HEALTH ECONOMICS GROUP

Faculty of Medicine and Health

Norwich Medical School

Hospital Procurement with Concentrated Sellers:

A Case Study of Hip Prostheses

Dr Charlotte Davies[1], Assoc Prof Paula Lorgelly[2]

[1]Health Economics Group, University of East Anglia

[2]Centre for Health Economics, Monash University

December 2013 HEG working paper 13-06

Hospital Procurement with Concentrated Sellers: A Case Study of Hip Prostheses

[1] Dr Charlotte Davies & [2]Assoc Prof Paula Lorgelly

[1]Health Economics Group, University of East Anglia

[2]Centre for Health Economics, Monash University

Word count: 7174

We would like to thank the following people for their helpful comments: Professor Morten Hviid and Professor Bruce Lyons, the Centre for Competition Policy, University of East Anglia and Professor Andrew Street, The Centre for Health Economics, The University of York. We would also like to thank the participants at the Network of Industrial Economists Winter Meeting, December 2012 for their helpful comments.

Publication: This paper is published jointly as part of the Health Economics Group and CCP (University of East Anglia) working paper series':

http://www.uea.ac.uk/medicine/health-economics-group/working-papers

http://competitionpolicy.ac.uk/publications/working-papers-2013

Contact details: Charlotte Davies, Health Economics Group, Norwich Medical School, University of East Anglia, Norwich, NR4 7TJ , UK. *Charlotte.davies@uea.ac.uk*

Keywords Medical devices, competition, concentration, diversification, oligopoly, buyer power

Classification codes I11, I18, L11, L113, L25

Abstract

Procurement within the NHS is attracting increasing research and policy interest. However, most of the emphasis has been on the buyer (the NHS), with less attention paid to the behaviour of suppliers (often pharmaceutical companies). For medical devices very little is publicly documented about procurement and even less about the supplying industry.

This paper uses a case study of artificial hip prostheses to indirectly explore how procurement choices are made within the NHS. We recognise the roles of the various players (patient, surgeon and hospital procurement department) when purchases are made from a potentially highly oligopolistic supplying industry.

Using data from the National Joint Registry for England and Wales, we show that the supplying industry is indeed highly oligopolistic, with the potential for the exercise of market seller power. At the national level the NHS as a whole purchases from the equivalent of just four large sellers. However, typically individual hospitals are buying from only two, or in some instances one seller. Given this backdrop, we develop a theoretical framework explaining prosthesis choice, considering the roles and preferences of the patient, surgeon, hospital and supplier. This provides a set of hypotheses tested using an econometric model in which the diversity of prosthesis choice at the hospital level is explained by a vector of patient and hospital characteristics. This reveals little evidence that patient heterogeneity is a major determinant of diversity of procurement choices. More important are hospital size (which will be related to the number of surgeons), status of the hospital, recent NHS reforms and the potential role of the supplier.

These findings provide a basis for future survey analysis of surgeons and hospital procurement departments designed to discover more directly how decisions are made and how suppliers bargain with hospitals.

1. Introduction

The purchasing behaviour of the National Health Service (NHS) in the United Kingdom (UK) has attracted considerable attention of late(Sir Philip Green 2010, National Audit Office 2011, Department of Health 2012). Various market-based reforms have been introduced to affect choice and procurement in the NHS(Cooper, Gibbons et al. 2010). 'Payment by Results' (PbR) is an activity based payment system, in which fixed national prices are based on healthcare resource groups (HRGs) and calculated on the basis of average costs(Mays N, Dixon A et al. 2011). 'Patient Choice' was designed to offer patients a choice of alternative providers for their treatment; and hospitals were offered financial autonomy through the establishment of Foundation Trust (FT) status for 'high performing' hospitals.

Hospital purchasing and procurement is, however, only one side of the story. The behaviour of the suppliers and the nature of their transactions with the NHS are also relevant. While one of the key supplying sectors, pharmaceuticals, has attracted considerable policy interest (EU Commission 2009), another broad sector, medical devices, has attracted much less interest.

This paper examines what can be inferred about procurement of hip prostheses from an analysis of diversification of choice revealed by hospital purchases. It focuses on three issues surrounding the purchase decisions: 1). The relative importance of the preferences of patients, surgeons and hospitals in the choice, 2) the potential exercise of market power by the manufacturers of hip prostheses and 3) the bargaining power of the hospital.

We start with an analysis of the structure of a key medical devices industry, and how this might impact on NHS procurement at both the national and local (hospital) levels. We use as a case study Total Hip Replacement surgery (THR) to identify what determines the diversification of choices made by individual hospitals given the range of different prostheses (artificial joints) available on the market. THR is selected because it is a routine procedure, widely carried out throughout the NHS and accounts for a large share of the aggregate NHS budget for surgery(2.9% (Department of Health 2012, The National Joint Registry for England and Wales 2012, The Telegraph 2012)).

For each patient undergoing THR surgery, there is a subset of one or more artificial hip prostheses on the market[1] (cup and stem, method of fixation: cemented or cementless) which meet their physiological and medical needs. No one prosthesis type best meets the needs of all patients, rather there is horizontal product differentiation because patients are not identical. In addition to the needs of the patient, three other 'players' are involved in the choice decision: the surgeon, the hospital and the manufacturer of the prosthesis. This paper is designed to show how information on the variability of choices in prostheses observed at the hospital level can provide valuable, if indirect, evidence on the roles of each these players as to how choices are made.

The analysis has three stages. We first provide a statistical description of the structure of the hip prosthesis industry in the UK, to establish whether, at the national level, the

[1] During THR surgery the existing hip joint is removed and replaced with both an artificial stem (replacing the upper part of the femur) and artificial cup (the natural socket for the head of the femur). The artificial joints are either fixed into place using an acrylic cement or cementless components are made from a permeable material, allowing the bone to grow into it and thus holding it in place. NHS choices. (2012). "Hip replacement." Retrieved 11/11/2013, from http://www.nhs.uk/conditions/Hip-replacement/Pages/Introduction.aspx..

industry has the structural features necessary, although not sufficient, to exercise market power. The national picture is important as a first step in order to assess the relative potential powers of the buyer (the NHS is a near monopsony in the UK) and its suppliers. However, unless all purchase decisions are taken at the national level, this is only a first step. Local and national levels of concentration are not necessarily identical: while there may be many suppliers at the national level, if decision making is taken at the hospital level, it is possible that each hospital may deal with only a small number of those suppliers, perhaps just one. Consider the analogy with community pharmacies – there are thousands at the national level, but in a particular locality the consumer may only have the choice between one or two. We offer a conceptual framework, which shows how national concentration translates into concentration at the hospital level, i.e. how many suppliers a typical hospital purchases from. Hospital level concentration is, in effect, the degree to which the individual hospital specializes its purchases. Therefore, throughout the paper this is referred to as hospital diversification.

In the second stage we introduce a theoretical framework to guide empirical work for this and subsequent papers. It identifies the main actors involved in the choice process on which prosthesis is used to implant. This has implications for the variability in choices within the individual hospital. This theoretical framework informs the third stage which identifies what determines diversification of an individual hospital with respect to its purchases of prostheses, in terms of its size and status, the timing of NHS reforms and regional differences.

This rest of the paper is organized as follows. Section 2 provides a brief overview of the medical devices market and presents the data-set. Section 3 derives some key features of the market structure. Section 4 presents a theoretical framework for prosthesis

choice used to generate predictions which are tested in the empirical model described in Section 5. Section 6 summarizes and discusses limitations, some policy implications, and directions for future work.

2. The market and data

There is very little evidence on either procurement or market structure in medical devices in contrast to pharmaceuticals(Davies C 2011). However, there are useful parallels: most parts of the pharmaceutical sector are dominated by just a few firms(Department of Health and Association of the British Pharmaceutical Industry 2002). As will be seen below, the UK market for hip prostheses is similarly highly concentrated. Competition in pharmaceuticals is mostly driven by innovation (Agrawal M 1999),with uncertainty a key feature because of the risks regarding whether Research and Development (R&D) will generate a useable product, and also uncertainty regarding the drug's long-term effectiveness. We show below that there are similarly a large number of alternative hip prostheses, and innovation is frequent. Technical uncertainty can be as problematic, a prosthesis should last for at least 15 years, and reliability of a new model is difficult to assess at the time of its first introduction.

There is only a small evidence base of anticompetitive behaviour in the medical devices market. 'Pharmalot' a U.S based blog/website (edited by medical journalists), posts examples such as: Johnson and Johnson's sub-section, (J&J) Depuy settling a kickback charge in 2007, and more recently, a general discussion of the 'Undisclosed conflicts among Docs (doctors) and device makers' was posted with respect to disclosure (Silverman E 2007, Silverman E 2010).

The European Commission (EC) conducted investigations of two mergers: Johnson and Johnson (J&J) and Depuy (1998), and Smith and Nephew's and Centerpulse (2003) (Commission of the European Communities 1998, Commission of the European Communities 2003). It found neither to be anti-competitive.

On the other hand, hip prostheses are well documented in the medical literature, and this paper benefits from access to a valuable large national patient level data-set: the National Joint Registry (NJR) for England and Wales. This is the largest national joint registry in existence (although not the longest which is in Sweden) and this is the primary source for this paper.

Data on all patients who underwent a cemented or cementless primary THR from 2004 to 2008, were aggregated into a hospital level panel, with the hospital year (of surgery) as the unit of observation.[2] This resulted in a total of 2281 hospital-year observations, covering 278,063 patients. Patients undergoing any knee surgery, hip resurfacing and hip revision surgery were excluded from the analysis.

The NJR does not collect data on hospital characteristics, and so, for this purpose, data from the Hospital Episode Statistics (HES) were mapped onto the NJR data at the individual hospital level. The HES database includes information on hospital characteristics such as: primary care trust (PCT) referral, provider type and so on. The mapping process resulted in a sample of 258,069 patients, the data-set was then aggregated to hospital year averages resulting in 2018 hospital year observations i.e. for hospital x in year x.

[2] Data was available for 2003 also, but it was considered to be incomplete due to it being the year of the NJRs inception.

3. The Market Structure

The NJR data provides an excellent utility with which to describe the structure of buyers and sellers in the market for hip prostheses in England and Wales. We identify the main sellers (the manufacturers of hip prostheses) and their market shares, having defined the product and geographical markets, and explain how seller concentration is measured. At the aggregate level, the dominant buyer is the NHS, but the analysis is also disaggregated by hospital types, and a measure of buyer concentration is derived. We estimate an index of hospital diversification (of prostheses choices) to present a conceptual framework which links national seller concentration to buyer concentration. The diversification index (derived from the patient level data) is the main focus of the remainder of the paper.

3.1 Seller concentration

The NJR identifies 25 manufacturers supplying 124 brands of acetabular cups and 137 brands of femoral stems to hospitals in England and Wales between 2004 and 2008(The National Joint Registry 2009). However, only five (Stryker Osteonics, Depuy [part of J&J], Zimmer, Joint Replacement Instrumentation [JRI] and Biomet) had a market share consistently over 5% - see Table 1. Of these, Stryker, Depuy, Zimmer and Biomet are all American based multi-nationals and conglomerates (i.e. hip prostheses are only part of their overall product range). It follows that hip prostheses in England and Wales, form only a small part of their worldwide activities. JRI is the exception: it is owned wholly by the British Furlong Research Charitable Foundation, and appears (from a search of the web and four other joint registries) to be present only in the UK market, producing orthopaedic implants and surgical instrumentation only.

As shown in Table 1, the two largest firms, Stryker and Depuy, constitute a dominant duopoly, together accounting for 69% of the market in 2008, partly reflecting the results of previous mergers (Anderson J, Neary F et al. 2007). The next four largest (Zimmer, Biomet, JRI and Smith and Nephew) each have much smaller shares of 5-7%, leaving a fringe of very small players together accounting for less than 10%. As mentioned above, Depuy (formerly part of Roche) was acquired by the J&J group in 1998, following clearance by the EC. There have been a number of other recent smaller acquisitions; in October 2003 Zimmer acquired Centerpulse, increasing their international market share by approximately 3%, while Smith and Nephew acquired Medical Technologies in March 2004, increasing their international market share by 0.01%.

The product and geographic market definitions follow those adopted by the EC in its merger investigations. In both cases, the product market was defined as the market for hip prostheses for primary THR. While the EC acknowledged two broad types of hip prosthesis: cemented and cementless, it argued that there is a high degree of substitutability between the two, such that both should be included as belonging to one broad product market (Commission of the European Communities 1998). We follow the EC's precedent in these investigations by assuming that the geographic market is England and Wales.

To measure the extent of seller concentration in this market we follow the convention in industrial economics and competition policy by employing the Herfindahl-Hirschmann Index (HHI), defined at time *t* as the sum of squared market shares of all firms(Motta M 2004):

$$SellerHHI_t = \sum_{i=1}^{N} {s_{it}}^2 \qquad (1)$$

where s_i is the market share for seller *i*, *i=1…..N*.

The HHI rises with increasing concentration and can vary from a lower limit of *1/N*, which occurs if each of the *N* sellers has an identical market share towards an upper limit of 1 (monopoly), which is approached as the largest seller has an increasing dominance of the market. For presentational purposes in this paper, the index is expressed in what is known as its reciprocal *numbers-equivalent of sellers* (NS) form:

$$NS_t = \frac{1}{HHI_t} \qquad (2)$$

This has the effect of measuring concentration as a hypothetical number of equal sized sellers – the number of sellers that would record that value of HHI if they had equal shares (see section 3.4 for an illustrative example).

3.2 Buyer concentration

In aggregate the NHS is considered to be a near monopsony buyer. However, recent literature has suggested that purchasing takes place at the hospital level(National Audit Office 2011), thus we now consider buyer concentration as a potential measure of buyer power at the local hospital level, as well as at the national level separately. Concentration can be measured by buyer HHI and the numbers equivalent of buyers can be defined analogously to equations (1) and (2) respectively, where the summation now refers to *m* hospitals.

Table 2 reports the values of the HHI on a yearly basis for both buyers and sellers. The seller HHI has been very stable over these years: 0.25 to 0.26 and buyer HHI around 0.0057. The values for seller HHI, easily exceed the magnitude usually associated by Concentration Authorities with a highly concentrated market – typically 0.2 (The Competition Commission & The Office of Fair Trading 2010). In its numbers equivalent form, this translates to approximately 4, implying that the size distribution is as equally concentrated as a hypothetical industry of just 4 equal sized sellers.[3]. In contrast, the buyer HHI is far less concentrated, typically 0.0057, translating into approximately 175 equal sized buyers (hospitals).

The data allows disaggregation by hospital type (see Table 3). The most common type is the NHS Trust, but in 2004, the government introduced the incentive for all acute NHS trusts to achieve FT status by 2014. FTs primarily differ from acute NHS trusts in their management structure, unlike NHS trusts (under the central control of the Department of Health), FTs are financially autonomous, with the option to retain surpluses and borrow to invest in future services/interventions. They are locally (not centrally) accountable to their local governors and members and are regulated by Monitor[4] (Monitor 2013). To date in 2013, 99 acute trusts have achieved FT status (NHS choices 2013).

A small private sector for health care exists alongside the NHS, referred to here as the Independent Sector (IS). The IS carries out a variety of medical and surgical

[3] The Concentration Ratio of the combined shares of the largest five sellers (CR5) is also stable and very high at 89-90% over the five years.

[4] NHS trusts will be required to be licensed with Monitor from April 2014 under the Health and Social Care Act, 2012

interventions which are privately funded and provided at private hospitals or clinics. Services are purchased by the patient either through private medical insurance (PMI) or through self-funding. Most private patients have PMI, funded through a corporate policy (approximately 69%). The Office of Fair Trading (OFT) estimated that in 2011, "approximately 15.8% of people in the UK had some kind of PMI policy"(Office of Fair Trading 2011).

There is also a small number of Treatment Centres (TC) which are both NHS (NHS TC) and privately run (IS TC). They provide elective day and short-stay surgery for interventions such as THR surgery(Department of Health 2013).

As Table 3 shows, since their introduction in 2004, there has been a steady increase in the number of FTs at the expense of NHS trusts. The three remaining hospital types account for only a small proportion of the hospital types.

3.3 Estimating Hospital Diversification

The primary focus of the analysis in this paper is the disaggregation down from the national market to the local 'market', defined as the individual hospital. The NJR data can be used to calculate an index of the concentration of sellers to each specific hospital, again, using the HHI index, but now calculated using each manufacturer's share in that hospital's purchases.

The HHI computed in this way could be interpreted as the concentration of sellers at the hospital level, but it is more appropriate for our purposes to think of it as a measure of the extent to which the hospital specializes or diversifies its purchases across different suppliers. The upper limit of 1 indicates that the hospital specializes its purchases, buying from only a single manufacturer, while the lower limit of 1/N indicates that it

purchases equal amounts from all *N* manufacturers. In its numbers equivalent form, for hospital *j* at time *t*, purchasing from up to *N* suppliers, it is:

$$DIVB_{jt} = \frac{1}{\sum_{i=1}^{N} {s_{ijt}}^2} \qquad (3)$$

Figure 1 shows the distribution of *DIVB*, pooled across all hospital years (the year by year histograms are similar). It is bi-modal with modes at 1 and at 2, and a mean of 1.9. Thus, there are a significant number of hospitals that buy exclusively from just one supplier, but more typically hospitals are somewhat diversified, albeit purchasing from only two different suppliers. There is considerable variability around these modes.

For comparability, the dotted line in the figure represents the numbers equivalent (*NS*) at the national level (3.9 on average). Hypothetically, if each individual hospital was a small replica of the national market, then it would record 3.9 as its value for *DIVB*. In fact, a mean of 1.9 shows that the 'typical' hospital is much more specialized than the NHS as a whole, buying from roughly two, as opposed to four 'numbers equivalent' suppliers.

Our analysis of the THR market has identified three key features of the medical devices industry as shown in tables 1 and 2: (i) it is highly concentrated; (ii) concentration has been stable; and (iii) the individual market shares of all leading sellers have remained stable. There has also not been any significant entry of new firms over this period. If we were to apply the usual criteria adopted by Competition Authorities, such a market might be conducive to the exercise of market power by sellers. On the buyer side, while the NHS is a near monopsonist, given buying is conducted at the individual hospital

level, the market comprises of a much larger number of fragmented buyers. Typically, the buyers only buy from one or two of the sellers.

3.4 National seller concentration and hospital diversification

The level of national seller concentration and the diversification of individual hospitals' purchasing are both important for understanding how the market structure of the supplying industry may impact on competition. Additionally, these are linked by a third potentially important factor: how suppliers' sales are distributed across hospitals. This section shows how these concepts can be statistically integrated within a unified framework.

To aid intuition, consider the following hypothetical symmetric example. Suppose that the NHS comprises 400 equal sized hospitals and that nationally there are four equal sized suppliers. Now consider two alternative extreme assumptions about hospital diversification: in Case A, each hospital specializes by buying from only one supplier, in which case each of the four suppliers is the monopoly seller to 100 of the hospitals; in Case B, each hospital diversifies its purchases equally between the four sellers, in which case, each seller sells equally to all 400 hospitals. In Case A, hospital specialization (concentration) is much greater than national concentration, but in Case B, hospital specialization (concentration) is identical to the national concentration. In other words, for a given level of national concentration, hospital specialization will be higher, the more each seller specializes in selling to a smaller number of hospitals. This can be generalized to:

$$NS \equiv NB \times \frac{DIVB}{DIVS} \qquad (4)$$

Where *NS* and *NB* are the number of equal sized sellers and buyers respectively, *DIVS* is the number of hospitals each supplier sells to, and *DIVB* is the number of suppliers each hospital buys from: the extent to which the hospital specializes. So in the above example: *NS*=4, *NB*=400; and in Case A, *DIVB*=1 and *DIVS*=100, but in CASE B, *DIVB*=4 and *DIVS*=400. Thus, although the following econometrics relate to hypotheses about DIVB, these apply similarly to the diversification of sellers as it is simply the inverse.

In reality, neither all manufacturers nor all hospitals are equal-sized, and manufacturers will differ in the extent of their diversification, and hospitals will differ in the extent of their specialization. This means that the above relationship must be modified in order to allow for heterogeneity amongst both buyers and sellers.

Fortunately, the decomposition properties of the HHI index provide a straightforward but elegant way of doing this, previously shown in a quite different context[5](Davies S & Lyons B 1996). This can be applied in the following context as follows: first define NS as in (2) and analogously NB as the numbers equivalent of equal sized hospitals. Let *DIVB* be the sales weighted mean value across hospitals of $DIVB_j$ as defined in (3); and analogously *DIVS* is the weighted mean numbers equivalent hospitals supplied across sellers. Then equation (4) carries over exactly to the general case where hospitals and suppliers are both heterogeneous in size and distribution, if all four terms are now defined by their HHI numbers equivalents.

To summarise then, remembering that, concentration is inversely measured by its numbers equivalent, concentration at the national level will be higher the more concentrated is the hospital sector, the more diversified are sellers, and the less

[5] This showed how concentration at a supranational level (the EU) is related to average concentration at the national level, allowing for firms to be diversified across industries and across countries (i.e. multinational).

diversified are hospitals. This identity provides a simple structure to an underlying set of relationships, without imposing causality.

Table 4 shows the results obtained when each of the relevant numbers equivalent indices are estimated using the NJR data. Using 2004 as an example, we find that in the numbers equivalent form, while there were 4 'sellers' at the national level, on average within hospitals concentration was twice as high, with prostheses being purchased from only two of the sellers. This is because each seller sold to only half of the hospitals (87 of the 173).

Thus, from the buyers' angle, purchases are much more specialized (concentrated) within hospitals than nationally within the NHS, while, from the sellers' perspective, the national market is 'shared' in the sense that each seller sells to only about a half of all hospitals (given DIVB is approximately half of NB).

4. Theoretical Framework

We now focus more closely on the *DIVB* index, and explore what it can reveal about procurement patterns within the NHS. In the absence of any micro information on price, and remarkably little in the public domain about how procurement decisions are actually made, and by whom, the analysis is inevitably exploratory. Thus, we do not employ a formal structural model[6], but proceed instead by assessing what can be

[6] The framework we employ draws loosely on a recent model by Grennan, M. (2013). "Price Discrimination and Bargaining: Empirical Evidence from Medical Devices." American Economic Review **103**(1): 145-177. of a medical device market in the US. He has access to a much richer panel dataset than is available here, on buyer-supplier transfers, and this enables estimation of a full structural model to empirically analyze bargaining and price discrimination. Because the NJR dataset is more restricted, without any information on transactions prices, that is not possible in the current paper. It is the purpose of our future survey work of surgeons, hospitals and suppliers to collect such data.

reasonably assumed and what testable hypotheses follow concerning how diversification of prosthesis choices vary across hospitals.

4.1 Framework

From the above, there are two key features of this market. First, the supplying industry is highly oligopolistic with potential market selling power, while the main buyer, although a near monopsony, is fragmented into a large number of hospitals. Second, decision making within each hospital will reflect the preferences and objectives of a number of different players - the hospital, its surgeons and (perhaps ideally) the patients.

Decision making within hospitals

We assume that the process begins with the patient-surgeon consultation, the patient having been referred by their GP, and the patient perhaps been given a choice of hospital (via the 'choose and book' facility).

For a given patient, the surgeon derives different utilities from fitting the different prostheses on offer. The surgeon's utility function may include the patient's characteristics, but it may also reflect the hospital's preferences (or be constrained by the hospital's procurement policy and budget constraints). It will also reflect the surgeon's professional preferences and experience, and these may be susceptible to persuasive activities (marketing) by the suppliers. There may be an intermediate stage, in which surgeon teams consolidate their personal preferences into a 'team wish list'. Then, on the basis of the choices of all its surgeons, the hospital assembles a potential list of prostheses. There may also be stages of iteration, where the hospital feeds back to surgeons with further constraints on choice.

Bargaining between hospitals and suppliers

The hospital procurement department takes its own 'wish list' into negotiations with all, or a sub-set of, suppliers, with whom it bargains about quantities and prices. The hospital bargains so as to maximize its utility, subject to a financial budget constraint. Depending on its financial autonomy, this constraint may be strict – a simple break even per period – or with some flexibility across years, and possibly across areas of medical activity.

Each potential supplier is assumed to profit maximize. Depending on the nature of the competition amongst suppliers, their behaviour might imply tacit collusion when bargaining with hospitals. Drawing on what is known from the previous cartel literature (see for example (Levenstein 2006)), this tacit collusion could take the form of either or both of (i) price fixing, where each supplier offers high prices to all hospitals, or (ii) market sharing arranged along the lines or customer or territorial allocations, i.e. the firms implicitly allocate hospitals amongst themselves and do not bid fiercely for hospitals tacitly recognized to be captives of their rivals.

Potential prices and quantities emerge from the bargaining. These reflect the relative strengths and skills of the buyer and seller. Amongst other things, these may depend on the flexibility of the hospital in the price it can afford to pay; the size of its order; and the nature of outside options for each side (i.e. an alternative intervention(Grennan 2013).) Conceptually, this could be formally modelled using the generalized Nash bargaining equilibrium (p. 159(Grennan 2013)).

4.2 Hypotheses

Within this framework, we propose the following hypotheses about diversification of choices revealed in the hospital's purchases.

A. *Relative importance of preferences of patients, surgeons and hospitals*

Consider first how the preferences of each of the players on the buyer's side may influence diversity.

If only patient 'preferences' matter, then considerable heterogeneity of choices should be observed in all hospitals (assuming that no one prosthesis best fits all patients). Think of each hospital as a sample of patients drawn from the national population. If the sample is unbiased, the variance of patient characteristics/preferences within each hospital would be the same as the variance in the national population. If so, there is no reason for expecting any systematic inter-hospital differences in diversification, except to the extent that (i) the small number of prostheses in very small hospitals might mean that the sample has a restricted range, and (ii) some hospitals, perhaps in big metropolitan centres, may have a particularly heterogeneous patient base. These qualifications apart, little difference should be observed between hospitals, and diversification of all hospitals should be similar.

If surgeon preferences dominate, and in the extreme case their choices are independent of the characteristics of the patients and of the financial constraints of the hospital, then diversity within the hospital depends only on the number of surgeons and the diversity of their preferences.

If hospital procurement preferences dominate, then only cost constraints should matter. To the extent that the hospital is able to negotiate volume discounts from suppliers, this will lead to specialization – especially in smaller hospitals.

Denoting the expected levels of diversification under the three alternatives by patients (P), surgeons (S) and hospitals(H) respectively, we propose two key hypotheses.

(H1) DIV(P)>DIV(S)>DIV(H): typical levels of hospital diversification will be greatest (near to the national level) if patient characteristics dominate, but lower if surgeon preferences dominate, and lower still if hospital procurement dominates.

(H2) The relationship between diversification and hospital size (measured by number of THR patients) will differ between the alternatives. Given **(P)** all hospitals (perhaps above some threshold size) would be as diversified in their choices as is the NHS as a whole, and DIVB will be largely invariant with respect to hospital size. Under **(S),** diversity will be higher in larger hospitals, assuming that larger hospitals use more surgeons. Under **(H)**, there may be only very limited increases in diversity as hospital size increases, unless very large hospitals are able to exert buyer power (see below.)

B. Exercise of market power by suppliers.

We hypothesise two possible consequences of seller power: exclusive contracts and/or tacit collusion .

(H3) Strict exclusive contracts. In a small number oligopoly such as this, the supplier will only offer volume discounts to the hospital on condition that the hospital makes all (or some high proportion) of its purchases from that supplier. This

implies low levels of hospital diversification, perhaps even for large hospitals, and DIVB will largely be insensitive to hospital size[7].

(H4) Tacit collusion. As discussed above, this could take the form of price fixing – where all hospitals are charged a price higher than the competitive level – but this has no obvious implication for diversity of buyer purchases, and anyway is untestable with the current data-set. However, information on DIVB may be suggestive of market sharing. We already know from the above (Table 4) that suppliers typically sell to only half of the hospitals (in numbers-equivalent form). Beyond this, each of the leading firms may have its own 'captive hospitals', and this is recognized by its rivals, who refrain from competing for those customers. This may be in the form of (i) 'customer sharing', in which certain identifiable types of hospital are more likely to be targeted for market sharing than others, e.g. IS hospitals and FTs, and (ii) territorial allocation, in which hospitals are shared out by their regional location.

C. Bargaining power of hospitals

We propose three hypotheses concerning the buyer power of hospitals.

(H5) Differences by Hospital (Financial Autonomy and Flexibility). To the extent that financially more autonomous hospitals (e.g. FTs) have less commitment to balancing the budget in any given year, there will be a reduced necessity to concentrate purchases on a single supplier in order to maximize volume discounts. Similarly, hospitals in the independent sector (IS) will be less budget-

[7] However, as we note later, any evidence that hospitals are highly specialized is not necessarily evidence of suppliers imposing exclusivity, this maybe the voluntary choice of hospitals.

constrained. For similar reasons, financially more autonomous and/or less constrained hospitals will be more able to accommodate divergent surgeon preferences and avoid the 'costs' of over specialization.

(H6) The introduction of Payment by Results (PbR) in 2006/7 may have increased hospitals' cost-awareness – pushing them towards specialization in order to maximize volume discounts.

(H7) Buyer power from scale. Larger hospitals can exploit their greater buyer power by securing a low price without locking into exclusive contracts with suppliers: this is an additional reason why diversity should increase with hospital size.

5. Empirical Model and Results

5.1 Estimating Equation

The hypotheses presented in section 4, are explored using the linked NJR-HES panel data for the period 2004-8 for the hospitals identified in the NJR (n=1673). We investigate diversification at a hospital level using the following equation:

$$DIVB_{jt} = f(\boldsymbol{P}_{jt},\ S_{jt},\ \boldsymbol{HT_{jt}},\ \boldsymbol{R}_{jt}, Year, \mu_{jt}, v_j) \qquad (5)$$

The dependent variable, $DIVB_{jt}$ measures the extent to which hospital j at time t diversifies its purchases across different manufacturers. It is employed in its numbers equivalent HHI form as defined by equation (3).

The explanatory variables reflect the above hypotheses. $\boldsymbol{P}_{jt}$ is a vector of patient characteristics (age, gender, side of surgery). These are included to capture any systematic differences between hospitals in their patient-casemix. These particular

characteristics have been found to be most significant in determining which types of prosthesis patients are fitted with, for example a patient is more likely to be fitted with a cemented prostheses if they are female or older (Davies C 2011). Here, they are measured as hospital averages or proportions (e.g. average age and proportion of females) of all patients treated in a given hospital. S_{jt} is the size of the hospital as measured by the number of THR operations performed. It is included in logged form to allow for possible non-linearities[8]. $\boldsymbol{HT}_{jt}$ is a vector of dummy variables representing the type of hospital: NHS Trust, FT, IS and TCs. These can be time-variant given the change in status of many NHS trusts to FTs. $\boldsymbol{R}_{jt}$ is a vector of dummy variables representing the geographical location of the hospital, measured by which of the (now defunct) 10 Strategic Health Authorities (SHAs) it is located in. *Year* is the year of observation, for each of 2004 to 2008. This is included in order to test for any effects of the introduction of PbR in 2005/6 (although it is acknowledged that they may pick up other temporal effects). u_{jt} is a conventional idiosyncratic disturbance term and v_j is a random time invariant hospital effect.

The equation is first estimated using a logarithmic random effects model with robust standard errors: as previously shown in Figure 1, *DIVB* is positively skewed, with a lower bound of 1, and taking the log corrects for this skewness. It is then re-estimated using the Tobit estimator to deal with the left censoring of DIVB (40 observations are less than 1). As can be confirmed from Table 5, the two estimators give almost identical results – likely to be because only 40 observations (2%) lie at the lower bound *DIVB=0*.

[8] We experimented with different functional forms of the hospital size variable, such as including it in a quadratic form. None of the different forms revealed a different result to the one on the log of hospital size reported in the paper.

Therefore the standard random effects model is preferred because it has robust standard errors.

5.2 Results

As shown in Table 5, none of the three ***patient characteristics*** are significant, suggesting that inter-hospital differences in the patient casemix are not an important cause of differences in diversification. This is not entirely unexpected because the means of these characteristics are unlikely to vary much across different hospitals. The result (discussed below) – that London hospitals are significantly more diversified than those in all other regions – may reflect a greater heterogeneity amongst patients in the big cities.

The significant positive coefficient on ***hospital size*** confirms a tendency for larger hospitals to be more diversified, however, although significant, the elasticity is low, 0.065. Thus, predicted values for *DIVB* (evaluated at mean values for London NHS trusts in 2006) rise only slowly from 2.63 to 2.75 to 2.88 at the three quartiles for observed size (52, 100 and 184 patients respectively).

The estimated coefficients on ***hospital types*** imply a clear ranking of the three main hospital types: those in the IS are significantly more diversified, while FTs are less diversified (p=0.10) than NHS trusts (the default).

The coefficients on each of the ***regions*** are negative and statistically significant, indicating that hospitals in all other regions in the country are less diversified than in London, the reference region. Wald tests were conducted to test for significant differences amongst the remaining regions. These reveal that Yorkshire, East Anglia, the North West and West Midlands are significantly more specialized than the least

specialized regions. Interestingly, Yorkshire is the region in which Depuy headquarters are located, and the North-West is immediately adjacent.

The equations are estimated with four separate ***year dummies.*** Subsequent Wald tests revealed no significant difference between each of 2004 to 2006 but significant effects for 2007 and 2008. This indicates a one-off fall in diversification, which coincides with the introduction of PbR around that time.

5.3. Implications for hypotheses

These results offer little evidence that patient heterogeneity is a major determinant of the diversity of purchasing choices made by hospitals, and it appears that hospitals and or surgeon preferences dominate (H1). Moreover, Figure 1 shows that approximately 90% of hospitals are more specialized than is the NHS at the national level. Given that diversification tends to increase only moderately with hospital size, this remains true even for the larger hospitals.

The positive relationship to size could be consistent with both a larger number of surgeons in bigger hospitals (H2) and greater buyer power for larger hospitals. However, diversification is relatively insensitive to hospital size, and the fact that typically most hospitals are specialized could be consistent with hospital procurers seeking to secure favourable volume discounts by concentrating most of its purchases on one or two main suppliers.

The relatively low levels of diversification by most hospitals, largely regardless of size, would be consistent with relatively exclusive contracts (H3). Regarding implicit market sharing (and perhaps tacit collusion) by the main suppliers, the evidence for this is suggestive but not conclusive (H4). The greater specialization of FTs and of hospitals in

the regions closest to Depuy's base (Yorkshire and the North-West) might suggest that there is a systematic element to market sharing. On the other hand, there is significantly greater diversity in the London area, in which perhaps all players are keen to secure a presence, and competition is fiercer. Other supporting evidence for some sort of market sharing is provided by (Davies C 2011) which considered in greater detail the shares of hospital purchases accounted for by the two main sellers. Stryker accounts for the majority of hospital purchases in about 29% of hospitals, and Depuy for the majority in another 30% of hospitals, while each having trivial shares (5% or less) in 34% and 29% of hospitals. There is also a significant negative correlation (r=-0.447) in their shares across all hospitals.

It was hypothesised that financially autonomous hospitals may be less constrained to balance their budget in any given year, and that this might lead to greater diversity in their choices of suppliers. This may allow them to accommodate divergent surgeon preferences, reinforcing the expectation of greater diversity. Our results suggest that this is true for IS hospitals, but the reverse is appears to be the case for FTs (H5).

It was also suggested that the introduction of PbR may have led to reduced diversification, because of a greater need to secure cost savings through volume discounts (H6). This is consistent with the structural break between 2006 and 2007.

Any offsetting effect for larger hospitals by virtue of possible greater buyer power appears to be minimal (H7).

6. Summary and Conclusions

This paper has revealed the medical devices market for THR is highly oligopolistic: the HHI levels are such that, if observed in other markets, they would raise concern about seller market power(The Competition Commission & The Office of Fair Trading 2010). It has also shown that within a typical hospital, concentration of chosen sellers– referred to as specialization of choices – is even higher. This means, from the seller side, that the leading firms each tend to concentrate their sales on some, but not all, hospitals. This further implies that there is potential for seller market power, through market sharing.

Given this factual background, we went on to explore why hospitals appear to specialize in this market? A series of hypotheses were assessed using panel data techniques for over 300 hospitals over a 5 year period. We found that diversification in choice of suppliers tends to be somewhat higher in larger hospitals. This could be because larger hospitals, with more surgeons, result in a diversity of preferences by surgeons for different prostheses. However, this effect is not strong and it does not rule out the possibility that suppliers are still able to impose a degree of exclusivity on hospitals, even those with some degree of buyer power. The results also indicate that policy implementation has potentially contributed to a decreasing level of diversification post 2006. The results suggest that hospitals have become less diversified since the introduction of PbR, and that its implementation may have had a direct impact on how hospitals are purchasing hip prostheses.

Moreover, the regression analysis reveals that FTs are less diversified than NHS trusts, but that IS hospitals are more diversified. This provides some of the first evidence on the behaviour of hospitals with more financial autonomy; that they are choosing not to

diversify in their purchasing of prostheses, and may instead be opting to exploit opportunities for cost savings (in negotiations) arising from purchasing from only one or two manufacturers. London is significantly more diversified than all other regions. which may be due to a lack of a specific manufacturer presence or because there is a higher prevalence of teaching hospitals, who are potentially less influenced by manufacturer loyalty.

Our analysis confirms the findings from the recent National Audit Office (NAO) report(National Audit Office 2011), that procurement in the NHS is not at all uniform, appearing to differ significantly between hospitals. Manufacturers may have realised their potential to exploit the market power, such that, rather than being faced with a single powerful buyer, the NHS, they instead sell to a fragmented set of disaggregated buyers. Thus the NHS is failing to exploit its potential position as a purchaser with considerable buyer power; this is not the case with pharmaceuticals where it has considerable market power. Recent policy implementation such as PbR and the introduction of FTs is also potentially reducing the diversity of purchasing at the hospital level. This implies that procurement within the NHS deserves closer attention and more research to inform future reforms.

An important limitation of the paper is that we have not been able to draw on hard evidence on how procurement decisions are actually made in the NHS – very little is documented in the public domain – nor the specific outcomes of bargaining between hospitals and suppliers. This paper offer insights on the diversity in choice of suppliers, utilising NJR data, but we have no information of the negotiated prices. Such information would allow our theoretical framework to be completely specified, thus supporting more specific assumptions and conclusions.

Further work is clearly required to better understand how procurement for medical devices takes place within the NHS, particularly as our findings suggest, but certainly do not prove, tacit collusion amongst suppliers. Again, information on negotiated price would be crucial for future work.

Despite these limitations, our analysis of the medical devices market structure (including the concentration and diversification of the market, and the determinants of diversification of choice) advances the understanding of how purchasing decisions within the NHS may be influenced by the potential market power of the supplying industry.

References

Agrawal M (1999). Global competitiveness in the pharmaceutical industry - The effect of national regulatory, economic, and market factors,, Pharmaceutical Products Press - The Haworth Press, Inc.

Anderson J, Neary F and Pickstone J V (2007). Surgeons, manufacturers and patients - A transatlantic history of total hip replacement, Palgrave Macmillan.

Commission of the European Communities (1998). Regulation (EEC) No.4064/89 Merger Procedure - Case No IV/M.1286 - Johnson and Johnson/Depuy,. Luxembourg.

Commission of the European Communities (2003). Regulation (EEC) No. 4064/89 Merger Procedure - Case No COMP/M.3146 - Smith & Nephew/Centerpulse,. Luxembourg,.

Cooper, Z., S. Gibbons, S. Jones, & and A. McGuire (2010). "Does hospital competition improve efficiency? An analysis of the recent market-based reforms to the English NHS,." CEP Discussion Paper **988**.

Davies C (2011). An analysis of choice: a case study on hip prostheses. Doctorate of Philosophy, University of East Anglia.

Davies S & Lyons B (1996). Industrial Organization in the European Union - Structure, Strategy, and the Competitive Mechanism, Oxford University Press.

Department of Health. (2012). "2012-13 tariff information spreadsheet." from http://www.dh.gov.uk/health/2012/02/confirmation-pbr-arrangements/.

Department of Health (2012). NHS procurrement: Raising our game.

Department of Health. (2013). "Treatment centres." from http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/Healthcare/Primarycare/Treatmentcentres/index.htm.

Department of Health and Association of the British Pharmaceutical Industry (2002). PPRS: The study into the extent of competition in the supply of branded medicines to the NHS,.

EU Commission (2009). EU competition inquiry into pharmaceutical sector - final report, European Commission - Competition

Grennan, M. (2013). "Price Discrimination and Bargaining: Empirical Evidence from Medical Devices." American Economic Review **103**(1): 145-177.

Levenstein, M. C. S., V.Y., (2006). "What determines cartel success?" Journal of Economic Literature **XLIV**(March): 43-95.

Mays N, Dixon A and Jones L. (2011). Return to the market: objectives and evolution of New Labour's market reforms,, The King's Fund.

Monitor. (2013). "Becoming and NHS foundation trust,." from http://www.monitor-nhsft.gov.uk/about-nhs-foundation-trusts/what-are-nhs-foundation-trusts.

Motta M (2004). The assessment of market power,. Competition Policy - Competition and Practice,, Cambridge University Press,**:** 124.

National Audit Office (2011). The procurement of consumables by NHS acute and Foundation trusts,.

NHS choices. (2012). "Hip replacement." Retrieved 11/11/2013, from http://www.nhs.uk/conditions/Hip-replacement/Pages/Introduction.aspx.

NHS choices. (2013). "NHS authorities and trusts." The NHS in England, from http://www.nhs.uk/NHSEngland/thenhs/about/Pages/authoritiesandtrusts.aspx.

Office of Fair Trading (2011). Private Healthcare Market Study.

Silverman E. (2007). "J&J's DePuy settles kickback charges,."

Silverman E. (2010). "Undisclosed conflicts among Docs and device makers."

Sir Philip Green (2010). Efficiency review by Sir Philip Green - Key findings and recommendations,.

The Competition Commission & The Office of Fair Trading (2010). Merger Assessment Guidelines,.

The National Joint Registry (2009). 6th Annual Report.

The National Joint Registry for England and Wales (2012). 9th Annual Report.

The Telegraph (2012). Budget 2012: NHS savings of £500m helping to fund 50p tax cut, says Labour.

Abbreviations

NHS – National Health Service

UK – United Kingdom

PbR – Payment by Results

HRGs – Healthcare resource groups

FT – Foundation Trust

THR – Total Hip Replacement

R&D – Research & Development

J&J – Johnson & Johnson

EC – European Commission

NJR – National Joint Registry

HES – Hospital Episode Statistics

PCT – Primary Care Trust

JRI – Joint Replacement Instrumentation

HHI – Herfindahl-Hirschmann Index

NS – Numbers-equivalent of sellers

NB – Numbers-equivalent of buyers

IS – Independent Sector

PMI – Private medical insurance

OFT – Office of Fair Trading

TC – Treatment Centre

DIVB – Diversification of buyers

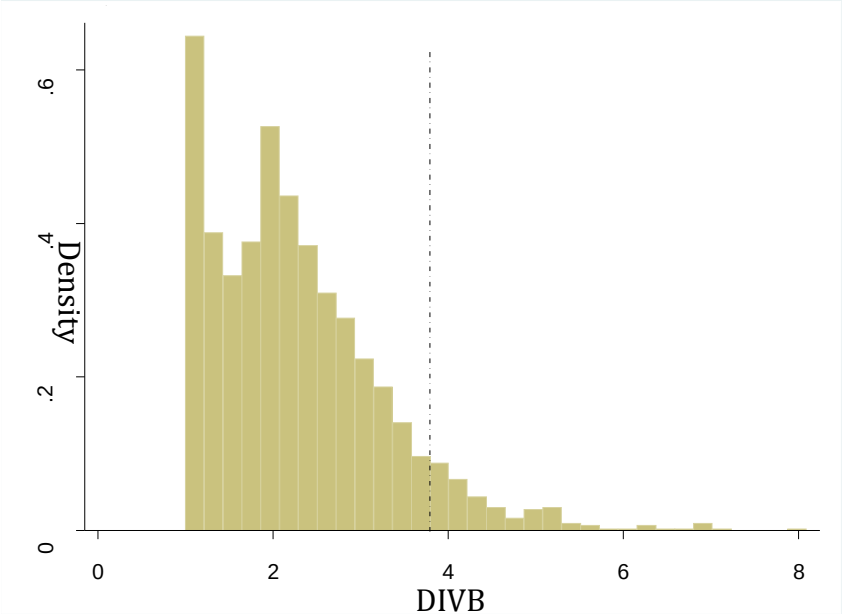
DIVS – Diversification of sellers

GP – General Practitioner

SHA – Strategic Health Authority

NAO – National Audit Office

Figure 1. Diversification of hospitals (DIVB)



*Dotted line depicts NS, concentration at the national (NHS) level

Table 1 Leading suppliers of hip prostheses in England and Wales

Market Shares (%)*					
	2004	2005	2006	2007	2008
Stryker	31	35	35	36	35
Depuy	37	34	33	34	34
Zimmer	7	7	8	7	7
JRI	9	9	8	7	7
Biomet	5	5	6	6	5
Smith & Nephew	3	3	3	3	3
Others**	8	7	7	7	9

* Market shares measured by volumes of prostheses

** None of the 19 other manufacturers exist has a market share of more than 2% in any one year

Source: authors' calculations, based on primary NJR data

Table 2: Concentration, 2004-8

	2004	2005	2006	2007	2008
Seller HHI	0.248	0.255	0.252	0.258	0.259
Buyer HHI	0.0057	0.0053	0.0058	0.0057	0.0057
NS	4.034	3.92	3.967	3.879	3.861
NB	173	189	171	177	174

Source: Authors calculations, using NJR data

Table 3: Size distribution of hospital types, 2004-8

	NHS Trust	FT	IS	NHS TC	IS TC
2004	292	14	23	8	4
2005	278	22	21	12	8
2006	271	41	17	9	12
2007	233	73	17	8	13
2008	212	76	25	8	15

Source: Authors calculations, using NJR data

Table 4 Linking national concentration to hospital diversification, using the decomposition

	NS	DIVB	NB	DIVS
2004	4.03	2.03	173	87
2005	3.92	1.98	189	95
2006	3.97	1.98	171	86
2007	3.88	1.88	177	89
2008	3.86	1.90	174	87

Table 5 Hospital diversification by manufacturer: panel estimation

Dependent Variable	lnDIVB	lnDIVB
Explanatory variables	Random effects Robust SE	Tobit random effects
Patient Characteristics (P)		
ln(age)	0.250	0.261
% female	-0.051	-0.042
% right sided surgery	0.106	0.127
lnS (hospital size)	0.065***	0.072***
Hospital Type (HT)		
Foundation Trust	-0.050+	-0.051+
Independent Sector	0.121**	0.116**
Treatment Centres & Others	-0.018	-0.019
Region		
East Midlands	-0.171*	-0.180**
South West	-0.207**	-0.215**
South Central	-0.225**	-0.228**
North East	-0.231**	-0.237**
East Anglia	-0.299***	-0.309***
West Midlands	-0.301***	-0.310***
North West	-0.304***	-0.312***
South East	-0.350***	-0.362***
Yorkshire	-0.393***	-0.404***
Years	-0.046**	-0.044***
2005	-0.0267	-0.0294
2006	-0.024	-0.026
2007	-0.056**	-0.055**
2008	-0.073***	-0.072***
Constant	-0.370	-0.459
σ u	0.336	0.337***
σ e	0.233	0.237***
Log Likelihood		-429.83
R-squared	0.0673	
Number of observations	1673	1673
Left censored observations		40
Default: NHS Trust, London, 2004-6		

legend: +p<0.10, * p<0.05; ** p<0.01; *** p<0.001