe:[45] *"It is important to stress that a regression equation does not distinguish correlation and causality and estimation will usually pick up correlations even if there is absolutely no causal relationship between the variables".*

6.7 In contrast, in the PCA working paper the CC asserts at paragraph 12 of that paper that when its assumptions 1 and 2 hold *"then the parameter β can be interpreted as the causal effect of concentration on price."* This is a bare assertion and involves no discussion of the realities of the dataset at hand, the available dataset (and likely omitted variables), the types of data variation available (across hospitals, across patients within a hospital etc). The word 'causal' does not appear further in the PCA working paper. This is far from an adequate basis for a serious investigation of such a significant topic.

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43 See Annotated IS, Appendix B, Annex 3, slide 15.

44 See Annotated IS, Appendix B, Annex 3, slide 15.

45 Davis, P. and E. Garcés. 2010. "Quantitative Techniques for Competition and Antitrust Analysis," Princeton University Press, page 89, Chapter 2.

6.8 It is well known that there are a variety of potential reasons beyond market power which may mean that market shares and prices are correlated. These include in particular: (i) costs (high cost areas may charge high prices and attract few competitors) and (ii) product quality (high quality hospitals may charge relatively high prices and achieve a high market share). Thus to properly make a finding that a correlation between market share and price is indicative of a causal relationship the CC would clearly need to consider the various potential explanations for such a finding.

6.9 The CC does provide some discussion of its assumptions 1 and 2 which it believes are sufficient for establishing a causal relationship between price and concentration.

6.10 In terms of its discussion of assumption 1, the CC's tests of assumption 1 (functional form) amount to only examining two distinct specifications (i) linear versus taking logs of the variables and (ii) a division of the data by treatment. This constitutes a very limited test of functional form. For example, the CC provides no tests of whether it would be appropriate to include other variables in the specification (such as the distance to nearby hospitals for example) or for non-linearities other than logs. Moreover, the CC's test is an unconventional one in the sense that the CC does not test for departures from its baseline model using the full dataset – i.e. all the information the CC has. Rather it divides the dataset into different parts and then uses the data part-by-part. More conventional functional form tests consider whether the model successfully fits the full dataset. This is not quite the same as asking whether we get the same relationship when we apply the model to a subset of the data. We have already mentioned that the CC's baseline model fails the conventionally applied RESET test of model specification. And also that when looking at subsets of its dataset, the CC does not consistently get the same answer as that provided by its baseline model. In Table 5 the CC finds only half of the LOCI coefficients (4 out of 8) are statistically significant while the other half are not. The results also show the R-squares fall significantly relative to the baseline model. In Table 6 the CC finds just over half (5 out of 8) are statistically significant while the others are not.

6.11 In terms of its discussion of assumption 2, the CC promptly dismisses conventional economic concerns around endogeneity at around paragraph 46 of the PCA. The authors of the academic paper to which the CC refers in terms of the LOCI measure argue: *"LOCI is likely endogenous, for the usual reasons. Market shares are not likely to be independent of unobserved factors that determine prices*".[46] However, the CC comes promptly to the view that "*any endogeneity bias is likely to be limited*" and that *"LOCI and the other covariates are likely to be exogenous*". The CC's "*reasoning relates primarily to the use of regional dummy variables*", arguing that this will "*capture any differences in the average market conditions hospitals face in different regions – this will include, for example, differences in population*."

[46] Akosa Antwi, Y.O.D., Gaynor, M. and W.B. Vogt. 2006. "A competition index for differentiated products oligopoly with an application to hospital markets", unpublished manuscript, page 12.

6.12 We do not believe this primary reasoning is convincing. The reason is that regions are not economic markets but contain groups of local markets which may have quite different characteristics. For instance some are big while others are small, and if the omitted variable were, say, local population then that would vary within any given region and so regional dummy variables would not properly control for it. Similarly, regional dummy variables do not obviously address concerns about, say, local hospital quality driving local high shares and also high local prices since hospital quality and hospital self-pay prices will vary within region. Indeed, the presence of regional dummy variables in the regression suggests that the CC's identification of the LOCI parameter will primarily be exactly from variation across price and concentration within the regions. Ultimately on this point the CC simply asserts without reasoning or justification that: "*These within-region factors are thought to be limited, and thus unlikely to induce substantial endogeneity bias*".[47]

6.13 There is no discussion of the role of measurement error of explanatory variables (except for one aspect of the measurement of LOCI) which may also introduce endogeneity bias.[48] Yet as we discussed in paragraphs 3.13 to 3.18, the same issue is likely to be at play for a number of other included variables such as episode cost.

6.14 We note that any attempt to find a causal relationship between price and market share measures such as LOCI is likely to require an identification strategy – usually at least in the form of a valid instrument for concentration.

6.15 It is well known that correlation does not imply causation. Therefore, even if a relationship (correlation) is found between price and concentration, it should not immediately be interpreted as a causal relationship between concentration and prices (i.e. higher prices as a result of higher concentration). Prices are in reality influenced by many factors and both prices and market concentration may be correlated with variables that are omitted from the analysis through lack of data.

6.16 The CC notes in the Annotated IS that its current view is that *"PCA results may approximate a causal relationship between price and concentration, but [the CC is] considering this further"*.[49] The CC did not mention any reasoning or evidence on which this view is based. The traditional economic view is that market shares and prices may be correlated for reasons that have nothing to do with market power. Thus to come to a defensible view about the causal nature of the relationship, the CC would need to engage in a strategy which attempted to distinguish the market power explanation of a correlation from those other potentially less problematic explanations – which include the possibility that cost and/or quality is introducing a correlation between price and concentration that is not related to

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47 PCA working paper, paragraph 46.

48 See for example the discussion in Davis, P. and E. Garcés. 2010. "Quantitative Techniques for Competition and Antitrust Analysis," Princeton University Press, at section 2.1.4.4 on page 86.

49 See Annotated IS, Appendix B, Annex 3, slide 32.

market power.

A simple robustness check on the instrumental variable specifications: exclusion of individual hospitals

6.17 We have also tested the robustness of the CC's conclusions by excluding individual hospitals from the data and conducting the CC's endogeneity analysis without any further modifications.

6.18 We identified hospitals with more than 300 episodes in the CC's cleaned dataset and tested the impact of excluding them individually on the CC's preferred results. Specifically, we considered specification (10) from Table 7 in the PCA working paper. We summarise the results of this analysis in the following table.

Table 17: CC's specification (10) excluding specific hospitals (GMM)

CC's specification (10) excluding the data for:	Estimator	LOCI	R-squared	N
Nuffield Bournemouth	GMM	[✂]	[✂]	[✂]
Spire Bristol	GMM	[✂]	[✂]	[✂]
Spire Bushey	GMM	[✂]	[✂]	[✂]
Spire Cardiff	GMM	[✂]	[✂]	[✂]
Spire Edinburgh	GMM	[✂]	[✂]	[✂]
Nuffield Glasgow	GMM	[✂]	[✂]	[✂]
Nuffield Exeter	GMM	[✂]	[✂]	[✂]
Nuffield Warwickshire	GMM	[✂]	[✂]	[✂]
Spire Manchester	GMM	[✂]	[✂]	[✂]
Spire Norwich	GMM	[✂]	[✂]	[✂]
Spire Parkway	GMM	[✂]	[✂]	[✂]
Spire Portsmouth	GMM	[✂]	[✂]	[✂]
Spire Southampton	GMM	[✂]	[✂]	[✂]
HCA Princess Grace	GMM	[✂]	[✂]	[✂]
BMI Goring Hall	GMM	[✂]	[✂]	[✂]
BMI Ross Hall	GMM	[✂]	[✂]	[✂]
BMI The Alexandra	GMM	[✂]	[✂]	[✂]
BMI Three Shires	GMM	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Notes: (i) the n/a on the LOCI column for these specifications indicates that Stata automatically chose to drop LOCI presumably because it was highly co-linear with the other variables also included in the regression.

6.19 In short, we find that the results for the CC's preferred specification (10) **are not robust to excluding the data of a range of individual hospitals one by one** - the LOCI coefficients vary in magnitude by almost [✂]% (from [✂] to [✂]) and becomes statistically insignificant for many of the hospital exclusions.

6.20 For instance, when we exclude Nuffield Glasgow hospital from the data, the LOCI coefficient falls from [✂] (CC's reported statistically significant result under specification (10)) to [✂] and it becomes statistically indistinguishable from zero.

6.21 This is additional evidence consistent with the proposition that the CC's results are simply not robust.

The theoretical validity of the CC's instrumental variable strategy in the benchmark Hotelling model

6.22 In the Hotelling model of spatial competition, pricing and distance are interrelated.[50] In fact, in this model with a uniform mass of consumers and two suppliers, demand at one of the locations can be shown to be given by the expression:

$$D_1(p_1, p_2, L_1, L_2) = \frac{S(p_2 - p_1)}{2t(L_2 - L_1)} + S(\frac{L_1 + L_2}{2}) \qquad (1)$$

where L_i represents the location of the hospital on the unit interval (where consumers are presumed to live), t represents the transport cost, S represents the total mass of consumers and p_i is the price of good i.

6.23 The CC has considered separately, as is standard in price concentration analyses, that market concentration (as a proxy of competition) is related to pricing. If we take a standard profit maximising single product firm, we find that the price which optimises profits is as follows:

$$p_1{}^* = c - D_1(p)[\frac{\partial D_1}{\partial p_1}]^{-1} \qquad (2)$$

where p_1 is the price, D_1 is the demand for the product given by (1), and c is the constant marginal cost of production.

6.24 The optimal price of a firm thus depends on the sensitivity of demand to changes in own-prices, i.e. the $\frac{\partial D_1}{\partial p_1}$ term. If we assume that demand for the good follows the Hotelling model, we find the following relationship (from equation (1)):

$$\frac{\partial D_1}{\partial p_1} = \frac{-S}{2t(L_2 - L_1)}$$

6.25 At a symmetric equilibrium where prices are equal so that $p_2 - p_1 = 0$, we can write $D_1(p_1, p_2, L_1, L_2) = \frac{S(p_2 - p_1)}{2t(L_2 - L_1)} + S\left(\frac{L_1 + L_2}{2}\right) = S\left(\frac{L_1 + L_2}{2}\right)$. Thus our analysis suggests that the optimal price a firm sets would ordinarily be related to the distance from its competitors:

$$p_1{}^* = c - S\left(\frac{L_1 + L_2}{2}\right)\frac{2t(L_2 - L_1)}{-S} = c + t(L_1 + L_2)(L_2 - L_1) = c + t(L_2^2 - L_1^2)$$

[50] See Davis, P. and E. Garcés. 2010. "Quantitative Techniques for Competition and Antitrust Analysis," Princeton University Press, page 472.

6.26 The extent of the relationship is affected by the scale of transport costs t. This analysis suggests that distance to competitors should be expected to affect pricing and so should be included as a relevant regressor in the pricing equation and therefore should not be excluded from our analysis. This is intuitive – prices ordinarily depend to a greater or lessor degree on how close substitute products are.

6.26 The extent of the relationship is affected by the scale of transport costs t. This analysis suggests that distance to competitors should be expected to affect pricing and so should be included as a relevant regressor in the pricing equation and therefore should not be excluded from our analysis. This is intuitive – prices ordinarily depend to a greater or lessor degree on how close substitute products are.

6.27 The CC's instrumental variable (IV) approach requires that the CC have an instrumental variable that is (i) correlated with the variable being instrumented (LOCI) and (ii) should not itself appear in the pricing model. If it should appear itself, then it could and should not simultaneously be used as an instrumental variable for the CCs concentration measure. The Hotelling model directly suggests that the distance variables (or functions of them) should indeed appear as regressors in the PCA and so would not be valid IV's for LOCI.

CC's tests of its instrumental variables

6.28 The CC performs several statistical tests to check for endogeneity of the LOCI variable when using instruments. These tests include Wooldridge's robust score test, the difference-in-Sargan statistic for GMM models, and the Hansen J-statistic.[51]

6.29 These tests are important because instruments must meet a number of conditions in order to solve the problem of endogeneity. These conditions include the following:

a) the instrument is correlated with the variable being instrumented (i.e. LOCI);

b) the instrument is uncorrelated with the unobserved term in the regression; and

c) the instrument is not included as a covariate in the regression equation.

6.30 The tests above can help identify whether the instruments selected meet conditions (a), (b) and (c). We have also expanded on the CC's checks for the selected instrumental variables. In this section we set out the CC's results (presented in Table 7 of the PCA working paper) as well as the results of our further robustness analysis.

[51] PCA working paper, Table 7.

CC results

6.31 The CC has considered whether it should be concerned that the LOCI measure of concentration used in the PCA may be correlated with one or more unobservable(s) in the pricing equation. In order to control for this, an instrumental variables approach can be used.

6.32 The CC has used as instruments two different variables which the CC believes meet the requirements of an instrument as set out above. The CC uses the following instruments:

(1) the distance from the hospital being analysed to the nearest hospital in the same network;

(2) the distance from the hospital being analysed to the nearest hospital in a competing network; and

(3) a combination of (1) and (2).

6.33 The CC's rationale for using distance as an instrument is that *"hospitals that are farther away from rival hospitals and/or closer to hospitals under common ownership are likely to have higher market shares and lower LOCI (producing a correlation between the instruments and LOCI)"*.[52]

6.34 We first make a note that the CC seems to have mislabelled the IV regression results in Table 7 of the PCA working paper. Specifications (7) and (8) seem to have the labels inverted, as specification (7) uses the distance to the nearest hospital under common ownership, and specification (8) the distance to the nearest rival hospital as instruments. The CC's results reported in Table 7 are accordingly reversed.

6.35 We set out the CC's results from the Data Room corresponding to the Table 7 from the PCA working table below. As can be seen the key pattern in this table is that the LOCI coefficient in columns (7) and (8) are not statistically significant while those in (9) and (10), which use both instrumental variables, are found to be statistically significant.

[52] PCA working paper, paragraph 48.

Table 18: CC's PCA results from the Data Room – Table 7 (endogeneity analysis)

	(3)	(7) *IV, distance to nearest hospital under common ownership*	(8) *IV, distance to nearest rival hospital*	(9) *IV, both instruments*	(10) *GMM, both instruments*
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]					
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]
N	[✂]	[✂]	[✂]	[✂]	[✂]
Test of null hypothesis that instruments are irrelevant (F-statistic)		[✂]	[✂]	[✂]	[✂]
Test of null hypothesis that the covariates are exogenous (p-value)		[✂]	[✂]	[✂]	[✂]
Test of null hypothesis that the instruments are exogenous (p-value)					[✂]

Note: In the PCA working paper, the labels of specifications (7) and (8) seem to have been inverted.

Source: CC's PCA results from the Data Room.

The first stage regression results

6.36 We first report the first-stage results of the CC's instrument specifications for its Table 7. When considering IV and 2SLS regression results (or indeed GMM regression results), standard practice involves reporting and examining first stage regression results.

First-stage instrument regressions

6.37 We set out the first-stage results of the CC's 2SLS instrument regressions in the table below.

Table 19: First-stage IV regression results

Variables	Instrument (1)		Instrument (2)		Instrument (3)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Drive-distance to own hospital	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Drive-distance to competing hospital	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]						
Constant	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	
N	[✂]	[✂]	[✂]	[✂]	[✂]	

Source: Compass Lexecon analysis.

Note: The dependent variable in these first-stage regressions is the LOCI variable. All other control variables are also included in the first-stage regression.

6.38 These results show that the drive-distance to own hospital, that is a hospital in the same network, is found to have a statistically insignificant relationship with LOCI when considered alone (column labelled 'Instrument (1)'), while the drive-distance to a hospital in a competing network has a negative statistically significant relationship with LOCI (column labelled 'Instrument (2)'),

6.39 It is only when both instruments are used (specifications 9 and 10, CC Table 7) that the own-distance instrument becomes statistically significant ('Instrument (3)'). This finding of a relationship between the driving distance to own hospital and network LOCI is not robust (in the sense that it does not emerge in specification 7). The first stage regression results therefore suggest that the choice of instrument set is significant and it is therefore important that the CC should consider seriously whether the right specification involves both instruments or not.

6.40 In that regard, in column (3) the first stage regression results do indicate that both instruments are statistically significantly correlated with LOCI conditional on the available included control variables. However, the results in column (1) begin to indicate that the correlation between 'Drive-distance to own hospital' and LOCI is not strong and the fact that in moving from column (2) to column (3) we are adding this instrument 'Drive-distance to own hospital' but only increasing the first-stage R-squared by 0.029 is informative. It tells us that instrument (1) is explaining very little variation in LOCI that is additional to instrument (2), 'Drive-distance to competing hospital'. While statistically significant, the conditional correlation between the 'Drive-distance to own hospital' and LOCI (conditional on all the other covariates) is actually very small. In addition, if there are any excluded variables then the conditional correlation the CC is finding may be a spurious one.

6.41 We conclude that there are some significant markers in the first stage regression results that are consistent with the 'Drive-distance to own hospital' being a 'weak' instrument. We discuss the potential role and implications of 'weak' instruments in the next section.

The CC's tests of relevance of the instruments

6.42 The CC concludes that its endogeneity tests suggest that instrument (1) 'may not be a relevant instrument' (paragraph 54, PCA) while instrument (2) 'is a relevant instrument'. The question then becomes what to make of the CC's finding that the null hypothesis that *both* instruments are jointly irrelevant are rejected in columns (9) and (10). The CC appears to prefer columns (9) and (10) but this does not appear to be an obviously statistically legitimate inference. In particular, if the first instrument is irrelevant then when we use it to over-identify the model in columns (9) and (10) we are assuming implicitly that we have some power of identification when in reality we have what appears to be a largely or wholly irrelevant instrument. The CC does not explain why it thinks that is a legitimate statistical activity.

6.43 Weak instruments are known to have the potential to both cause bias in small samples and also magnify the bias caused by small violations of exclusion restrictions.[53] So on the face of it, including apparently largely or wholly irrelevant instruments appears to be an odd thing to do. In short, the fact that the CC rejects the null hypothesis that *both* instruments are irrelevant (in 9 and 10) does not in any way contradict the CC's earlier finding that one of them is irrelevant. Overall, the appropriate inference seems to be that specification (7) and also the over-identified specifications (9) and (10) should be rejected in favour of (8) on the basis of the CC's 'instruments are irrelevant' tests in column (7) and the very small amount of additional explanatory power in the first stage regressions provided by instrument (1).

6.44 In this regard we note that only columns (9) and (10) report a statistically significant relationship between price and concentration at the 5% or below level. Price-concentration relationships reported by the CC for columns (7) and (8) are not statistically significant.

53 See in particular the discussion in Bound, Jaeger and Baker (1995) "Problems with Instrumental Variables Estimation when the Correlation Between the Instruments and the Endogenous Explanatory Variables is Weak" *Journal of the American Statistical Association*, 90 (June): 443-450.

6.45 Finally we note that the CC's contention at paragraph 53 is unsafe. Specifically, the CC contends that: *"The general increase in the magnitude of the estimated price-concentration relationship, relative to the baseline estimates, indicates (on the basis of the distance instruments) that any bias stemming from endogeneity is likely downwards - ie the baseline regression may understate the true price-concentration relationship."* However, we have shown that one of the CC's instruments is not likely to be valid while the other is likely largely or wholly irrelevant. And of course, we found that the CC's IV results are wildly sensitive to small changes in either the data (removing individual hospitals) and the model (allowing hospital operator specific LOCI parameters.)

Section 7

Using self-pay LOCI instead of a LOCI based on data for insured patients in the PCA

7.1 The CC has used the LOCI measure based on insured patients in the PCA. In this section we discuss another approach to calculating LOCI following the CC's methodology but based on data for self-pay patients instead of insured patients.

7.2 As with the insured patient LOCI, our results indicate that Nuffield data is driving the finding of a significant price-concentration relationship and that once a differential relationship by operator is allowed for in the data there is no indication of a statistically significant relationship between price and concentration for any hospital operators other than perhaps Nuffield.

7.3 We have discussed the likely usefulness of LOCI as a measure of concentration in our previous submission to the CC[54] and we do not repeat those comments here.

Using self-pay LOCI instead of LOCI based on data for insured patients in the PCA

7.4 Both measures of concentration used by the CC in the PCA (fascia counts and LOCI) are based on Healthcode data for insured patients[55] and not self-pay data, which is inconsistent with the price measure which is for self-pay patients. Thus, in its PCA, the CC actually analyses the relationship between self-pay prices and concentration measures based on data for insured patients. In other words, the CC analyses how self-pay prices vary with hospitals' market share of insured patients.

7.5 The CC's argumentation is purely pragmatic in nature. Namely that:[56]

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54 Compass Lexecon paper: "Comments on CC's annotated issues statement: The CC's approach to measuring concentration", dated 17 April 2013.

55 Annotated IS, Appendix B, Annex 3, slide 13.

56 Annotated IS, Appendix B, Annex 3, slide 13. The CC reiterated this argument in the PCA working paper (paragraph 18) stating that "[the Healthcode dataset] represents the most consistent and complete picture of patient journeys that is available to [the CC]".

a. *"The Healthcode data (on insured patients) provides a more complete and consistent picture of patient journeys than the hospital data (on self-pay patients)"*; and

b. *"Concentration measures calculated on the basis of insured patients are expected to be highly correlated with those calculated on the basis of self-pay patients."*

7.6 Part (a), while true is not in itself a compelling reason to use the Healthcode data unless the self-pay data is insufficiently complete to be reliable. Part (b) may potentially be true, but there may also be significant differences in concentration at the individual hospital level.

7.7 The Annotated IS offers no explicit support for an assumption that concentration measures calculated on the basis of insured patients are expected to be highly correlated with those calculated on the basis of self-pay patients. It is not immediate that this would be the case. For example, where insurers have the ability to send their patients to their preferred consultants/hospitals within their network which could vary by specialism, a concentration measure based on insured patients would inevitably reflect to some degree the network design and patient direction preferences of insurers (which are irrelevant when analysing self-pay patients).

7.8 There is also evidence in the surveys conducted by the CC that self-pay patients are willing to travel further for treatment than insured patients.[57] This is evidence indicating that the concentration measure calculated from data for insured patients would not necessarily reflect the actual concentration in terms of self-pay patients.

7.9 The CC's measure of concentration (based on insured patients) is thus only a proxy for the concentration measure which the CC would ideally like to include in the PCA, i.e. concentration based on data for self-pay patients.

7.10 We have therefore analysed the LOCI measure based on the available self-pay data for the five main hospital groups in order to identify any potential price-concentration relationship based on self-pay data. We did not have access to the "raw" dataset before the CC's cleaning adjustments, and therefore we could only base our calculation on the cleaned dataset available in the Data Room (which was significantly more limited in terms of number of observations).

7.11 In this section we set out the approach to calculating LOCI based on self-pay episodes and we show the PCA results incorporating this LOCI measure of concentration based on self-pay episode data.

7.12 We find similar results as those obtained for the CC's baseline specification, i.e. the results suggest that Nuffield has a statistically significant price-concentration relationship while the other operators do not.

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[57] GfK. 2012. "Private Healthcare Market Investigation. Surveys of Patients – November/December 2012. Conducted on behalf of the Competition Commission," slide 18.

Calculation of LOCI based on self-pay data and PCA results

7.13 In the Data Room the CC provided its calculation of the insured LOCI for each hospital. Since the CC's overall dataset includes both insured and self-pay episode data, we adjusted the CC's analysis files to calculate LOCI based on self-pay data[58] and used this calculated "self-pay LOCI" for a PCA sensitivity analysis.

7.14 We note that the Healthcode dataset includes considerably more patient episodes compared to the self-pay dataset. As a result, the number of episodes on which the self-pay LOCI is based (114,688 episodes) is lower than the number of episodes used for the calculation of LOCI from the insured data (582,451 episodes). The mean number of episodes per hospital for the self-pay LOCI (770 episodes) is also lower than the insured data (3,367 episodes).

7.15 We set out the PCA results using self-pay LOCI as a measure of concentration in the table below.

Table 20: PCA results using self-pay LOCI – corresponding to Table 3 in the PCA working paper

	(1)		(2)		(3)	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	
N	[✂]	[✂]	[✂]	[✂]	[✂]	

Source: Compass Lexecon analysis.

7.16 These results show that although the self-pay LOCI coefficient is negative and significant under the baseline CC specification, it is lower in magnitude compared to the CC's baseline specification (3) which uses LOCI based on insured patients.

7.17 We have also analysed the self-pay LOCI concentration measure when allowing the LOCI coefficient to be operator specific. The results are set out in the table below.

[58] We simply chose to keep the self-pay data rather than the insured data in the do-file 'create_lookup_LOCI.do' which calculates the LOCI concentration measure.

Table 21: PCA results using self-pay LOCI with operator interaction – corresponding to Table 3 in the PCA working paper

	(1)		(2)		(3)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

7.18 These results show that the only statistically significant price-concentration relationship using the self-pay LOCI is once again found for Nuffield, with each of the other operators lacking a statistically significant LOCI coefficient. Detailed regression results of other specifications using the self-pay LOCI are set out in Annex E.

7.19 To further verify whether Nuffield is driving the results, we have performed statistical tests on whether the restriction used by the CC, which requires the LOCI parameter to be equal for all operators, is appropriate. The results are set out in the table below.

Table 22: Tests for restricting the specification to require the LOCI coefficient to be equal for all operators (self-pay LOCI)

Null hypothesis	(1)		(2)		(3)	
	F-statistic	p-value	F-statistic	p-value	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
All except Nuffield = 0	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The table provides the results of an F-test of significance asking whether (i) the LOCI coefficients for all the operators are jointly equal to zero and (ii) whether the LOCI coefficients for all the operators except Nuffield are jointly equal to zero. The results suggest that the answer to the first question is 'no' and the answer to the second question is 'yes'.

7.20 These test results again suggest that it is inappropriate to restrict the specification to require the LOCI parameter to be equal for all operators when estimating the price-concentration relationship using the self-pay LOCI concentration measure. The results are again consistent with general proposition that the price-concentration relationship that the CC found is, to the extent it exists, driven largely or wholly by Nuffield while the other operators do not show a statistically significant price-concentration relationship.

Section 8

Implications of the CC's analysis on the estimate of the total potential economic harm

8.1 In this section we make some initial remarks regarding the economic significance of the price effects estimated by the CC in the PCA.

8.2 According to the CC's interpretation of the baseline specification results (see paragraph 31 of the PCA working paper), a change in LOCI of, say, 0.2 (i.e. a 20% decrease in the weighted average market share) is estimated to cause a price reduction for self-pay inpatients of around 3.6%. We sought to estimate, at least approximately, the total economic transfer from consumers to hospital operators (overcharge) which would be implied from such a price effect following a change in concentration. The aim of this analysis is simply to consider whether there are implications of the CC's PCA estimates for the scale of the issues being examined and also for the extent of excess profitability being alleged. In this way, the CC's PCA analysis can potentially provide a cross-check on the reasonableness (or otherwise) of the CC's profitability analysis.

8.3 Before we report our initial indicative calculation – a caveat. We have explained in this report that, in our view, the CC's baseline specification is clearly not indicative of a robust market wide statistically significant relationship between price and concentration. As such the baseline specification does not represent a reliable estimate of a causal relationship between price and concentration in these markets. Even so, it is worth thinking about what the CC's baseline specification implies since it provides an opportunity to sense-check or cross-check the various pieces of evidence. In particular, whether the CC's results from the PCA and the results from the profitability analysis are pointing in the same direction.

8.4 Note that in an effort to be ultra conservative in our analysis, we use the LOCI point estimates to calculate the implied level of the overcharge and, in particular, we do not take into account whether they are statistically significant or not.[59] This is not a reasonable basis for such an overcharge – except to the extent that it potentially provides a 'worst case scenario' for the potential economic harm implied by the CC's PCA analysis. In addition, our 'worst case scenario' supposes that the price increase would be faced by all of BMI's inpatients – not just the self-pay inpatients to which the CC's analysis actually applies. If the analogous calculation were performed using only a price increase on self-pay inpatients, the estimated 'worst case' overcharge would accordingly be very significantly reduced.

8.5 We use the following data to estimate the total overcharge which would result from the price increases estimated by the CC's PCA model:

- Median price for all focal treatments provided by the CC in the PCA working paper (Table 2).
- The LOCI coefficient based on the CC's baseline specification results (Table 3 of the PCA working paper) and our robustness checks reported in this report.
- BMI's number of inpatients (self-pay *and* insured) for FY2011 submitted by BMI to the CC in the response to the Market questionnaire dated 12 September 2012.

8.6 We have calculated the overcharge for all BMI's inpatients and assumed that the change in LOCI is 0.2, following the CC's interpretation of its PCA results. We have calculated the total overcharge by first calculating (i) the implied change in price that would result from a change in LOCI of 0.2 and we have multiplied the result by (ii) the median price of the focal treatments and (iii) the total number of BMI's inpatient episodes for financial year 2011.[60]

8.7 We set out the results of this calculation for a variety of the specifications in the table below.

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59 If we did take into account whether coefficients are statistically significant, the total estimated overcharge for the coefficients which are not statistically significant would be zero. Our approach is therefore conservative in that it does calculate the overcharge value based on the value of the LOCI coefficients without taking into account whether they are statistically significant.

60 The excess profits are calculated as the change in price Δp times the volume of remaining sales, q. The change in price Δp is calculated by taking the % change in price (the LOCI coefficient times the change in LOCI) since $\frac{\Delta \ln p}{\Delta LOCI} = \beta$ and so for small changes we can write $\frac{\Delta p}{p} = \beta\ \Delta LOCI = \ \beta * 0.2$) and multiplying by the level of prices gives the absolute change in prices is $\Delta p = \beta\ \Delta LOCI * p = \ 0.2 * \beta * p$. The 'excess profits' associated with this extra concentration would then be estimated simply as $q\Delta p$ where we take q to be the volume of BMI inpatients. That is, $q\Delta p = \beta\ \Delta LOCI * p * q = \ 0.2 * \beta * p * q$.

Table 23: Initial estimate of the overcharge for BMI based on the CC's PCA model

Specification	Median price (£)	LOCI coefficient	BMI number of inpatients	Overcharge (LOCI change of 0.2)
CC's baseline specification	[✂]	[✂]	[✂]	[✂]
Excluding Nuffield	[✂]	[✂]	[✂]	[✂]
LOCI-BMI interaction	[✂]	[✂]	[✂]	[✂]
BMI data only	[✂]	[✂]	[✂]	[✂]
LOCI-BMI interaction (using statistically significant results)	[✂]	[✂]	[✂]	[✂]

Notes: Median price is based on all focal treatments as reported by the CC in the PCA working paper (Table 2). The total number of BMI inpatients is based on data for FY2011 Actual submitted to the CC [✂]. The total estimated overcharge is based on a change in LOCI of 0.2.

Source: PCA working paper – Table 2; Compass Lexecon analysis.

8.8 The implied total overcharge in the CC's baseline model (i.e. the transfer from consumers to hospital operators), assuming a change in LOCI of 0.2 and the resulting price changes estimated by the CC's baseline specification PCA model, is approximately £[✂] per annum for all BMI's inpatients (i.e. on a 'worst case scenario' basis as set out above).

8.9 We have found that the CC's baseline specification does not provide reliable estimates of the price-concentration relationship. We therefore also calculate an estimate of the extent of the overcharge using various alternative specifications derived from our robustness checks. Specifically, we use the LOCI coefficient estimates based on: (i) the CC's benchmark specification but estimated including data for all operators except Nuffield, (ii) the mild generalisation of the CC's baseline specification (using operator specific LOCI coefficients), and (iii) the CC's baseline specification estimated using only BMI's data. Finally, we also show the estimated overcharge if we consider statistical significance of the results of the LOCI-BMI interaction: This calculation is particularly trivial since the LOCI coefficient is not statistically significant with only BMI data and so the effect is thus statistically not different from zero. As we have shown – this would also be the case for a large number of alternative specifications also.

8.10 The total worst-case implied BMI overcharge to all BMI inpatients using these specifications ranges from [✂] to [✂] for BMI per year.

8.11 The key takeaway in respect of these various implied estimates of BMI's excess profitability obtained by using the CC's benchmark PCA model are each very considerably smaller than the 'excess profitability' estimated by the CC in its profitability analysis.

8.12 To illustrate the potentially different scales of the effects being proposed by the CC, note that in the Annotated IS the CC estimated that BMI was earning a ROCE of approximately [✂]% on average in the period FY2007-FY2011. To bring this down to the upper end of the range of WACC (i.e. the upper bound of 10%) would involve reducing annual profits by approximately £[✂] on the basis of the CC's profitability model. That is obviously a prediction which is an order of magnitude larger than the scale of the problem being indicated in the CC's benchmark PCA analysis. Simply put – it appears unlikely that the CC's profitability and PCA predictions can both be of the right order of magnitude.

8.13 For illustration of how small the pricing effect and associated harm implied by the CC's PCA analysis is, we considered what the implied overcharge would mean for total profitability of BMI calculated by the CC:

- Consider that the total profits of BMI can be considered a sum of the competitive profits and the excessive profits: $\pi^{BMI} = \pi^{COMP} + \pi^{EXCESS}$. According to the CC's profitability model, BMI's total profits in FY2011 were £[✂] (π^{BMI}). We estimated above that under the 'worst-case scenario' assumptions, the PCA implies total overcharge of £[✂] (π^{EXCESS}). This leaves £[✂] of competitive profit (π^{COMP}) for BMI – calculated as £[✂].
- CC's preferred measure of profitability is return on capital employed (ROCE), which is calculated as profits (EBIT) divided by the total capital employed. If the level of competitive profit for BMI is £[✂] and the CC's profitability analysis indicates that a competitive ROCE would be equal to around [✂]% (the mid-point of the range of WACC's estimated by the CC), this calculation implies a particular level of the BMI's capital employed. For ROCE to be equal to [✂]% where competitive profits are £[✂], the capital asset base must be equal to £[✂].
- The combination of the CC's estimate of BMI's total profit and the asset base calculated above can be used to calculate the value of BMI's ROCE under excessive profits which would be consistent with both the profit figure used by the CC in the profitability analysis (£[✂]) and the capital employed (£[✂]) consistent with the implied economic harm from the PCA analysis. The implication is that accounting for extra profits earned by BMI from high concentration, gives a ROCE for BMI that is equal to just [✂]% (£[✂]) under the PCA analysis. This estimate of ROCE is within the CC's range for the industry WACC, consistent with BMI's submissions with respect to its profitability. Moreover, such a level of profit would not ordinarily be considered indicative of excessive profitability from a competition policy perspective.

8.14 This illustration shows that the results of the CC's PCA analysis are not apparently consistent with the CC's profitability analysis in terms of the level of BMI's alleged excessive profits or in terms of the predicted degree of excessive profits being earned. Moreover, according to this analysis the PCA results imply a level of ROCE for BMI which is within the CC's range of reasonable WACC's. Thus such analysis – while indicative – does at least begin to draw out what appears to be a significant tension between the CC's profitability analysis and its PCA analysis about the scale of the problem that the CC is concerned about.

Annex A

[✂]

[✂]

[✂]

Annex B

Testing price-concentration relationship under operator-LOCI interacted regressions by treatment

B.1 In this Annex we analyse the price-concentration relationship for each treatment, using operator-LOCI interactions which allow us to test the price-concentration relationship by treatment and by hospital operator.

B.2 We analyse the effect of interacting operator dummies with the LOCI variable by treatment in order to determine whether there is a specific operator/operators driving the CC's results for particular treatments. We also statistically test whether it is appropriate to restrict the specification to require the LOCI parameter to be equal for all hospital operators, as required to justify estimating a single price-concentration relationship for each treatment.

B.3 We find that there are different relationships between price and concentration within each treatment (CCSD code). It appears that for several treatments, Nuffield has significantly different results (price-concentration relationship) from the other operators, and statistical tests confirm that the CC's model restriction (requiring LOCI parameter to be equal for all operators) is not appropriate when estimating the price-concentration relationship. There is also a statistically significant price-concentration relationship for Spire (but only in two treatments) and Ramsay (but only in one treatment) and the statistical tests indicate that the LOCI coefficients for those respective treatment-operator combinations should not be analysed with other operators.

B.4 We set out below the results by treatment for all eight focal treatments selected by the CC.

Treatment c7122

B.5 The following tables set out the results of the CC's base specification for CCSD code c7122 using prices with a logarithmic transformation and linear prices without a logarithmic transformation, respectively.

Table 24: Regression results (CCSD code c7122)

LOCI by operator	Base specification – Log price		Base specification – Linear price	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	-	-	-	-
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

B.6 These results show that there is no significant relationship between price and concentration (LOCI) for any operator for the c7122 treatment.

B.7 We set out in the following table the statistical tests assessing whether it is appropriate to restrict the specification to require the LOCI parameter to be equal (and non-zero) for all operators.

Table 25: Tests for treatment c7122

Null hypothesis	Base specification – Log price		Base specification – Linear price	
	F-statistic	p-value	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: In technical terms, we are performing an F-test of joint significance (i.e. equal to 0) for the LOCI coefficients of selected operators.

B.8 The test results suggest that for this CCSD code, we cannot reject the null hypothesis that the LOCI coefficients for all operators are equal to zero. It may therefore not be problematic to restrict the specification to require the LOCI parameter to be equal (and non-zero) for all operators.

B.9 After restricting the specification in this way, the CC's results in Table 5 (with logarithmic transformation) and in Table 6 (with no logarithmic transformation) of the PCA working paper do not show a statistically significant relationship between price and concentration for this treatment.

Treatment e0260

B.10 The following tables set out the results of the CC's base specification for CCSD code e0260 under both log-prices and linear prices, respectively.

Table 26: Regression results (CCSD code e0260)

LOCI by operator	Base specification – Log price		Base specification – Linear price	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

B.11 These results suggest that only Nuffield has a significant relationship between price and concentration (LOCI).

B.12 The statistical tests whether it is appropriate to restrict the specification to require the LOCI parameter to be equal (and non-zero) for all operators (and for all operators except Nuffield) are set out in the table below.

Table 27: Tests for treatment e0260

Null hypothesis	Base specification – Log price		Base specification – Linear price	
	F-statistic	p-value	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]	[✂]	[✂]
All except Nuffield = 0	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: In technical terms, we are performing an F-test of joint significance (i.e. equal to 0) for the LOCI coefficients of selected operators.

B.13 The test results show that while we can reject the null hypothesis that the LOCI coefficients for all operators are equal to zero (at least at the 10% level), we clearly cannot reject the null

hypothesis that the LOCI coefficients for all operators other than Nuffield are equal to zero.

B.14 After restricting the specification to require the LOCI parameter to be equal (and non-zero) for all operators, the CC's results in Table 5 (with logarithmic transformation) and in Table 6 (with no logarithmic transformation) of the PCA working paper do show a statistically significant relationship between price and concentration for this treatment.

B.15 Our regression results with operator-interacted LOCI terms suggest that Nuffield is driving the results, and also our test results suggest that it is inappropriate to restrict the model to require the LOCI coefficient for all operators to be equal (and non-zero).

B.16 When we exclude Nuffield from the regression analysis in Annex C, we find that there is no statistically significant relationship between price and market concentration for the remaining operators.

Treatment g3080

B.17 The following tables set out the results of the CC's base specification for CCSD code g3080 under both log-prices and linear prices, respectively.

Table 28: Regression results (CCSD code g3080)

LOCI by operator	Base specification – Log price		Base specification – Linear price	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

B.18 These results suggest that Nuffield has a significant relationship between price and concentration, while the other operators do not. HCA and Ramsay do not have data for this treatment.

B.19 The statistical tests on the CC's model restriction requiring the LOCI coefficient to be equal (and non-zero) for all operators are set out in the table below.

Table 29: Tests for treatment g3080

Null hypothesis	Base specification – Log price		Base specification – Linear price	
	F-statistic	p-value	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]	[✂]	[✂]
All except Nuffield = 0	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: In technical terms, we are performing an F-test of joint significance (i.e. equal to 0) for the LOCI coefficients of selected operators.

B.20 The test results show that while we can reject the null hypothesis that the LOCI coefficients for all operators are equal to zero, we cannot reject the null hypothesis that the LOCI coefficients for all operators other than Nuffield are equal to zero. This indicates that the price-concentration relationship for Nuffield is different from the other operators.

B.21 After restricting the model to require the LOCI coefficients for all operators to be equal, the CC's results in Table 5 (with logarithmic transformation) and in Table 6 (with no logarithmic transformation) of the PCA working paper do show a statistically significant relationship between price and concentration for this treatment.

B.22 Our regression results with operator-interacted LOCI terms suggest that Nuffield is driving the results reported by the CC, and also our test results suggest that it is not appropriate to restrict the model in the way the CC does.

B.23 When we exclude Nuffield from the regression analysis in Annex C, we find that there is no statistically significant relationship between price and market concentration for the other operators.

Treatment j1830

B.24 The following tables set out the results of the CC's base specification for CCSD code j1830 under both log-prices and linear prices, respectively.

Table 30: Regression results (CCSD code j1830)

LOCI by operator	Base specification – Log price		Base specification – Linear price	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

B.25 These results suggest that only Ramsay has a statistically significant relationship between price and concentration for this treatment.

B.26 We set out in the table below the statistical tests on the CC's model restriction requiring the LOCI parameter to be equal (non-zero) for all operators.

Table 31: Tests for treatment j1830

Null hypothesis	Base specification – Log price		Base specification – Linear price	
	F-statistic	p-value	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]	[✂]	[✂]
All except Ramsay = 0	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: In technical terms, we are performing an F-test of joint significance (i.e. equal to 0) for the LOCI coefficients of selected operators.

B.27 The test results show that while we can (marginally) reject the null hypothesis that the LOCI coefficients for all operators are equal to zero, we cannot reject the null hypothesis that the LOCI coefficients for all operators other than Ramsay are equal to zero for this treatment. This indicates that the price-concentration relationship for Ramsay is different from the other operators for this CCSD code.

B.28 After restricting the specification to require one LOCI coefficient for all operators, the CC's results in Table 5 (with logarithmic transformation) and in Table 6 (with no logarithmic transformation) of the PCA working paper do show a statistically significant relationship

between price and concentration for this treatment.

B.29 Our regression results with operator-interacted LOCI terms suggest that Ramsay is driving the results, and also our test results suggest that it is inappropriate to restrict the model to require the LOCI coefficient to be equal for all operators. This is because the price-concentration relationship for Ramsay appears to be different from the other operators.

Treatment m6530

B.30 The following tables set out the results of the CC's base specification for CCSD code m6530 under both log-prices and linear prices, respectively.

Table 32: Regression results (CCSD code m6530)

LOCI by operator	Base specification – Log price		Base specification – Linear price	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

B.31 These results suggest that only Nuffield has a statistically significant relationship between price and the concentration measure (LOCI).

B.32 The statistical tests whether it is appropriate to restrict the LOCI coefficient to be equal (and non-zero) for all operators are set out in the table below.

Table 33: Tests for treatment m6530

Null hypothesis	Base specification – Log price		Base specification – Linear price	
	F-statistic	p-value	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]	[✂]	[✂]
All except Nuffield = 0	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: In technical terms, we are performing an F-test of joint significance (i.e. equal to 0) for the LOCI coefficients of selected operators.

B.33 While we can reject the null hypothesis that the LOCI coefficients for all operators are equal to zero, we cannot reject the null hypothesis that the LOCI coefficients for all operators other than Nuffield are equal to zero. This indicates that the price-concentration relationship for Nuffield is different from the other operators for this treatment.

B.34 After restricting the model to require the LOCI coefficient to be equal for all operators, the CC's results in Table 5 (with logarithmic transformation) and in Table 6 (with no logarithmic transformation) of the PCA working paper do not show a statistically significant relationship between price and concentration for this treatment.

B.35 Our regression results with operator-interacted LOCI terms suggest that Nuffield has a statistically significant relationship between price and concentration, and also our test results suggest that it is inappropriate to restrict the model. The price-concentration relationship for Nuffield is significantly different form the other operators for this treatment.

B.36 When we exclude Nuffield from the regression analysis in Annex C, we find that there is no statistically significant relationship between price and market concentration for the data of the other operators.

Treatment t2000

B.37 The following tables set out the results of the CC's base specification for CCSD code t2000 under both log-prices and linear prices, respectively.

Table 34: Regression results (CCSD code t2000)

LOCI by operator	Base specification – Log price		Base specification – Linear price	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

B.38 These results suggest that for this procedure, no operator has a negative and statistically significant relationship between price and market concentration. Spire has a significant relationship between price and concentration, but with the opposite sign (indicating that prices are higher where concentration is lower).

Treatment w3712

B.39 The following tables set out the results of the CC's base specification for CCSD code w3712 under both log-prices and linear prices, respectively.

Table 35: Regression results (CCSD code w3712)

LOCI by operator	Base specification – Log price		Base specification – Linear price	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

B.40 These results suggest only Spire and Nuffield have a statistically significant relationship

between price and market concentration for at least one of the log/linear prices specifications.

B.41 We set out in the table below the statistical tests on whether it is appropriate to restrict the specification to require the LOCI coefficient to be equal (and non-zero) for all operators.

Table 36: Tests for treatment w3712

Null hypothesis	Base specification – Log price		Base specification – Linear price	
	F-statistic	p-value	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]	[✂]	[✂]
All except Nuffield = 0	[✂]	[✂]	[✂]	[✂]
All except Spire = 0	[✂]	[✂]	[✂]	[✂]
All except Spire and Nuffield = 0	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: In technical terms, we are performing an F-test of joint significance (i.e. equal to 0) for the LOCI coefficients of selected operators.

B.42 We can reject the null hypothesis that the LOCI coefficients of all operators are equal to zero, we cannot reject the null hypothesis that the LOCI coefficients for Spire (and marginally also for Nuffield) are equal to zero.

B.43 After restricting the model specification to require the LOCI coefficient for all operators to be equal, the CC's results in Table 5 of the PCA working paper (with logarithmic transformation) do not show a statistically significant relationship between price and concentration for this treatment. The CC's results in Table 6 (with no logarithmic transformation) do show a statistically significant relationship.

B.44 Our regression results with operator-interacted LOCI terms suggest that Nuffield and Spire are driving the CC results, and also our test results suggest that it is inappropriate to restrict the model as the CC did. Both Spire and Nuffield have significantly different price-concentration relationships than the other three operators.

B.45 When we exclude Nuffield from the regression analysis in Annex C, we find that there is no statistically significant relationship between price and market concentration.

Treatment w4210

B.46 The following tables set out the results of the CC's base specification for CCSD code w4210 under both log-prices and linear prices, respectively.

Table 37: Regression results (CCSD code w4210)

LOCI by operator	Base specification – Log price		Base specification – Linear price	
	Coefficient	SE	Coefficient	SE
BMI	[✂]	[✂]	[✂]	[✂]
Nuffield	[✂]	[✂]	[✂]	[✂]
Spire	[✂]	[✂]	[✂]	[✂]
HCA	[✂]	[✂]	[✂]	[✂]
Ramsay	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: The operator LOCI variables have been created by multiplying the LOCI variable by a dummy variable for each hospital operator. All other variables follow the CC's specifications.

B.47 These results suggest that both Nuffield and Spire have a statistically significant relationship between price and market concentration.

B.48 The statistical tests on whether it is appropriate to restrict the specification to require the LOCI parameter to be equal (and non-zero) for all operators are set out in the table below.

Table 38: Tests for treatment w4210

Null hypothesis	Base specification – Log price		Base specification – Linear price	
	F-statistic	p-value	F-statistic	p-value
All operators jointly = 0	[✂]	[✂]	[✂]	[✂]
All except Nuffield = 0	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Note: In technical terms, we are performing an F-test of joint significance (i.e. equal to 0) for the LOCI coefficients of selected operators.

B.49 The test results show that while we can reject the null hypothesis that the LOCI coefficients for all operators are equal to zero (at least for the specification using linear price), we cannot reject the null hypothesis that the LOCI coefficients for operators other than Nuffield are equal to zero.

B.50 After restricting the model to require the LOCI coefficient to be equal for all operators, the CC's results in Table 5 (with logarithmic transformation) and in Table 6 (with no logarithmic transformation) of the PCA working paper do show a statistically significant relationship between price and concentration for this treatment.

B.51 Our regression results with operator-interacted LOCI terms suggest that Nuffield and Spire are driving the results, and also our test results suggest that it is inappropriate to restrict the specification to require the LOCI parameter to be equal (and non-zero) for all operators.

B.52 When we exclude Nuffield from the regression analysis in Annex C, we find that there is no statistically significant relationship between price and market concentration.

Annex C

PCA results under CC's baseline specification for all operators except Nuffield

C.1 In this Annex we present the results of the PCA analysis when considering data for all operators except Nuffield. We report the results of the analysis corresponding to Tables 5-9 from the PCA working paper. (See also our Table 4 on page 26 which provides the analogous estimates for the CC's Table 3 in the PCA working paper.)

Table 39: Regression results excluding Nuffield – Table 5 from the PCA working paper

	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Table 40: Regression results excluding Nuffield – Table 6 from the PCA working paper

	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
LOCI				[✂]				
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Table 41: Regression results excluding Nuffield – Table 7 from the PCA working paper

	(7)		(8)		(9)		(10)	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]			
N	[✂]	[✂]	[✂]	[✂]	[✂]		[✂]	
Test of null hypothesis that instruments are irrelevant (F-statistic)	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	
Test of null hypothesis that the covariates are exogenous (p-value)	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	
Test of null hypothesis that the instruments are exogenous (p-value)							[✂]	

Source: Compass Lexecon analysis.

Table 42: Regression results excluding Nuffield – Table 8 from the PCA working paper

	Benchmark LOCI		**Excluding areas affected by missing invoices**	
	Coefficient	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]				
R-squared	[✂]		[✂]	
N	[✂]		[✂]	

Source: Compass Lexecon analysis.

Table 43: Regression results excluding Nuffield – Table 9 from the PCA working paper

	No exclusions		All treatments		NUTS3	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]						
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	
N	[✂]	[✂]	[✂]	[✂]	[✂]	

Source: Compass Lexecon analysis.

Annex D

PCA results under CC's baseline specification for BMI

D.1 In this Annex we report the results of the PCA analysis when considering the data for BMI only. These results correspond to Tables 5-9 included in the CC's PCA working paper.

Table 44: Regression results for BMI – Table 5 from the PCA working paper

	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
N	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Table 45: Regression results for BMI – Table 6 from the PCA working paper

	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
N	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Table 46: Regression results for BMI – Table 7 from the PCA working paper

	(7)		(8)		(9)	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]						
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	
N	[✂]	[✂]	[✂]	[✂]	[✂]	
Test of null hypothesis that instruments are irrelevant (F-statistic)	[✂]	[✂]	[✂]	[✂]	[✂]	
Test of null hypothesis that the covariates are exogenous (p-value)	[✂]	[✂]	[✂]	[✂]	[✂]	
Test of null hypothesis that the instruments are exogenous (p-value)						

Source: Compass Lexecon analysis.

Table 47: Regression results for BMI – Table 8 from the PCA working paper

	Benchmark LOCI		**Excluding areas affected by missing invoices**	
	Coefficient	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]				
R-squared	[✂]		[✂]	
N	[✂]		[✂]	

Source: Compass Lexecon analysis.

Table 48: Regression results for BMI – Table 9 from the PCA working paper

	No exclusions		All treatments		NUTS3	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]						
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	
N	[✂]	[✂]	[✂]	[✂]	[✂]	

Source: Compass Lexecon analysis.

Annex E

PCA results using self-pay LOCI as a measure of concentration

E.1 This annex sets out the results of the CC's price concentration analysis when we consider the self-pay LOCI as the concentration variable rather than the insured LOCI.

Table 49: Regression results using self-pay LOCI – Table 5 from the PCA working paper

	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
N	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Table 50: Regression results using self-pay LOCI – Table 6 from the PCA working paper

	C7122	E0260	G3080	J1830	M6530	T2000	W3712	W4210
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
N	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

Source: Compass Lexecon analysis.

Table 51: Regression results using self-pay LOCI – Table 7 from the PCA working paper

	(7)		(8)		(9)		(10)	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]								
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	
N	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	
Test of null hypothesis that instruments are irrelevant (F-statistic)	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	
Test of null hypothesis that the covariates are exogenous (p-value)	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	
Test of null hypothesis that the instruments are exogenous (p-value)							[✂]	

Source: Compass Lexecon analysis.

Table 52: Regression results using self-pay LOCI – Table 8 from the PCA working paper

	Benchmark LOCI		**Excluding areas affected by missing invoices**	
	Coefficient	**SE**	**Coefficient**	**SE**
LOCI	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]				
R-squared	[✂]		[✂]	
N	[✂]		[✂]	

Source: Compass Lexecon analysis.

Note: The areas excluded are those which are missing insured invoices, not self-pay.

Table 53: Regression results using self-pay LOCI – Table 9 from the PCA working paper

	No exclusions		All treatments		NUTS3	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]						
R-squared	[✂]		[✂]		[✂]	
N	[✂]		[✂]		[✂]	

Source: Compass Lexecon analysis.

Table 54: Regression results using self-pay LOCI – Table 10 from the PCA working paper

	BMI		HCA		Nuffield		Ramsay		Spire	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
LOCI	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
[Other covariates not shown]										
R-squared	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	
N	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]	

Source: Compass Lexecon analysis.