Inpatient Bed Occupancy and Specialty Costs within Scottish Hospitals

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Glossary of terms and abbreviations

Average Occupancy Ratio (AOR) - is the percentage of available staffed beds actually occupied by inpatients. The figure given is the average for the year.

Average (available)staffed beds - for any specialty they may be allocated beds from the specialty bed complement, or borrowed beds from another specialty, or temporary beds.

Cost per case - is calculated by dividing the total cost of inpatients in a specialty by the number of inpatient discharges from the specialty.

DRG - Diagnostic Related Group

ENT - ear, nose and throat

High occupancy specialty grouping - general medicine and its associated sub-specialties (such as cardiology or gastroenterology).

HRG - Healthcare Resource Group

Inpatient - a patient who occupies an available staffed bed in hospital and remains overnight. This includes a mother who delivers in hospital and a patient who is admitted as an emergency regardless of how long they stay.

LGMTH - large general major teaching hospital

Low occupancy specialty grouping - combination of ear, nose and throat (ENT), gynaecology and ophthalmology

LOS - length of stay

MSH - mixed specialist hospital

Occupied bed days - are available staffed beds which are either being used to accommodate inpatients or reserved for patients on pass. The figure given is the number of occupied beds for the year.

SMR1 - Scottish Morbidity Record 1, day cases and inpatient discharge form.

Summary

The main motivation behind this piece of research were the wide variations apparent in inpatient bed occupancy rates and specialty costs within Scottish hospitals. Routine hospital discharge summaries (form SMR1) and *Scottish Health Service Cost* data were used to investigate these variations for two specialty groupings; general medicine and its associated sub-specialties (such as cardiology or gastroenterology) as a high occupancy, high emergency admission category and combination of ear, nose and throat (ENT), gynaecology and ophthalmology as a lower occupancy, high elective admission category. It was important to have this distinction because the workload undertaken by each is likely to vary considerably, which could influence the bed use and costs of each.

Aims

The main aims of this thesis were:

- to unpack annual bed occupancy rates by looking at daily and seasonal trends
- to examine the effects of case-mix on length of stay and hence the effects on the perceived efficiency of a hospital
- to investigate the variation in specialty costs between hospitals in Scotland and to highlight any factors that may contribute to increased unit costs such as bed occupancy, length of stay (LOS) and teaching status.

Methods

Daily bed occupancy

Patients' length of stay, dates of admission and discharge are recorded on SMR1 which made it possible to calculate the number of occupied beds in a particular specialty on any given day. The number of available beds to each specialty within each hospital was also recorded in the *Scottish Health Service Costs*, allowing occupancy to be estimated in all hospitals for general medicine and its associated sub-specialties and for ENT, gynaecology and ophthalmology for each day of the

financial year 1994/95. The calculation of daily bed occupancy rates, then enabled seasonal and day of the week trends to be plotted for eight chosen hospitals (see Chapter 2).

Case-mix and length of stay

The information recorded on SMR1 also made it possible to examine the case-mix differences of hospitals. Healthcare Resource Groups (HRGs) were used to obtain an adjusted length of stay score based on hospital caseload compositions (see Chapter 3). A score of a 100 was taken to be the Scottish average, with anything above and below 100 taken to represent an average LOS, respectively, longer than or shorter than expected. This may suggest which hospitals are running more or less efficiently than the average. Crude LOS scores were also calculated from average lengths of stay recorded in Scottish Health Service Costs.

Cost analysis

Scottish Health Service Costs data for the financial years 1991/92-1995/96 for 26 acute Scottish hospitals were used to investigate factors which may influence unit costs. This was done by using a type of *"ad-hoc"* method of regressing cost per case (direct or total) on various explanatory variables such as bed occupancy, length of stay (crude or HRG- adjusted) and teaching status. The regression analysis was also carried out within a multilevel framework, so that variation attributable to year-on-year differences within hospitals and the variation between hospitals could be disentangled (see Chapters 4 and 5).

Results

Daily bed occupancy

For the medical grouping average annual bed occupancy ranged from 76-90% for the eight study hospitals, with daily averages ranging from 45-116%. For the elective specialties, although annual bed occupancy was lower, daily variations were generally larger. For all specialties, the majority of hospitals had bed occupancy levels greater than 90%, 95% and 100% for a number of days throughout the year, indicating that the practice of boarding patients in the beds of other specialties was a common occurrence.

Further, daily bed occupancy rates varied both by day of the week and seasonally. The eight study hospitals tended to follow a similar pattern by day of the week within each specialty. For the medical grouping bed occupancy was higher Monday to Thursday and lower at the weekend, while for the elective specialties ENT, gynaecology and ophthalmology bed occupancy was generally higher mid-week. In contrast no similar trend appeared to hold for seasonality, apart from the usual winter peak for general medicine and corresponding trough for the "elective" specialties.

Case-mix and length of stay

There were large variations both over time and between the crude and HRG adjusted LOS scores for a number of the hospitals. While variation between the crude and HRG adjusted LOS emphasised the need to adjust for case-mix, differences from one year to the next may instead reflect change in bed management practices or clinical protocols during the five year study period.

Cost analysis

The results of the cost analysis suggested that the relationship between cost per case and bed occupancy was different for the two specialty groupings. In the lower occupancy grouping of ENT, gynaecology and ophthalmology total cost per case decreased as occupancy increased; however, for direct cost per case the relationship was dependent on hospital type. Direct costs increased with occupancy for large teaching hospitals and decreased for hospitals with little or no teaching. In the high occupancy specialty category the relationship between occupancy and cost per case was uncertain, although there was limited evidence to suggest that an increase in occupancy was associated with an increase in cost per case.

The relationship between cost per case and length of stay was much stronger than for bed occupancy. In general cost per case increased with length of stay for both specialty groupings, however when length of stay was adjusted for HRG-mix the relationship was weaker.

As found in previous studies teaching hospitals tended to have a higher cost per case even after length of stay and bed occupancy were taken into account. However, the variation in costs differed between the two specialty groupings. For the high occupancy group variation was greatest among teaching hospitals and for the low occupancy group among mixed specialist hospitals.

Conclusions and discussion

The descriptive analysis of daily bed occupancy rates reinforced the argument that annual bed occupancy figures do not effectively measure or indicate the efficient use of hospital resources. However, at the local level, short-term trends in daily bed occupancy can provide a helpful means for more effective management of beds.

It was also apparent that bed occupancy is not a suitable target variable for reducing unit costs (at most a probable 1% increase would reduce cost per case by £5). This is because desired levels of bed occupancy can be achieved in two different ways: either by increasing admissions or by treating more complex cases with longer associated lengths of stay. These will have contrary influences on the average cost per case; the sharing of fixed costs over a larger number of admissions will result in a decrease in the average cost per case, whilst increased length of stay has been shown to be associated with increased cost per case.

Length of stay instead appeared to be the driving force behind cost per case. Crude lengths of stay explained more of the cost variation than case-mix (HRG-mix) adjusted models. However, this may only be because the method of adjusting for case-mix was not appropriate, although an alternative method of adjusting for case-mix was outlined in Chapter 5 and still failed to explain costs better than crude lengths of stay. Ideally if information on the cost of individual cases or diagnoses had been available, case-mix adjusted costs could have been fitted to the model as well as case-mix adjusted lengths of stay.

In conclusion, as for other hospital cost analysis concerns about the available data have undermined attempts to explain variations in unit costs across hospitals.

Chapter 1: Introduction

1.1 Background

The increasing bed crisis and expenditure of the National Health Service (NHS) in Scotland and throughout the United Kingdom has highlighted the need for more efficient and cost effective use of hospital resources. Inpatient discharges and day cases in all acute specialties in Scotland rose by an average of 2.3% per year between 1975-76 and 1991-92 (Munro, 1994). The introduction by the previous government of an Internal Market into the NHS tried to combat this by encouraging hospitals to minimise costs through competition for contracts. It is questionable whether this has had much impact, since it is still apparent that wide variations in cost exist both within and between hospitals. The Internal Market is now in the process of being abolished by the new Labour government. Their white paper 'Designed to Care', published in December 1997 outlines their plans to replace the Internal Market with a more patient focussed system.

As well as patient costs, wide variations in bed occupancy rates also exist within acute specialties in Scottish hospitals. Precisely why this should be the case is not certain. Some of the variation may simply be a reflection of differences in the case-mix (e.g. sex, age and proportion of elective and emergency admissions) and diagnostic mix of patients. Variation may also derive from different social and demographic features of the population served by individual hospitals or be a result of differing clinical and management practices between hospitals. The way a specialty is managed has a direct affect on its level of occupied beds. For instance, a specialty may not be able to achieve greater bed occupancy due to delayed discharge of patients because of infrequent ward rounds. The size of a specialty and its available resources may also contribute.

Differences in bed occupancy rates can have implications on both the cost and quality of services provided and therefore it cannot simply be assumed that higher occupancy rates represent greater efficiency. Obviously to maximise efficiency (so far as possible) hospitals need to avoid having an insufficient number of beds to provide an adequate service and at the same time too many staffed beds remaining empty for long periods, as there are still costs attached to having unoccupied staff beds. For example, even though a trained nurse may have the capacity to treat Y patients, he/she is still required even if there are only X patients. The cost of heating, lighting, bed maintenance and so on are already paid for regardless of the number of beds that a filled and therefore if not all beds are occupied the cost per case appears higher.

1.1.1 Outline of study

Some of the research carried out in this thesis was part of a much larger multidisciplinary study 'Bed occupancy and bed management' (unpublished report, 1997) commissioned by the Chief Scientist's Office on behalf of the Management Executive to Inform Purchasing and Provision for Acute Admissions. The project was undertaken for a year and had three main components; *(i)* statistical analyses exploring efficiency of bed use, *(ii)* an econometric analysis looking at the association of costs and different levels of bed occupancy and *(iii)* a study of the organisational structure and bed management practices of eight acute Scottish hospitals. Both the statistical and econometric components involved analysis of routine Scottish discharge and cost data, while the latter used qualitative data on bed management practices, collected from 136 semi-structured interviews with staff in eight acute Scottish hospitals, which included clinical directors, bed managers and nursing staff. The interview survey and part of the statistical component which involved a "survival analysis" to investigate the association between daily bed occupancy rates and the discharge of a patient from hospital, will not be discussed in this thesis.

Due to the limited time scale of the project the research concentrated on inpatients within two acute specialty groupings: general medicine and its associated sub-specialties (such as cardiology or gastroenterology) and the combination of ear, nose and throat (ENT), gynaecology and ophthalmology. These two groupings were chosen since the first is a high occupancy, high emergency category and the second is a lower occupancy, high elective category (Table 1.1). It was important to have this distinction because the workload undertaken by each is likely to vary considerably, which could influence the bed use and costs of each.

Specialty group	% occupancy ratio	% emergency ratio
Medical*	82.67	60.26
Low occupancy group**	57.07	15.84

*general medicine, cardiology, metabolic disease, neurology, gastroenterology
**ENT surgery, ophthalmology, gynaecology

Table 1.1: Average occupancy ratio and proportion of emergency admissions by specialty type, Scotland 1993

The analysis is split into two main sections. Firstly a mainly exploratory statistical analysis of daily bed occupancy trends within eight chosen hospitals for the financial year 1994/95. Secondly an econometric analysis using multilevel modelling techniques (discussed in detail later) of the relationship between unit costs and such factors as bed occupancy rates, length of stay and teaching status in 26 acute Scottish hospitals for five financial years 1991/92 – 1995/96.

1.1.2 Hospital selection

To ensure that the eight study hospitals would be comparable each was chosen on the grounds that it was an 'acute' hospital, with an adequate number of beds in both specialty groupings. Further hospitals were selected with a range of annual occupancy above and below the Scottish average, since it was of interest why similar hospitals should have such wide variations in bed occupancy. The effect of teaching status was also of interest so the study sample is a mixture of teaching and non teaching hospitals (see Appendix A). The study hospitals are fairly representative of all eligible hospitals (see Table 1.2). It should perhaps also be noted that neurology was not included in the medical grouping for this study.

All 26 hospitals analysed in the study fall under four of the Information and Statistical Division (ISD) functional classifications as described in the *Scottish Health Service Costs* (see Appendix B):

(1) Large general major teaching hospital covering a full range of services (other than maternity in some cases) and with some special units,

(2) General hospital with some teaching units, but not necessarily wholly teaching,

(11& 12) Mixed specialist hospital. No special units. Consultant type surgery undertaken (with or without maternity).

1.1.3 Aims

The main aims of this thesis were:

- to examine the degree of variation in bed occupancy and hence investigate the feasibility of using patterns of daily and seasonal occupancy to aid hospitals to better manage their bed stock and associated resources
- to examine the effects of case-mix on length of stay and hence the effects on the perceived efficiency of a hospital
- to investigate the variation in specialty costs between hospitals in Scotland and to highlight any factors that may contribute to increased unit costs such as bed occupancy, length of stay (LOS) and teaching status.

Hospital	Medical group		Low occupancy group	
	% occupancy ratio	% emergency ratio	% occupancy ratio	% emergency ratio
A	76.45	62.95	57.53	23.77
B	77.63	72.13	55.86	20.21
C	80.21	56.00	66.18	20.34
D	81.82	79.34	45.78	26.29
E	82.22	83.85	59.09	14.39
F	83.37	73.33	61.04	18.25
G	87.28	68.88	69.60	26.39
H	90.43	75.48	49.44	31.08
1	74.64	85.11	43.57	6.88
2	76.58	82.39	46.61	13.81
3	76.63	76.00	51.01	27.62
4	78.06	86.91	55.62	36.56
5	78.88	82.66	46.66	16.71
6	79.82	73.09	56.50	28.72
7	80.14	86.47	59.42	6.88
8	80.94	59.38	67.45	18.93
9	81.27	79.85	60.68	15.63
10	81.66	66.74	53.48	22.16
11	81.98	68.80	64.23	44.89
12	82.36	77.81	60.56	23.61
13	84.01	88.90	63.63	38.44
14	84.49	83.23	59.60	41.03
15	88.31	88.65	58.03	37.60
16	88.56	58.61	50.09	32.85
17	89.00	85.81	50.77	37.68
18	90.73	81.10	61.83	26.05
Study	**82.43**	**71.50**	**57.44**	**22.59**
Non-study	**82.11**	**78.42**	**56.10**	**26.45**
All	**82.21**	**76.29**	**56.70**	**25.26**

Table 1.2: Average occupancy ratio and proportion of emergency admissions by specialty type, all eligible hospitals: financial year 1994/95[1]

[1] A-H are the study hospitals and 1-18 are the 'other' hospitals included in the cost analysis.

1.1.4 Data sources

Two data sources were used for the analyses, namely Scottish Morbidity Record 1 (SMR1) and Scottish Health Services Cost Data. Both were obtained from the Information and Statistics Division (ISD) of the National Health Service (Common Services Agency) in Scotland and are detailed below.

1.1.4.1 Scottish Morbidity Record 1 (SMR1)

Details of each inpatient and day case hospital episode (excluding maternity and psychiatric discharges) in Scotland are recorded on a standard discharge form (see Appendix C), SMR1 (Scottish Morbidity Record 1) which are then routinely computerised and linked by ISD (Kendrick and Clarke, 1993). Currently the linked data set covers the period 1981-1996, although SMR1 dates back until 1961 (Kohli and Knill-Jones, 1992). The records include information on the age, sex, diagnoses, procedures and case management of each discharge, death or transfer (i.e. when a patient is moved to another hospital or to another specialty within the same hospital). The diagnoses and procedures are coded according to the International Classification of Diseases Ninth Revision (ICD 9) (WHO, 1977) and the Office of Population Census and Surveys classification of surgical operation and procedures, Fourth Revision (OPCS 4) (OPCS, 1987). Each record also specifies the hospital and specialty of each patient, which was particularly important in this study, so that comparisons could be made between and within different hospitals.

1.1.4.2 Scottish Health Services Costs

Scottish Health Service Costs ("Blue Book") is published yearly by ISD, providing financial and related activity information at specialty level for inpatients, outpatients, day patients and day cases for individual hospitals. Most of the information is derived from Scottish Financial Returns completed by each hospital '*using common accounting principles as described in the Scottish Accounting Manual*' (ISD, 1991-1996). The form principally used is SFR5 (Hospital Running Costs), which divides inpatient costs into several components. Prior to the financial year 1994/95 they were broken into five components: direct patient care, hotel services, property costs, running expenses and capital charges. However, from 1994/95 this was reduced to two main components: direct and allocated costs with direct costs sub-divided into several sub-components; these being medical and dental, nursing, pharmacy, PAM (professionals allied to medicine), other direct care, theatre and laboratories (see Appendix D for full details on cost components). Direct costs are the costs attributable to direct patient care as before and allocated costs are a combination of the remaining four components. This distinction is important because unlike direct costs allocated costs are not directly related to the type of treatment a patient receives. A large proportion of allocated costs are also sunk costs, such as building costs, which will have already been spent, regardless of the number of patients. Therefore, as the marginal cost of an extra day or 1% increase in bed occupancy was of interested, it was better to model direct costs separately to remove as much of the sunk costs as possible[2].

As well as cost data *Scottish Health Service Costs* provides information relating to hospital size and activity, such as number of average staffed beds, occupied bed days, average occupancy ratio, number of discharges and average length of stay.

1.1.4.3 Data quality

The quality of the SMR1 data set has frequently been discussed (Denholm, Macintyre and Wilson, 1993; Harley and Jones, 1996; Kohli and Knill-Jones, 1992 and Pears, Alexander, Alexander and Waugh, 1992). Although coding is not 100% accurate (and probably never will be) it has continually been improved. Between 1992 and 1994 accuracy of coding for the primary diagnosis has improved from 88.4% to 89.9%, with a similar improvement for coding of the main operation from 85.3% to 90.7% (Harley and Jones, 1996). Accuracy of Blue Book data has also been questioned, as it is believed that variation may exist in costing methods across hospitals (Scott and Parkin, 1995).

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[2] Direct costs will still include for example, the capital cost of specialist medical equipment.

1.1.5 Structure of thesis

So far this first chapter has provided an introduction to the background of this research. The remainder of the chapter serves as a platform for the rest of the thesis and discusses past research and the reasons for the chosen methodology. Chapter 2 goes on to examine the variation in daily bed occupancy for the eight study hospitals including day-to-day and seasonal fluctuations and the amount of time the hospitals experience extremes of demand in terms of bed availability in each of the specialty groupings. Chapter 3 illustrates the use of Healthcare Resource Groups (HRGs) as a case-mix tool and shows the effects of case-mix on length of stay and hence the effects on the perceived efficiency of a hospital. Chapter 4 details both the methodology and results of the multilevel models used for the econometric analyses of specialty costs and bed occupancy. Chapter 5 considers alternative methods to the case-mix (HRG-mix) adjustment illustrated in Chapter 3 and gives an example of one alternative. The final chapter discusses the conclusions which can be drawn from Chapters 2-5, validity of the methods and data and any future recommendations.

1.2 Variations in bed occupancy

Bed occupancy is the average number of available staffed beds occupied by inpatients in a given time period. Bed occupancy has been used as an indicator of hospital efficiency for many years despite a great deal of criticism particularly from nursing and medical staff (such as Forrester, 1981; Gandy, 1980; Williams, 1968 and Yates, 1982), "there is a vast difference between a bedstead and a bed with adequate staff and services. A high bed occupancy may be associated with poor medical practice and service to the community" (Williams, 1968). Historically high bed occupancy was believed to represent a well-run hospital, which utilised its resources to the full, treating as many patients as possible. Although this may be the case in some instances, high bed occupancy can simply be achieved by keeping patients in longer than necessary, thereby indicating inefficient rather than efficient use of resources (Yates, 1982 and Forrester, 1981). There has also been much debate in the past over "low" occupancy rates, in 1977 a minimum average rate of 80% was set for community hospitals in America (Phillip, Mullner and Andes, 1984).

Despite the above arguments bed occupancy rates are still a focus of efficiency (at least) within Scotland. In one study a similar target rate as above (80.2%) has been set by the end of the decade for all acute specialties, compared to an average of 72.1% in 1990-1991 (Munro, 1994). Another study predicted that average bed occupancy will be between 85% and 95% for most specialties by the year 2003 (Pollock et al, 1997). Chapter 2 proceeds to demonstrate that bed occupancy is not completely a redundant statistic. Daily bed occupancy figures can be useful in predicting weekly and seasonal patterns of bed occupancy, which in turn can be an effective tool in enabling better planning of hospital resources.

1.2.1 Variation in bed occupancy by day of the week

The demand for acute beds is known to vary considerably depending on the day of the week. Generally the number of acute admissions has been found to be higher on Monday and lower on Saturday and Sunday (Audit Commission, 1992; Bartholomew, Gelder and Jenkins, 1994 and London Health Economics Consortium, 1995). Two of the main causes identified are the postponement of GP and self referral to after the weekend (Audit Commission, 1992 and Bartholomew et al, 1994). Few elective admissions on Saturday and Sunday are also an added likely cause. Similar patterns have been seen in other countries such as the Netherlands, resulting in bed occupancy being higher mid-week (Vissers, 1995).

1.2.2 Seasonality

It is also apparent that acute admissions behave in a seasonal manner, with a peak for emergency admissions in winter and corresponding trough for electives; however exactly when the peak in emergencies will occur is impossible to anticipate. In Scotland it is usually seen between January and March, although it can happen at any time during the year; in 1992, June had the highest number of emergency admissions (Kendrick, Frame and Provey, 1997). Disruptions in the seasonal pattern such as this are probable consequences of extreme weather conditions and epidemics of infectious diseases (Edwards and Werneke, 1994 and Kendrick et al, 1997).

However, this is obviously a simplistic overview since the number and type of admission to different acute specialties can be very different. One of the downfalls of much of the literature is precisely this since it tends to look at the number of acute admissions for a country or hospital as a whole over a period of time, when there are likely to be individual differences between hospitals and between, for example a 'high' emergency specialty such as general medicine, and a 'high' elective specialty such as ENT.

1.2.3 Elective and emergency admissions

The rapid increase in acute emergency admissions over the last few years has been a major contributing factor to the recent bed crisis in the United Kingdom. Kendrick (1996) reported that the annual number of emergency admissions in Scotland had increased by nearly 50% between 1981 and 1994, with an average increase of 3% per year. The National Association of Health Authorities and Trust reports reported a 7-13% increase in acute medical admissions in 1993-1994, with similar rises documented throughout Britain by others such as Butler (1994) and Roberts (1995). Possible explanations identified in the literature include more GP referrals; fear of litigation, growth in readmission rates; premature discharge from hospital; an increase in self referral rates; people becoming more aware of rights and a change in social and cultural factors such as increased number of elderly living alone. It is likely that the rise is due to a combination of the above, although one of the most probable causes could simply be 'supply-induced' (or 'supplier induced') demand (Edwards and Werneke, 1994; Kendrick 1996; Round 1997), as described by Roemer's law "A built bed is a filled bed" (Roemer, 1961). Although there has been a reduction in the number of beds in recent years, shorter lengths of stay and turnover intervals, day cases and bed borrowing allow for increased admissions and thus a rise in emergencies (Edwards and Werneke, 1994).

The number of elective admissions has also increased in this time period. Within Scotland there was an 11% increase between 1981-1988, although remaining stable since then. Furthermore there is some evidence that the upward trend in admissions has not only occurred in high emergency specialties such as general medicine. For instance a study covering six health districts in the south of England, using the

Oxford Linkage data set, reported that gynaecology inpatient episodes had increased by 23.5% and day cases by 13.1% between 1975 to 1985 (Ferguson, Goldacre, Henderson and Gillmer, 1991).

1.2.4 Bed occupancy and emergency admissions

Despite the rapid rise in emergency admissions annual bed occupancy has remained surprisingly stable for acute specialties in Scotland. Between 1975/76 and 1991/92 the average rate stayed around 72-73% (Munro, 1994). This rate is higher for specialties such as general medical (see Figure 1.1). Between 1991/92 to 1995/96 the average was around 82%. Bed occupancy has probably been able to remain constant despite the increase in admissions to due the reduction in length of stay and shortening of patient turnover intervals, bed borrowing and increased day cases as mentioned above.

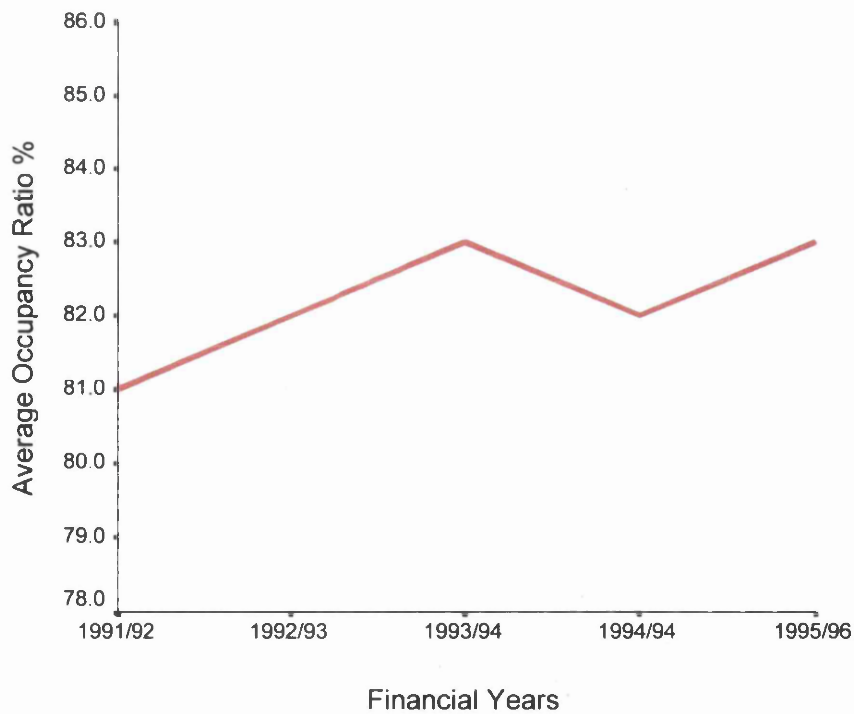

Figure 1.1: Average annual occupancy for general medicine and its associated sub-specilaties in Scotland: financial years 1991/92-1995/96 (Source: Scottish Health Service Costs)

1.2.5 Periods of pressure

It has become the norm in recent years for hospitals in the United Kingdom to experience levels of bed occupancy near or over 100%. When the bed occupancy of a specialty reaches this level it is an indication of bed borrowing from another specialty, temporary beds and in extreme cases patients left on trolleys (Pollock et al, 1997). Bed borrowing can have a detrimental effect on both staff and patients, since it leads to patients being 'decanted' into wards where the staff may not have the necessary skills or resources to deal with their particular needs.

1.2.6 Alternative measures to bed occupancy

Throughput and mean length of stay (LOS) are probably the two most commonly used statistics other than bed occupancy used to describe bed usage. Throughput is a measure of the average number of inpatient discharges treated in each acute hospital bed over a given time period and LOS is the number of occupied bed days divided by the number of inpatient discharges. It is perhaps worth noting here that bed occupancy rates are no longer collected in some countries, such as England (Pollock et al, 1997). However bed occupancy, throughput and LOS all boil down to the same thing. Each is just a different combination of the number of inpatient discharges, beds and total occupied bed days (see Figure 1.2). To make one comparison between Scotland and England; average LOS of acute specialties in England fell by 17% to 5.2 days between 1988-89 to 1994-95 and by 24% to 5.5 days in Scotland between 1988-89 to 1995-96 (Pollock et al, 1997).

Gandy (1980) compared bed occupancy to a statistic called 'percentage usage'. He suggested that this statistic was a more appropriate measure of bed usage since it included day casework. The number of day cases divided by 250 (365 minus weekends and bank and statutory holidays) were added to the numerator of bed occupancy. 'Percentage usage' only produced significantly different figures in some of the so called 'high elective' specialties: ENT, ophthalmology and dental surgery, which are likely to have a high proportion of day cases.

$$\text{Bed occupancy} = \frac{\text{occupied bed days}}{\text{staffed (available) bed days*}} \times 100$$

$$\text{Length of stay} = \frac{\text{occupied bed days}}{\text{number of inpatient discharges}}$$

$$\text{Throughput} = \frac{\text{number of inpatient discharges}}{\text{average staffed beds}}$$

*staffed bed days = average staffed beds x 365

Figure 1.2: Arithmetic definition of bed occupancy, throughput and length of stay

1.3 Healthcare Resource Groups

1.3.1 What are Healthcare Resource Groups?

Healthcare Resource Groups (HRGs) are a case-mix tool adapted from Diagnostic Related Groups (DRGs), which were developed in the late 1970's in the United States to monitor hospital performance and thus improve efficiency after it became increasingly apparent that widespread variations in cost existed between hospitals within the same specialty (Sanderson, Craig, Winyard and Bevan, 1986). Later DRGs were used for reimbursing hospitals in the Medicare programme in an attempt to control costs (Sanderson, Anthony and Mountney, 1995; Sanderson et al, 1986 and Söderlund, 1994). Medicare costs increased six-fold in the ten year period; 1974 to 1984 (Sanderson et al, 1986). It was felt necessary in Britain to develop a local version of the American DRGs after extensive use revealed that they did not relate particularly well to certain medical procedures carried out within the NHS. This was fundamentally due to differences in "clinical practice" and "diagnostic terminology" in Britain compared to the United States (Söderlund, 1994). Further motivation came from British clinicians themselves who wanted a system which they had clinically devised and thereby reflected their own workload (NCMO, 1997a). The first version of HRGs was introduced by the National Casemix Office (NCMO) in May 1992 and has become increasingly used within the NHS particularly in England (NCMO, 1996 and NCMO, 1997a and Sanderson et al, 1995).

1.3.2 HRGs versus DRGs

HRGs and DRGs are structurally very similar; they both try to group together hospital episodes that are similar in cost (using length of stay as a proxy) and resource mix (i.e. 'iso-resource' groupings), so that a price can be attached to individual services (NCMO, 1997a). This can then allow comparisons to be made between hospitals and specialties, so that more cost-effective practices can be identified. They also provide means for planning future services and since 1994, HRGs have been used in England as "costing for contracting" (NCMO, 1996 and Sanderson et al, 1995).

Despite their similarity HRGs have been shown to perform better statistically on English and Welsh data than DRGs (or any other presently available grouping method). This is shown by the amount of variation in length of stay (and hence costs) between episodes of each group explained by both methods in Table 1.3 (100 percent would represent all episodes having an identical length of stay). It is also perhaps worth noting that for Version 3 the variation for the clinical working groups ranged from 16.4% for haematology to 70.8% for gynaecology (NCMO, 1997a). The clinical performance of HRGs is also better because they are characteristic of the workload undertaken in the NHS, instead of the United States. Within the two countries the cost of and the type of procedures carried out often differ: for example, DRGs do not differentiate between primary and revisional hip replacements, when in the UK the cost is substantially different. Further, it is felt by clinicians that some of the recent advancements, such as additional DRGs for HIV (17) and opioid, cocaine and alcohol abuse (9) are not of high prevalence in the UK as they are in the United States (NCMO, 1997a).

Grouper	Percentage RIV*	Notes
DRG Version 4	28.6%	Grouper used in the original resource management work
AP DRG	32.0%	All patient DRG grouper used in Wales using Welsh data
Version 1.1 HRGs	25.0%	First version of HRGs 1992
Version 2 HRGs	32.2%	Using English data
Version 2 HRGs	37.6%	Using Welsh data
Version 3 (draft) HRGs	35.0%	English data

* reduction in variance

Table 1.3: Percentage of variation in length of stay explained by classification schemes (Source: NCMO, HRG Version 3 documentation set, 1997)

HRGs have been developed specifically for use within the NHS and therefore cannot be used to make comparisons with other countries. It has, however, been proposed by researchers such as Rhodes, Wiley, Tomas, Casas and Leidl, (1997) that since DRGs are used widely throughout the world they can be used to make international comparisons. This is somewhat questionable since most countries (including some parts of the US) have made at least some modification to the structure (e.g. Australian National DRGs) which can lead to large differences in the grouping of cases, thus reducing the potential of comparability (NCMO, 1997).

Although to date there have been few publications relating to the use of HRGs in Scotland, it was felt the most appropriate method for adjusting for case-mix in the econometric analysis of costs and occupancy in Chapter 4. It is likely that HRGs will perform similarly on Scottish data, since obviously clinical practice in Scotland is more comparable to England and Wales than the United States. The application of HRGs is further discussed in Chapter 3.

1.4 Hospital cost variation

This section discusses the unit and level of costs used in this study and some of the previous relationships found between hospitals costs and known influences such as case-mix and teaching status.

1.4.1 Cost per case versus cost per day

Two units of output are commonly used in hospital cost analysis, average cost per case (admission or discharge) and average cost per day. Cost per case is believed to be the more appropriate for measuring acute hospital care, due to the sometimes irregular behaviour of cost per day (Feldstein, 1967 and Butler, 1995). For example, unlike cost per case, reducing length of stay does not typically reduce cost per day. Instead cost per day is likely to increase because the beginning of a patients stay incurs the majority of the costs. It is perhaps not surprising then, to find that there is little correlation between the two variables, as highlighted by Feldstein (1967) in a study of 177 NHS hospitals and Butler (1995) in a study of 121 hospitals in Queensland, finding the correlation between the two variables to be 0.23 and 0.20 respectively. Furthermore those studies which have compared the two typically retain cost per case in the model, as the R^2 is usually found to be higher[3]. For example, Sloan and Becker (1981) found an R^2 of 0.65 compared to 0.49. Similar results have been found by others, such as Robinson and Luft (1985) and Sloan, Feldman and Steinwald (1983). For the above reasons cost per case was used in this study.

1.4.2 Hospital versus specialty level

Another important consideration when modelling hospital costs, is whether to measure them at hospital or specialty level. Previous studies tend to treat the hospital as a whole unit. In this study specialty costs were modelled, since cost per case will inevitably differ greatly between some specialties because different average lengths of stay, proportions of elective/emergencies and day cases mean individual specialties consume varied amounts of resources. The cost of operative procedures will also differ substantially from one specialty to the next; for example an organ transplant will obviously be more expensive than a routine tonsillectomy.

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[3] In regression analyses R^2 is typically used to determine how well a model fits the data. The higher the R^2 more of the variation in costs (say) is explained by the model.

1.4.3 Relationship between case-mix and costs

Many studies have shown that differences between the case-mix and diagnostic mix of hospitals and specialties accounts for the at least some of the variation in costs. In a study of all admissions to nine acute NHS hospitals in Oxford for the financial year 1991/92 it was found that approximately 77 percent of the variation in cost between hospitals could be explained by their differences in case-mix (Söderlund, Milne, Gray and Raftery, 1995). However most of the large variation in cost existing between and within specialties could not be explained by case-mix differences. Poor distribution of specialty costs in hospital financial returns was thought to be one probable explanation.

1.4.4 Teaching hospitals versus non-teaching hospitals

Teaching hospitals are found to generally incur higher costs than non-teaching hospitals. This is believed to be due to the more complex case-mix of patients treated within teaching hospitals. Frick, Martin and Shwartz (1985) in a study of 11 teaching and 20 non-teaching hospitals in New York State found that the average cost per case of the teaching hospitals was 68% greater than the non-teaching. However, only one-quarter of this increased cost appeared to be attributable to case-mix differences, a similar finding to that reported by Culyer, Wiseman, Drummond and West (1978) in their study involving 268 English hospitals. Frick et al (1985) highlighted four possible explanations for the remaining cost difference. They first suggested that there may be indirect costs linked to the training of medical students (e.g. more diagnostic test being carried out for teaching purposes). Secondly, teaching hospitals may be treating a more severely ill patient mix within Diagnostic Related Groups (DRGs). Thirdly, within teaching hospitals more costly treatments may be carried out to improve quality of care provided and hence patient outcomes. Lastly, higher costs may just reflect inefficiencies within teaching hospitals.

Several researchers in the US have attempted to determine whether the higher cost of teaching hospitals is due to the reasons mentioned above. The findings are varied. Some have suggested that costs related to medical education are the main cause (such as Cameron, 1985; Garber, Fuchs and Silverman, 1984 and Jones, 1985) while other studies reported that differences between teaching and non-teaching hospitals diminished considerably after taking account of severity of illness variables (such as Becker and Sloan, 1983; Horn, 1983 and Watts and Klastorin, 1980). There appears to be less published literature in Britain comparing the costs of teaching and non-teaching hospitals, although the study conducted by Culyer et al (1975) also found medical training to be one of the main contributors to the higher costs of teaching hospitals.

1.5 Modelling hospital costs

1.5.1 Introduction

Various econometric and statistical methods have been used to investigate hospital efficiency, which come under two headings, namely cost functions and production functions. Cost functions focus on the relationship between the costs of a hospital to the size of its outputs (e.g. occupied bed days), while production functions compare the size of a hospital's outputs to the amount of each resource used in its running. Cost functions are the more frequently used method and were used in this study, since the relationship between unit costs and factors such as bed occupancy were of foremost interest. These typically fall into two categories; those that concentrate on the relationship between average cost per case and/or day and variables (such as teaching status) thought to influence costs and those that are based on the economic theory of the firm, usually focused on total costs (Breyer, 1987 and Scott and Parkin, 1995).

Regression models using translog functions and the non-parametric method of Data Envelopment Analysis (DEA) are two of the most commonly used methods and will be briefly discussed below, with particular reference to two Scottish studies (Scott and Parkin, 1995 and Hollingsworth and Parkin 1995). The method employed in this study was a form of multilevel analysis; multilevel regression, which is an extension of simple regression theory developed since the mid 80's to explicitly model data which has a hierarchical structure; that is, where groups of observations or units are nested or clustered within different levels. This could for example be groups of individual patients with a particular diagnosis treated within different specialities within different hospitals. In this example there are three distinct levels: patients, specialties and hospitals. However, in the case of this study the hierarchy takes the form of a two level repeated measures model, where occasions – (years) are nested within individuals – (hospitals). Each occasion is a collection of variables (or measurements) such as average bed occupancy, mean length of stay and number of discharges taken for one year on an individual hospital. Therefore, as there were five years worth of data used in this study, each hospital will have a total of five occasions.

1.5.2 Translog cost functions

The parametric method of transcendental logarithmic (translog) cost functions has been employed in numerous studies examining the structure of hospital costs (such as Conrad and Strauss, 1983; Fournier and Mitchell, 1992; Gaynor and Anderson, 1995; Scott and Parkin, 1995 and Sauffham, Devlin and Jaforullah, 1996). The translog cost function has a flexible functional form due to the inclusion of higher order terms (for more detail see for example Scott and Parkin, 1995) focusing on the multiple input and nature of hospital production. However, the flexibility allowed by higher order terms is achieve at the price of reduced degrees of freedom and thus the number of parameters which can be estimated (Scott and Parkin, 1995).

Scott and Parkin (1995) looked at the usefulness of the translog cost function in assessing hospital efficiency within the NHS internal market (as it still was then). Their data set consisted of data from 76 Scottish 'acute' hospitals for the financial year 1992/93. The results of their analysis showed a very high R^2, and a large and highly significant intercept, which are symptomatic of deterministic processes. Other studies also reported a high R^2 (for example Montfort, 1981; Sauffham, Devlin and Jaforullah, 1996). This along with the limited degrees of freedom (and hence limited number of output variables) within the model raised concerns about the validity of applying translog cost functions to this data. However Scott and Parkin (1995) did suggest using several years data instead of a single year, increasing the degrees of freedom allowing for the disaggregation of output variables would produce a more stabilised econometric model. They also suggested that perhaps because of the deterministic nature of the model, that a non-parametric technique such as DEA would be more suited to the data. Hollingsworth and Parkin (1995) have analysed the same data set using this approach detailed below.

1.5.3 Data envelopment analysis

Data Envelopment Analysis (DEA) is a linear based programming method developed by Charnes, Cooper and Rhodes (1978) to compare the efficiency of non profit organisations (Nunamaker, 1983) such as hospitals, by looking at relationships between their inputs and outputs. Weights are assigned to each input and output using Pareto efficiency conditions (for details see, for example, Ganley and Cubbin, 1992) to produce a "best practice frontier" to which each of the units in the sample are compared (Hollingsworth and Parkin, 1995). It should be noted that those units deemed to be efficient may still be able to adopt better methods to improve their efficiency and only represent the "best practice" within the sample. Consequently, all inefficient units, may not be identified because all the hospitals in the sample may be inefficient (Sherman, 1984).

There have also been many studies using DEA, such as Hollingsworth and Parkin, 1995; Nunamaker, 1983 and Sherman, 1984. As mentioned above Hollingsworth and Parkin (1995) used DEA to analyse the same sample as Scott and Parkin (1995). They concluded that DEA analysis seemed to be a promising tool for assessing efficiency within the NHS, although it should be seen as complementary rather than a method, which can stand alone. A recent review of econometric cost studies (Aletras, 1997) further concluded that the results of DEA studies should be looked upon with caution because of number of problems associated with it, such as the selection of inputs and outputs, which is a purely arbitrary process. If the right inputs and outputs are not chosen then the information produced by the technique can be misleading. The analysis also provides no measurement of statistical error.

The results can also be questionable if the units in the sample are not comparable: "within the DEA framework, it makes little sense to compare a large teaching institution to a small community hospital" (Nunamaker, 1983). This may be the case with the results for Hollingsworth and Parkin (1995), since ISD's functional classifications 01-15 (see Appendix B) include children's and general practitioner cottage hospitals which are not likely to use similar amounts of resources as large teaching and district general hospitals. However it should be recognised that this could be a problem with other methods.

1.5.4 Ad hoc studies

Studies which use average cost per case and/or cost per day such as those carried out by Butler (1995); Feldstein (1967); Friedman and Pauly (1983); Lave and Lave (1970) and Lave, Lave and Silverman (1972) have been termed "*ad hoc*" analysis mainly because of the restrictive functional form usually adopted and the indiscriminate application of any variable believed to effect hospital costs (Breyer, 1987). These theoretical problems can lead to unreliable parameter estimates, giving inconsistent results across studies. In the cost analysis in this thesis we also used average cost per case, despite the above criticisms. One of the main reasons being that more complex methods favoured in recent years have failed to solve many of the problems previously found with cost and production functions (as already discussed). The flexible functional form of methods such as translog cost functions bring many added constraints, such as limited degrees of freedom which often means the exclusion of key output variables and an unsatisfactory adjustment for case-mix (see section 1.5.2). It also seemed sensible to use average cost per case here simply because of the way the available cost data is reported (see section 1.1.4.2). Finally it was hoped that since the multilevel modelling has many methodological advantages over the previous methods employed in the so called "*ad hoc*" studies (as detailed in the following section), more reliable estimates would be produced.

1.5.5 Multilevel modelling

Data analysis within a multilevel framework has been increasingly carried out by researchers especially in the fields of education (Goldstein, 1987), geography (Duncan, Jones and Moon, 1993 and Jones, 1991) and health service research (Rice and Leyland, 1996 and Leyland and Boddy, 1997). Rice and Jones (1997) recently proposed that such analyses would also be of benefit in the area of health economics, where as yet little use had been made of the method despite the hierarchical structure of much of the data in this field. Multilevel analysis has many names, the most familiar being multilevel models (as proposed by Goldstein, 1995 and used in this study), random coefficient models (Longford, 1992) and hierarchical linear models (Bryk and Raudenbush, 1993). The estimation process used in the multilevel modelling software MLn[4] (Rasbash and Woodhouse, 1996) is based upon iterative generalised least squares (for details see Goldstein, 1995).

Multilevel analyses has many benefits over traditional techniques, as it allows variation at different levels (i.e. patients within specialities within hospitals) to be modelled simultaneously. Single level methods such as the regression technique of Ordinary Least Squares (OLS) ignore the natural hierarchy of much data. They confound one effect within another, making it difficult to explore adequately the association within and between different levels of interest. As a result this leads to underestimation of the size of the standard errors (Rice and Leyland, 1996) which in turn overestimates the statistical significance of the explanatory variables in a model. This is commonly known as "misestimated precision" (Bryk and Raudenbush, 1993). The assumption of independence needed for OLS models is also not valid in the case of hierarchical data because of the high correlation between observations at different levels. For example, it would be expected that there would be at least some correlation between the costs of a hospital from year to year, if the costs are higher one year they are also likely to be the following year.

As already mentioned one of the problems with using regression methods such as translog costs functions on a small sample size is limited degrees of freedom. Multilevel modelling can overcome this problem, since including multiple observations taken over a period of time increases the number of observations and subsequently the degrees of freedom. An equal number of observations at each time point is also not required, which is often the case for repeated measure techniques.

Fitting a fixed effects model would also overcome problems of independence and "misestimated precision" since it estimates a mean for each hospital rather than an

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[4] A windows version; Mlwin is now available (Rasbash, Healy, Browne and Cameron, 1998).

overall mean. This is done by adding a dummy variable[5] for each hospital into the regression equation as an explanatory variable. However doing this also results in considerable loss of degrees of freedom (i-1 hospitals where i=1,...,n). To examine further whether any of the explanatory variables were random across hospitals would require the addition of another i-1 dummy variables. In contrast, only one random parameter is required in a multilevel model – the variance between hospitals – from which coefficients for each hospital effect can be calculated, conserving degrees of freedom. Here each hospital unit is treated as a random effect, which allows each hospital effect to be estimated based on data from all hospitals in the sample "borrowing strength" from the characteristics of their shared distribution, rather than just its own data, as in the case of the fixed effects model (Rice and Leyland, 1996).

Furthermore, multilevel analysis as a stochastic process differs both from non-parametric techniques such as DEA and more traditional stochastic frontier analyses favoured in recent years. DEA is unique in that it identifies a frontier (see section 1.5.3), while traditional stochastic frontier analyses identify average practice, and departures from this to measure efficiency of hospitals, through the imposition of half-normal distributions (Wagstaff, 1989). A multilevel model differs in that it identifies deviations from the mean by estimating random effects for individual hospitals within the sample (as discussed above).

As a non-parametric technique DEA is sometimes preferred, since it has the advantage of not having to rely on specific assumptions about the distribution of the data. However, it has disadvantages of not being able to estimate random error or identify average practice which are felt more important. It is also of interest to be able to estimate, for example, the average cost per case of a one day increase in length of stay.

Therefore, since multilevel modelling techniques have the potential to overcome at least some of the theoretical problems found by previous researchers, these methods were used to analyse the cost data in this study.

[5] Dummy variables are dichotomous (0,1). For example, if there were i hospitals (i= 1,.., n), the value 1 would be given to the dummy relating to the first hospital for responses corresponding to i=1 and 0 otherwise.

Chapter 2: Daily variations in bed occupancy

2.1 Introduction

In this chapter patterns of daily occupancy rates have been highlighted in order to give some insight into the wide variations in bed occupancy between hospitals and individual specialties.

2.2 Data

Analysis of data from the routine system of Scottish Hospital discharge summaries (form SMR1) and data from *Scottish Health Service Costs* for the financial year 1994/95 were used to investigate the wide variations in daily occupancy rates of inpatients in the two chosen specialty groupings: general medicine and its associated sub-specialties (such as cardiology or gastroenterology) as a high occupancy, high emergency admission category and the combined grouping of ear, nose and throat (ENT), gynaecology and ophthalmology as a lower occupancy, high elective admission category. It was possible to distinguish between the two groups in this manner since admission type is recorded on SMR1. For this part of the analysis, however, the three specialties in the lower occupancy grouping were considered separately. Daily occupancy rates were calculated for all hospitals in Scotland (see Appendix E), however the results here will focus only on the eight hospitals which comprised the "Bed occupancy and bed management" study (see section 1.1.2).

2.3 Methods

The statistical package SPSS was used to calculate the daily bed occupancy for inpatients for each of the hospitals for the specialties of interest. Bed occupancy (as a percentage) was defined as:

$$\text{Daily bed occupancy} = \frac{\text{number of occupied beds per day}}{\text{average number of available staffed beds per day}} \times 100$$

It was possible to calculate the number of daily occupied beds for specialty and hospital, because patients' lengths of stay, dates of admission and discharge are recorded on SMR1. Nearly 10% of medical inpatient discharges in the financial year 1994/95, however, were recorded as having a length of stay of zero days (that is, they did not remain overnight). For these patients a length of stay of 0.5 days was assumed. Information on the daily number of staffed beds was not available, so an average figure for the number of beds reported in the *Scottish Health Service Costs* for the financial year 1994/95 was used.

2.4 Results

2.4.1 Distribution of average daily bed occupancy

Figure 2.1 shows the distribution of average daily occupancy rates for the medical grouping for each of the eight hospitals. The hospitals have been labelled A to H in increasing order according to their annual bed occupancy for general medicine. The figure shows the substantial variations in daily occupancy rates throughout the year which annual averages conceal. Hospital H for instance had an average rate of 90%, yet on a daily basis in the financial year 1994/95 its occupancy ranged anywhere from 57 to 114%. This scenario was not unique to hospital H or to general medicine: each of the other hospitals had large variations for all four specialties (see Figures 2.1 – 2.4). However the variation was larger and minimum occupancy lower among the elective specialties.

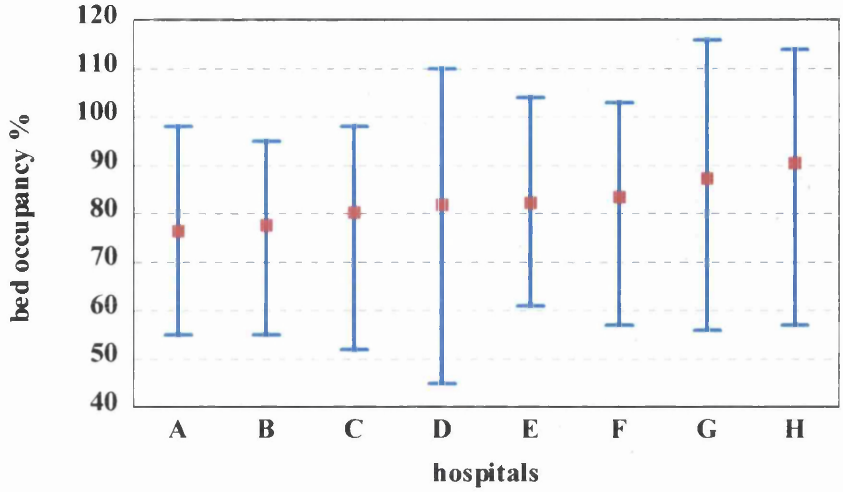

Figure 2.1: Distribution of daily bed occupancy for general medicine and its associated sub –specialties: financial year 1994/95

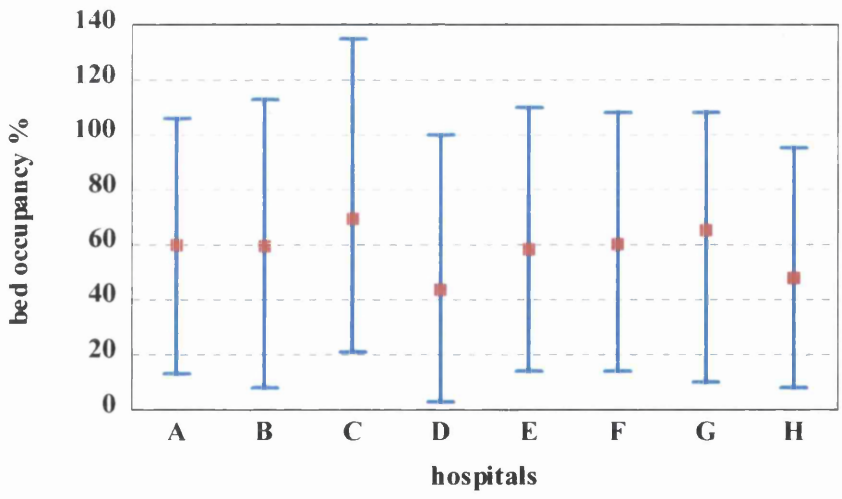

Figure 2.2: Distribution of daily bed occupancy for ENT surgery: financial year 1994/95

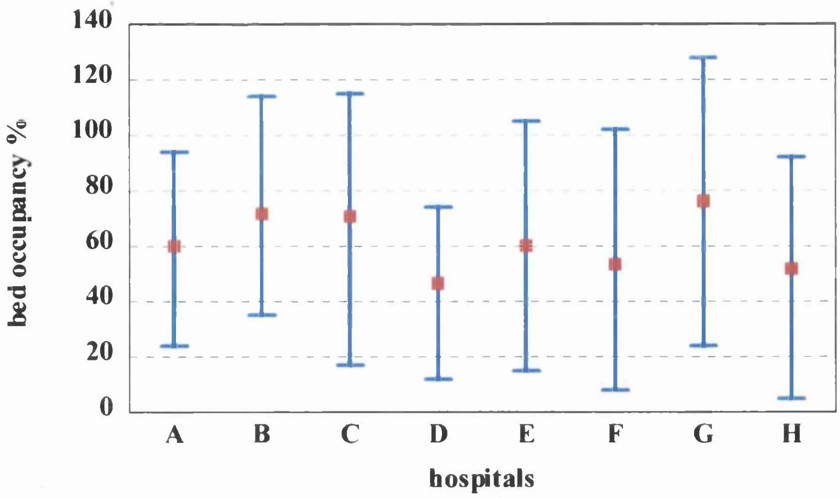

Figure 2.3: Distribution of daily bed occupancy for gynaecology: financial year 1994/95

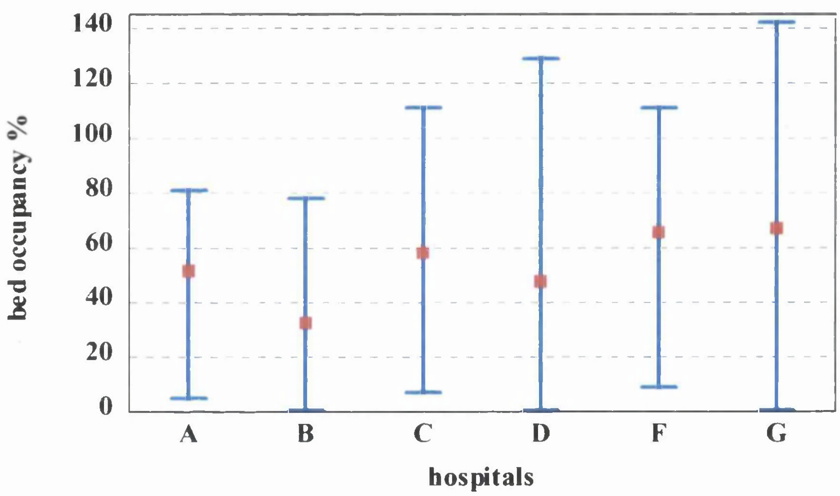

Figure 2.4: Distribution of daily bed occupancy for ophthalmology: financial year 1994/95

2.4.2 Variation in bed occupancy rates by day of week

Day-to-day averages highlight how the number of occupied beds changes during the week. Bed occupancy is usually lower at the weekend due to fewer admissions because there are relatively few or no medical electives. Generally, each of the eight hospitals followed a similar pattern for bed occupancy by day of the week. In the medical grouping the hospitals, have higher occupancy rates Monday to Thursday tailing off at weekend with an increase on Sunday (see Figure 2.5). In ENT and gynaecology occupancy rates tend be higher mid-week (see Figures 2.6 and 2.7).

Ophthalmology was the only specialty out of the four chosen that did not appear to have a clear trend for all the hospitals (see Figure 2.8): hospital G followed a similar pattern to ENT and gynaecology while hospital B's occupancy peaked on Tuesday and then gradually decreased until Saturday.

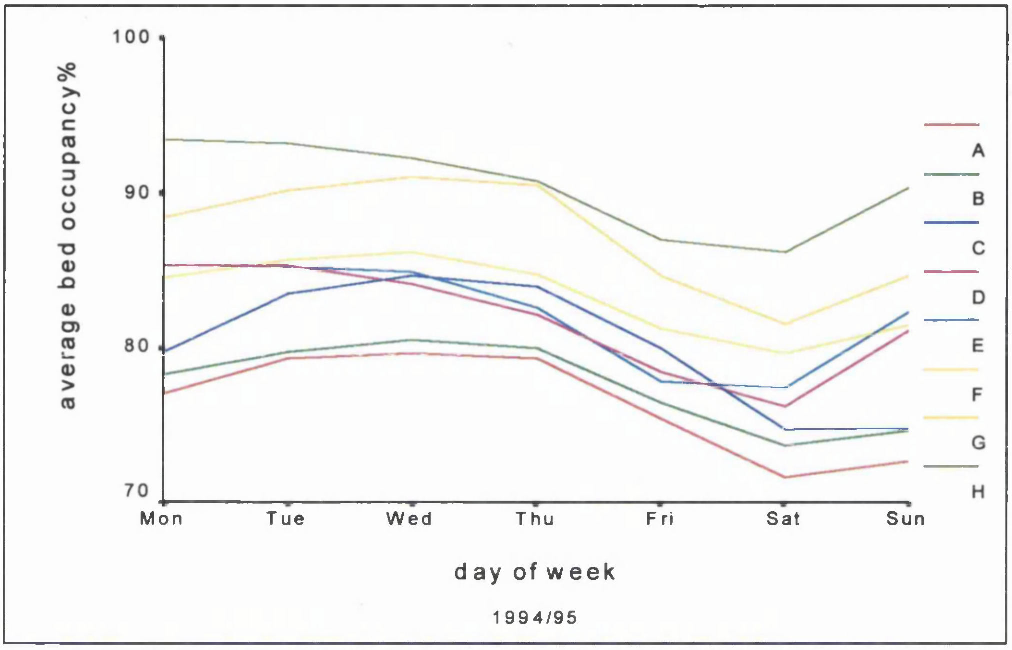

Figure 2.5 : Average bed occupancy by day of week for general medicine and its associated sub-specialties

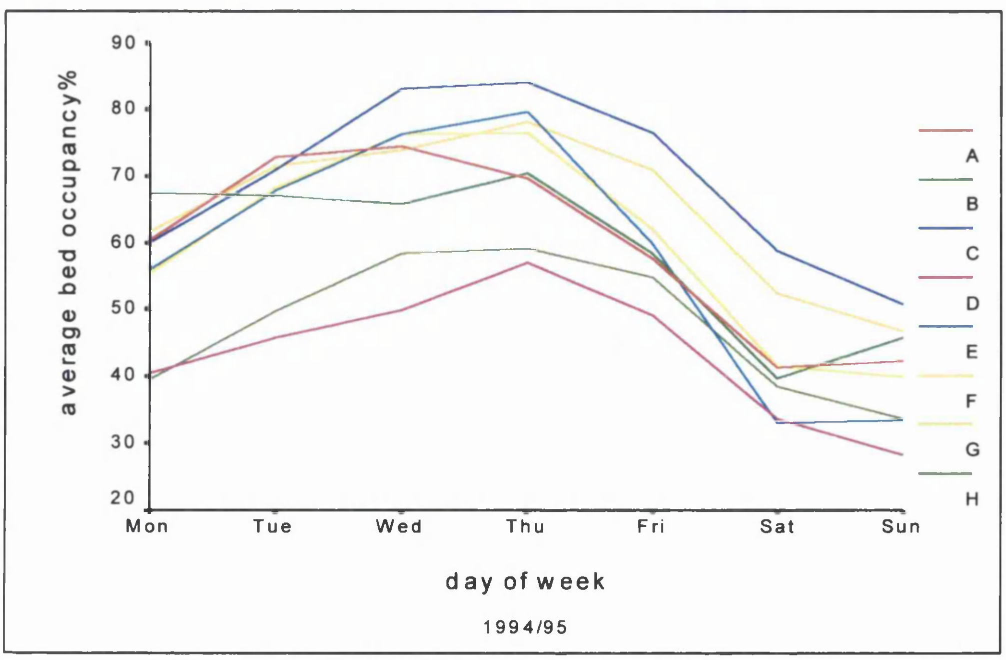

Figure 2.6: Average bed occupancy by day of week for ENT surgery

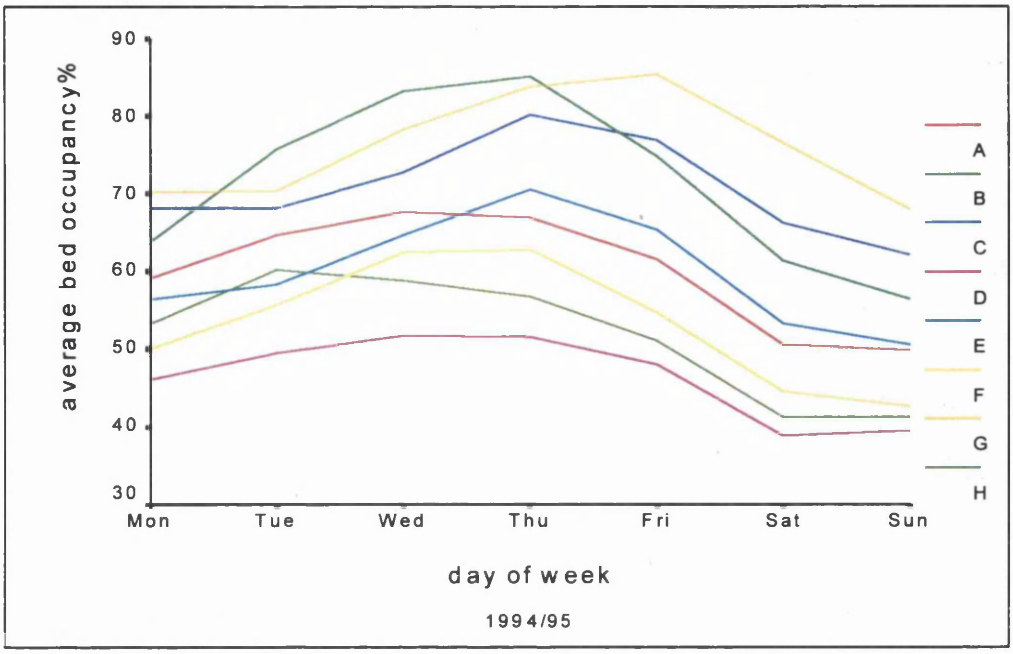

Figure 2.7: Average bed occupancy by day of week for gynaecology

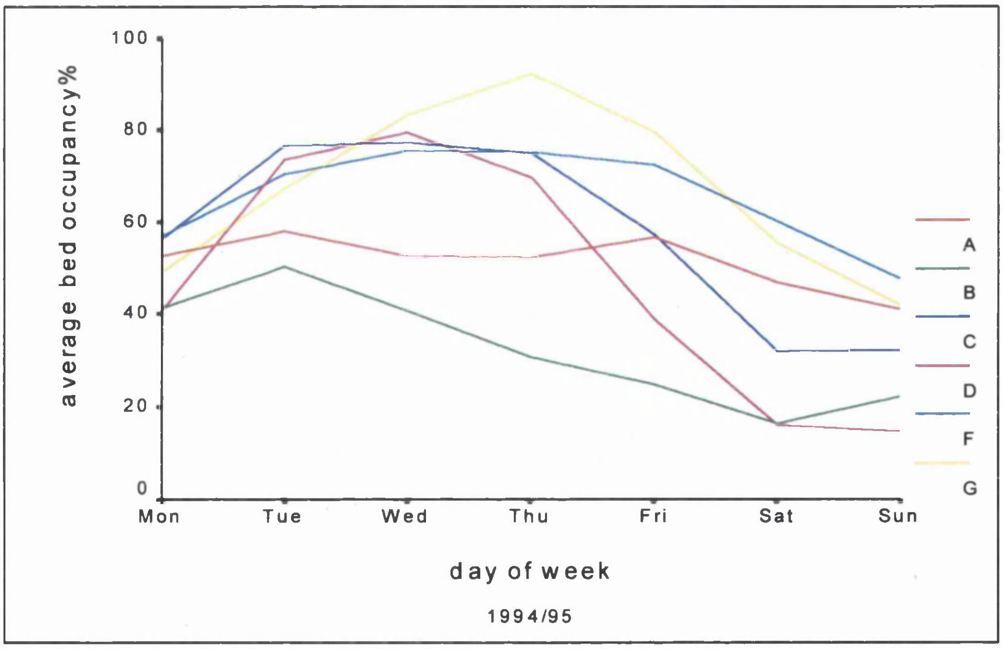

Figure 2.8 : Average bed occupancy by day of week for ophthalmology

2.4.3 Seasonality of bed occupancy

The seasonal pattern of bed occupancy was less obvious than the day-to-day variation. For the high emergency specialty of general medicine occupancy rates were high between January and March, with a drop in the summer months and a slight decline in December (Figure 2.9). It is also perhaps worth noting that the majority of the study hospitals have a higher average bed occupancy between January and March compared to the Scottish average (around 80% - see Appendix F). In the high elective specialties, (ENT - Figure 2.10 and gynaecology - Figure 2.11) occupancy rates remained steady for most of the year apart from a sharp decline in December. Occupancy rates were more erratic however for ophthalmology (Figure 2.12), with no great similarity between the hospitals apart from declines in July and December.

As well as the expected winter peak for general medical and corresponding trough for the elective specialties (especially noticeable in ENT and gynaecology) each of the eight hospitals tended to have their own individual peaks and troughs at different times of the year. As an example, hospital H did not appear to have an obvious winter peak for general medicine, but remained at a constant high level of occupancy for most of the year apart from a reduction in the summer months.

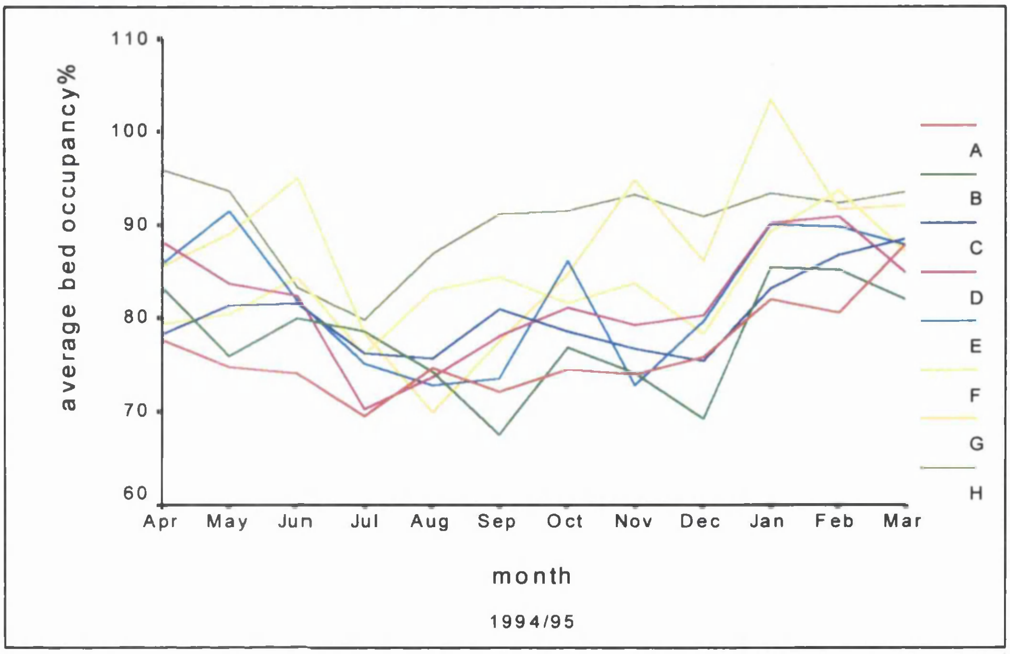

Figure 2.9: Average monthly bed occupancy for general medicine and its associated sub-specialties

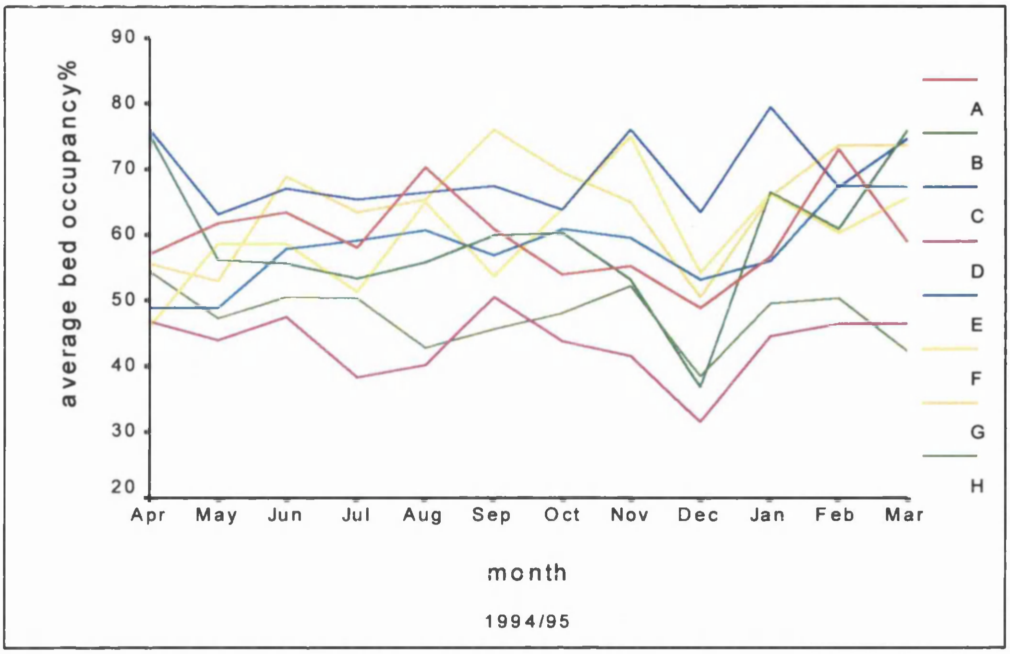

Figure 2.10: Average monthly bed occupancy for ENT surgery

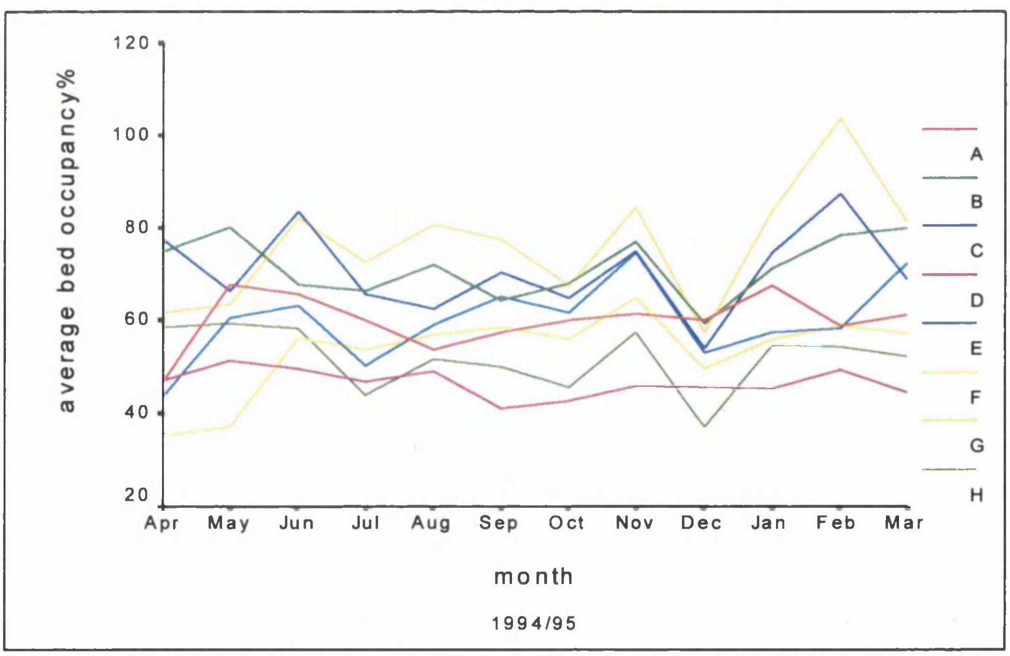

Figure 2.11 : Average monthly bed occupany for gynaecology

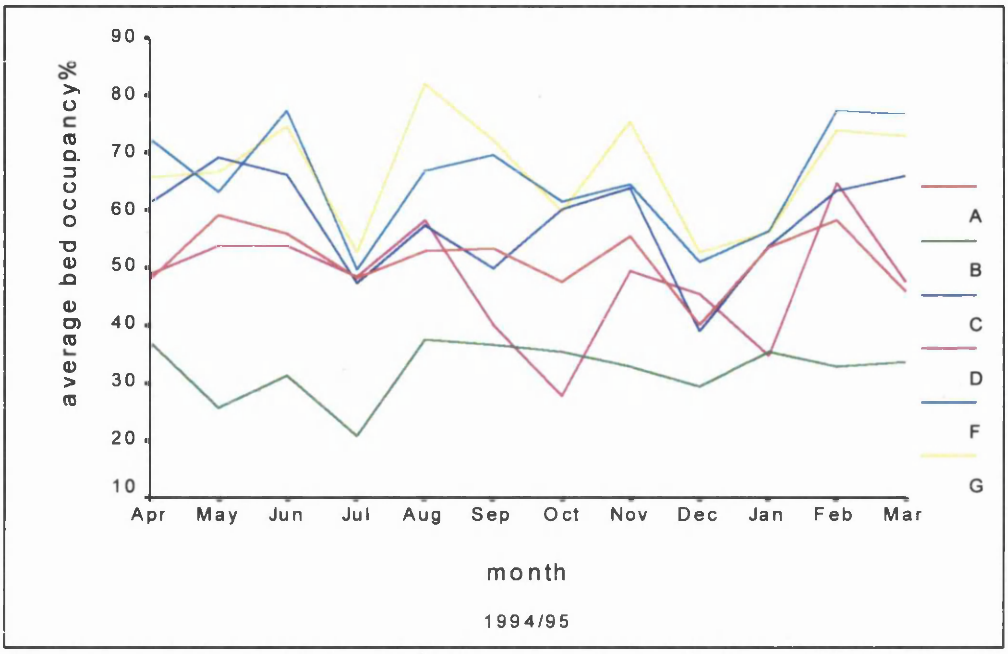

Figure 2.12: Average monthly bed occupany for ophthalmology

2.4.4 Bed occupancy and emergency admissions

The proportions of emergency admissions for the eight hospitals in the medical specialty ranged from 58% to 84%. There was a slight tendency for hospitals with a high average occupancy to have a greater number of emergency admissions (Figure 2.13). For all hospitals in Scotland the correlation between bed occupancy and emergency admissions was 0.529 (significant at 0.01 level, $p<0.001$). For the majority of hospitals, a large percentage of their emergency admissions are usually during the winter months and on certain days of the week (Audit Commission, 1992). Therefore, as occupancy rates tend to be higher at these times, this gives hospitals the potential to schedule elective admissions outwith these periods.

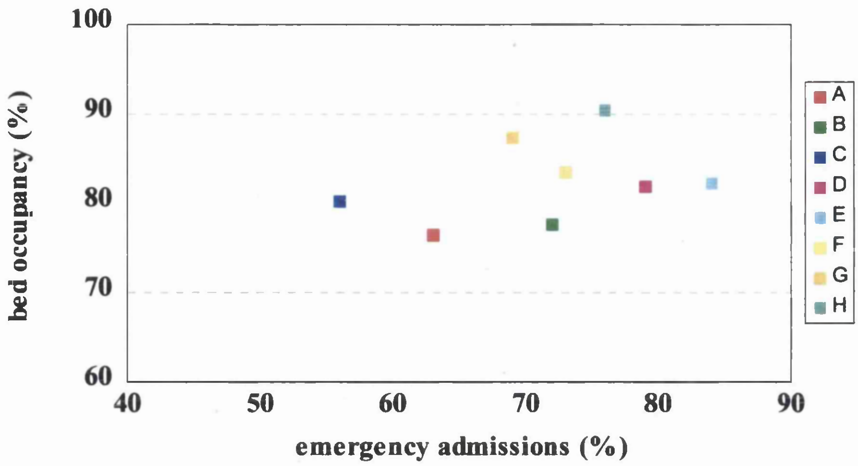

Figure 2 .13: Relationship between bed occupancy and emergency admissions for general medicine and its associated sub-specialties: financial year 1994/95

2.4.5 Proportion of elective, transfer and emergency admissions.

Figures 2.14-2.17 show the split of admission type in the financial year 1994/95 for each specialty in the eight hospitals. The obvious difference is the much larger proportion of emergency admissions in general medicine compared with ENT, gynaecology and ophthalmology. In general medicine the proportion of emergency admissions for all of the study hospitals (apart from C)is greater than the Scottish average (60.3% of admissions in 1993 were emergencies in medical group). There are also marked differences between hospitals in both their proporton of emergency admissions (ranging from 56% in hospital C to 84% in hospital E) and their proportion of patients transferred from another specialty (5% in hospital E to 20% in hospital B). Similar – although less substantial – differences were seen in the other specialties.

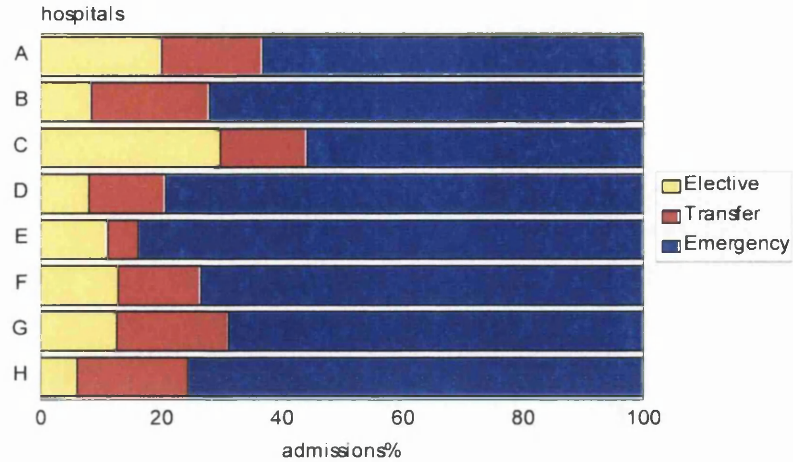

Figure 2.14: Proportion of elective, transfer and emergency admissions for general medicine and associated sub-specialties: financial year 1994/95

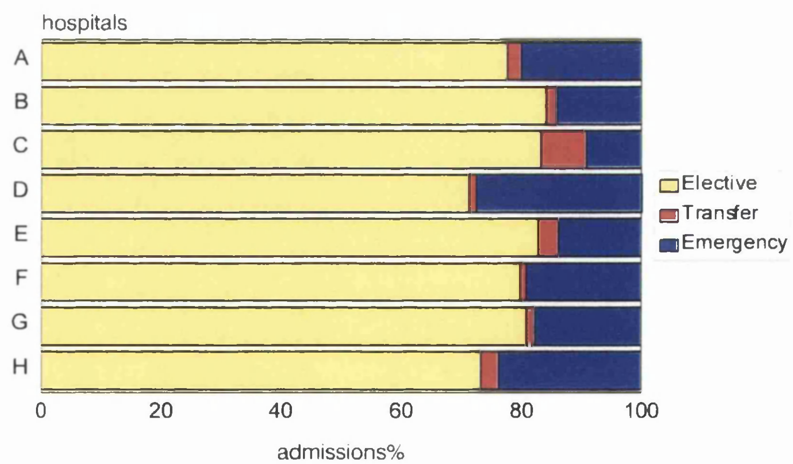

Figure 2.15: Proportion of elective, transfer and emergency admissions for ENT surgery: financial year 1994/95

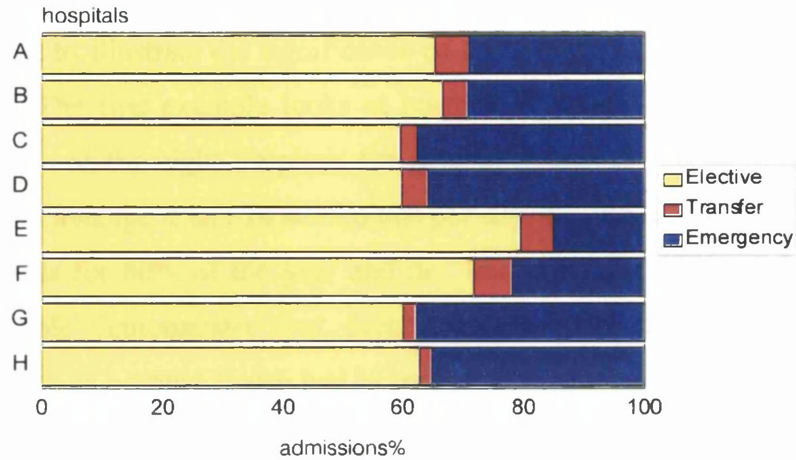

Figure 2.16: Proportion of elective, transfer and emergency admissions for gynaecology: financial year 1994/95

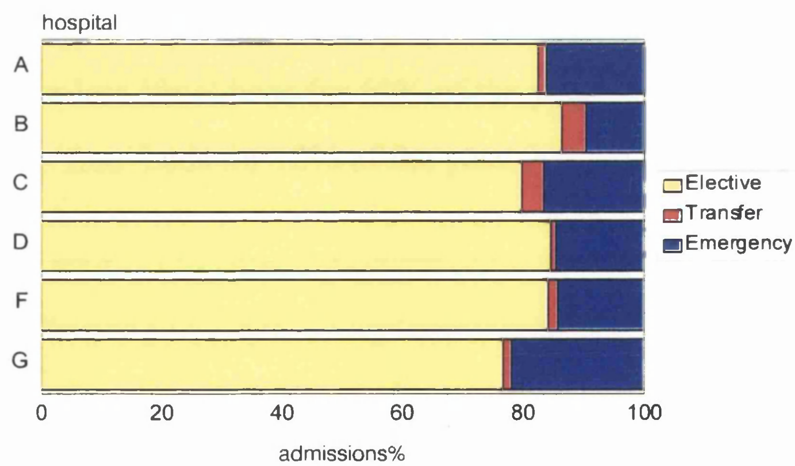

Figure 2.17: Proportion of elective, transfer and emergency admissions for ophthalmology

2.4.6 Periods of pressure

Levels of occupancy over 90%, 95% and 100% were investigated for the eight hospitals. For general medicine and its associated sub-specialties five out of the eight hospitals had occupancy rates of 100% or over for at least five days of the year

(Figure 2.18). It is interesting that these days as usually expected did not occur only during the winter period but were spread over several months. For example hospital E had peak rates in May (see figure 2.9). The boxed examples below (although fairly crude) attempt to illustrate the significance of these high occupancy rates in two of the hospitals The first example looks at hospital H which had the highest annual occupancy rate of the eight hospitals for general medicine and its associated sub-specialties. On average it had 14 admissions per day, despite having had only nine or less 'free' beds for 60% of the year and no 'free' beds for 12% of the year. The second example demonstrates that even hospitals with an average annual bed occupancy such as hospital E also had to cope with insufficient numbers of available staffed beds for a portion of the year. Hospital E had 16 or less beds 'free' for 23% of the year and no 'free' beds for 1% of the time even though on average it admitted 21 new patients a day.

Hospital H – high bed occupancy

- 14 admissions per day, on average
- 9 or less 'free' beds for 60% of the year
- no 'free' beds for 12% of the year

Hospital E –average bed occupancy

- 21 admissions per day, on average
- 16 or less 'free' beds for 23% of the year
- no 'free' beds for 1% of the year

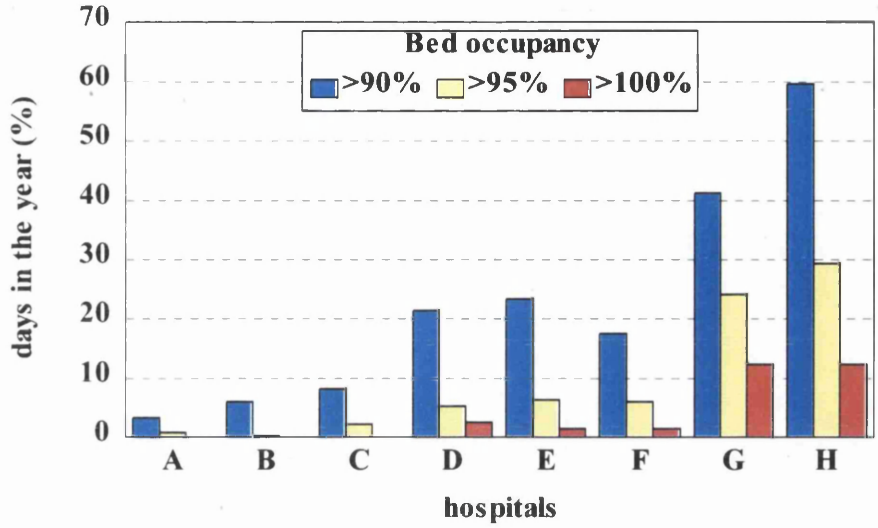

Figure 2.18 : Periods of pressure for general medicine and its associated sub-specialties: financial year 1994/95

The three specialties with high rates of elective admissions also had to deal with high occupancy rates. Figure 2.19 shows the percentage of days of the financial year 1994/95 when the combined elective specialties had occupancy rates of 90%, 95% and 100% or more. These days were again spread over a few months. The hospitals, with the highest levels of bed occupancy in general medicine were not necessarily the same as those for the elective specialties. Hospital H had the greatest percentage of days of 90% occupancy and over for general medicine, yet it has the lowest amount for the elective specialties, while hospital C had relatively few days for general medicine and had the second highest proportion for the elective specialties. These differences may be due to different ways of managing caseload and may also reflect the effects of bed borrowing in one or other hospital.

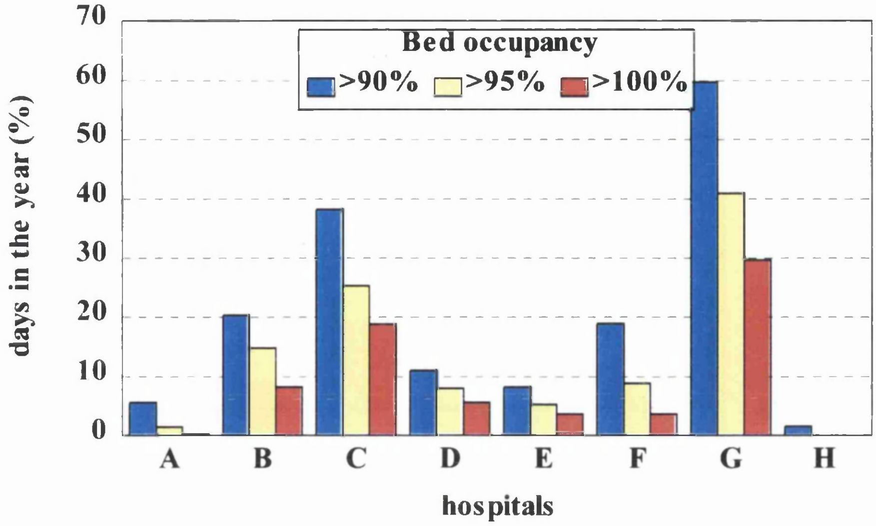

Figure 2.19: Periods of pressure for combination of ENT, gynaecology and opthalmology: financial year 1994/95

Tables 2.1-2.4 provide a summary of the average number of staffed beds, admissions per day, annual bed occupancy and the number of days occupancy was greater than or equal to 90%, 95% or 100% for each of the four specialties, respectively.

Hospital	***Average staffed beds per day***	***Average admissions per day***	***Average occupancy for 1994/95 (%)***	***No.(percentage) of days for 1994/95 occupancy ≥ 90%***	***No. (percentage) of days for 1994/95 occupancy ≥ 95%***	***No. (percentage) of days for 1994/95 occupancy ≥ 100%***
A	352	47	76.45	12(3.3%)	3(0.8%)	0
B	156	25	77.63	22(6.0%)	1(0.3%)	0
C	266	37	80.21	30(8.2%)	8(2.2%)	0
D	85	14	81.82	78(21.4%)	19(5.2%)	9(2.5%)
E	162	21	82.22	85(23.3%)	23(6.3%)	5(1.4%)
F	201	30	83.37	64(17.5%)	22(6.0%)	5(1.4%)
G	124	16	87.28	150(41.1%)	88(24.1%)	45(12.3%)
H	90	14	90.43	217(59.5%)	107(29.3%)	45(12.3%)

Table 2.1: Periods of pressure summary statistics for general medicine and its associated sub-specialties: financial year 1994/95

Hospital	*Average staffed beds per day*	*Average admissions per day*	*Average occupancy for 1994/95 (%)*	*No.(percentage) of days for 1994/95 occupancy ≥ 90%*	*No. (percentage) of days for 1994/95 occupancy ≥ 95%*	*No. (percentage) of days for 1994/95 occupancy ≥ 100%*
A	35	6	59.82	17(4.6%)	5(1.4%)	1(0.3%)
B	19	4	59.22	26(7.1%)	15(4.1%)	12(3.3%)
C	26	7	69.25	65(17.8%)	44(12.0%)	40(11.0%)
D	19	4	43.50	1(0.3%)	1(0.3%)	1(0.3%)
E	37	9	58.10	21(5.8%)	16(4/4%)	11(3.0%)
F	37	7	60.00	31(8.5%)	10(2.7%)	5(1.4%)
G	26	5	65.03	38(10.4%)	19(5.2%)	8(2.2%)
H	19	3	47.69	5(1.4%)	0	0

Table 2.2: Periods of pressure summary statistics for ENT surgery: financial year 1994/95

Hospital	*Average staffed beds per day*	*Average admissions per day*	*Average occupancy for 1994/95 (%)*	*No.(percentage) of days for 1994/95 occupancy≥90%*	*No. (percentage) of days for 1994/95 occupancy≥95%*	*No. (percentage) of days for 1994/95 occupancy≥100%*
A	85	13	60.04	3(0.8%)	0	0
B	33	6	71.53	48(13.2%)	29(7.9%)	18(4.9%)
C	23	6	70.63	42(11.5%)	28(7.8%)	13(3.6%)
D	25	3	46.44	0	0	0
E	41	7	59.90	9(2.5%)	3(0.8%)	2(0.5%)
F	30	4	53.25	5(1.4%)	2(0.5%)	1(0.3%)
G	23	5	76.06	92(26.0%)	65(17.8%)	43(11.8%)
H	33	6	51.76	1(0.3%)	0	0

Table 2.3: Periods of pressure summary statistics for gynaecology: financial year 1994/95

Hospital	*Average staffed beds per day*	*Average admissions per day*	*Average occupancy for 1994/95 (%)*	*No.(percentage) of days for 1994/95 occupancy≥90%*	*No. (percentage) of days for 1994/95 occupancy≥95%*	*No. (percentage) of days for 1994/95 occupancy≥100%*
A	37	6	51.48	0	0	0
B	23	3	32.35	0	0	0
C	23	6	58.08	32(8.8%)	20(5.5%)	13(3.6%)
D	12	3	47.61	39(10.7%)	28(7.7%)	19(5.2%)
E	-	-	-	-	-	-
F	23	5	65.46	33(9.0%)	20(5.5%)	7(1.9%)
G	18	3	66.98	85(23.3%)	65(17.8%)	57(15.6%)
H	-	-	-	-	-	-

Table 2.4: Periods of pressure summary statistics for ophthalmology: financial year 1994/95

2.5 Summary of results

The purpose of the descriptive analysis in this chapter has been to firstly illustrate the large daily, weekly and seasonal fluctuations concealed by annual bed occupancy figures and secondly, to identify short term trends in bed occupancy which may enable better planning of hospitals resources.

For the eight hospitals, bed occupancy varied by day of the week. For general medical beds there was a high occupancy rate from Monday to Thursday, which tailed off at weekend, while the elective specialties, ENT, gynaecology and ophthalmology tended to have higher rates in the middle of the week. However the pattern of seasonality for the hospitals was less clear: in addition to the usual winter peak for medical specialties (and corresponding trough for the "elective" specialties), each of the eight hospitals appeared to have other troughs and peaks at other seasons.

There appeared to be some association between bed occupancy and the number of emergency admissions for the medical specialty grouping. An increase in emergencies was related to an increase in annual bed occupancy. Further, the split of emergency, elective and transfer admissions varied considerably between the specialties and hospitals.

Finally, there were a number of days where bed occupancy exceeded 100 percent for each of the specialties, suggesting that bed borrowing is a frequent occurrence within most of the study hospitals.

Chapter 3: Application of Healthcare Resource Groups(HRGs)

3.1 Introduction

It has long been recognised that before any useful comparative research can be carried out between organisations such as hospitals an adjustment for case-mix (e.g. sex, age and diagnoses of patients) must first be made (Söderlund et al, 1995). There are many ways of doing this. For this study an established case-mix tool; the National Casemix Office's Healthcare Resource Groups (HRG) classification system was used. This particular method was chosen, since HRGs have been adapted specifically to relate to treatment carried out within the NHS and group together episodes of care "which are clinically meaningful and similar in resource use" (NCMO, 1997b). In total there are 572 HRGs, split into 19 chapters (see Table 3.1), which are based on International Classification of Diseases (ICD) diagnostic codes and the Office of Population Census and Surveys (OPCS) codes for surgical operations and procedures.

3.2 Data

The National Casemix Office's HRG grouper software version 3 was used to assign a HRG to each inpatient discharged in the 26 chosen Scottish hospitals in the econometric analyses (see Chapter 4) between the financial year 1991/92 and 1995/96[1] from ISD's SMR1 data set. The grouper algorithm primarily assigns each episode a HRG on the basis of the OPCS 4 procedure codes and ICD 9 diagnosis codes. It then may also take account of the patients' sex, age[2], length of stay (LOS) and whether or not they died before discharge. Further details of the classification can be obtained in the HRG, version 3 documentation set.

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[1] Full data set for 1995/96 not available, so HRG score taken from Scottish Health Services Costs.

[2] Age splits are used to separate older from younger patients using one of three age-breaks, < 17, 50 or 70 years. In some instances the base HRG is split into three age bands, again, using the age-breaks <17, 50 or 70 years. Age splits are often used in conjunction with complication and comorbidity splits.

HRG Chapter Heading	n HRGs
Nervous System	36
Eyes and Periorbita	12
Mouth, Head, Neck and Ears	31
Respiratory System	36
Cardiac Surgery and Primary Cardiac Conditions	38
Digestive System	65
Hepato-biliary and Pancreatic System	25
Musculoskeletal System	56
Skin, Breast and Burns	47
Endocrine and Metabolic System	19
Urinary Tract and Male Reproductive System	57
Female Reproductive System	21
Obstetrics and Neonatal Care	12
Diseases of Childhood	26
Vascular System	20
Spinal Surgery and Primary Spinal Conditions	20
Haematology, Infectious Diseases, Poisoning and Non-specific Groupings	27
Mental Health	17
Undefined Groups	7
Total	**572**

Table 3.1: HRG chapter headings and HRG content

3.3 Variation in HRG-mix of study hospitals

To demonstrate the variation in case-mix between the eight study hospitals, all discharges for the financial year 1994/95 have been grouped under the appropriate HRG chapter headings as shown in Table 3.1, of which less than 1% were assigned to an undefined group. Figure 3.1 shows the HRG split for general medicine and its associated sub-specialties for the six HRG chapters with the largest number of discharges and the remaining chapters grouped together. There are noticeable differences between the hospitals. For instance, even though hospitals C and D have similar proportions of discharges under the headings of Nervous Systems and Cardiac Surgery and Primary Cardiac Conditions, only 1.5% of hospital D's discharges were Urinary Tract and Male Reproductive System compared to 9.9% of hospital C. Hospital D further has approximately double the proportion of respiratory cases that hospital C has.

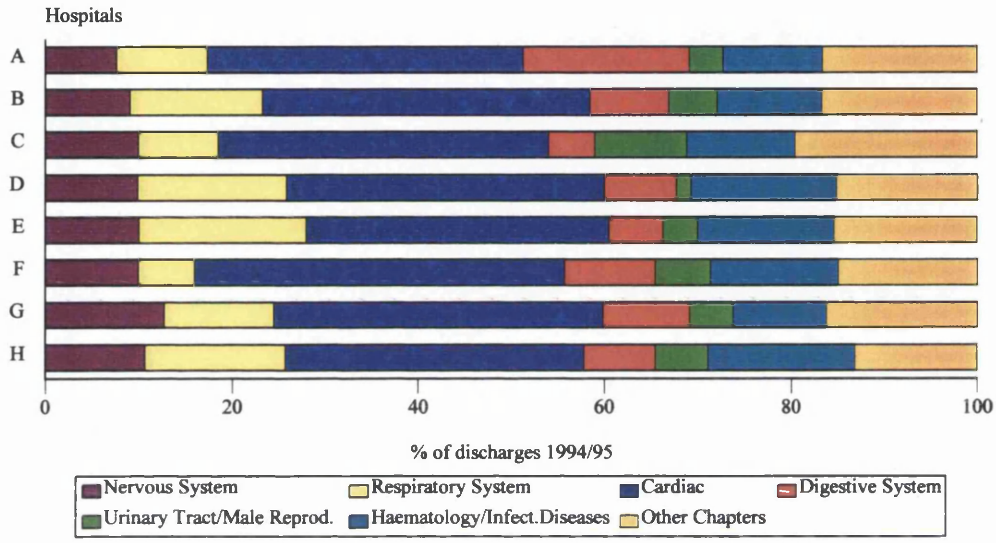

Figure 3.1: HRG-mix general medicine and its associated sub-specialties

In Figure 3.2 the HRG-mix for the combined specialty grouping of ENT, gynaecology and ophthalmology is illustrated, using the proportion of discharges from the five largest chapters and again grouping together the remaining. The obvious difference is between the HRG-mix of hospitals E and H compared with the others. Neither hospital E nor H has discharges within the HRG chapter of Eyes and Periorbita, due to not having an ophthalmology department. Over half (51%) hospital E's discharges for the financial year 1994/95 came under the HRG chapter Mouth, Head, Neck and Ears, while a similar proportion of hospital H's discharges were grouped under Female Reproductive System.

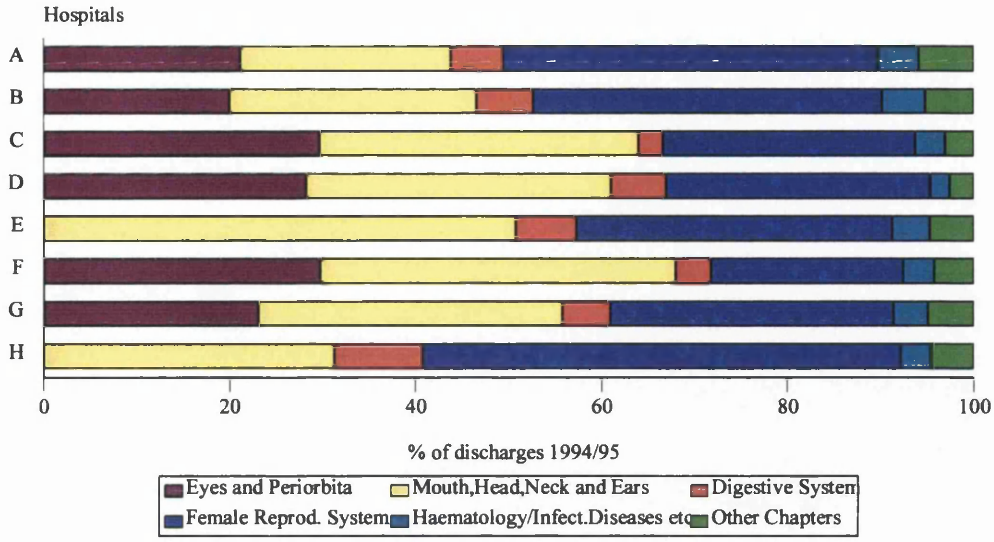

Figure 3.2: HRG-mix for combination of ENT, gynaecology and ophthalmology

It is also important to note that within each HRG chapter there can be up to 65 individual HRGs, meaning that although hospitals A and B in Figure 3.2 appear to have a very similar caseload they could in actual fact be treating completely different cases within each HRG chapter. For example under the HRG heading of Eyes and Periorbita, approximately 69% of hospital B's cases were Cataract Extraction with Lens Implant while hospital A only appears to have had two such cases for the entire year.

3.4 HRG adjusted LOS versus crude LOS

The average length of stay (LOS) of patients within a hospital or individual speciality (and thus its average cost per case) is greatly influenced by its case-mix. For the hospitals used in the econometric analyses, HRG adjusted and crude LOS scores were compared for the five year period 1991/92 – 1995/96. The crude LOS was obtained from *Scottish Health Service Costs* data and the HRG adjusted LOS derived from the SMR1 data set (see Appendix G). The scores were calculated separately for each of the two specialty categories (see Tables 3.2 and 3.3). A score of 100 was taken to be the average for Scotland, with anything above and below 100 taken to represent an average LOS, respectively, longer or shorter than expected. This may be, suggesting whether each hospital is running less or more efficiently than the average.

The HRG adjusted and crude LOS for some of the hospitals are very different, which emphasises the effect that case-mix has. For example, for general medical hospital B had a crude score of 95 for 1992/93 suggesting that its LOS was 5% less than would have been expected. However for the same year its HRG adjusted score was 107 suggesting that in actual fact its LOS was 7% greater than expected after taking consideration of the type of cases it treats. Similar occurrences were seen within the combined low occupancy specialty grouping (see Table 3.3).

Tables 3.2 and 3.3 as well as showing variations between the HRG adjusted and the crude LOS highlight differences over time. It should be noted that variation in the crude scores from one year to the next may be a result of case-mix differences rather than changes in LOS due to policy and organisational changes. Scores are not recorded for hospital '7' between 1991-93 and hospital '2' for 1991/92, since both hospital formerly had a functional classification of 44[3] (see Appendix B for full description of ISD's functional classifications).

In table 3.4 the performance of each of the 26 hospitals for 1994/95 has been ranked according to their crude and HRG adjusted LOS for the high occupancy grouping; general medical in relation to Scottish average. If all the hospitals treated an identical mix of patients, the crude LOS scores would equal the adjusted scores and the order of ranking would remain unchanged. However this is obviously not the case, since only one hospital has kept the same position. The biggest change was seen for hospital '8', which went from being ranked the most efficient to the sixteenth. The hospitals have also been ranked for the low occupancy grouping, ENT, gynaecology and ophthalmology (see Table 3.5).

Tables 3.6 and 3.7 compare the HRG adjusted LOS for 1994/95 and 1995/96 for each specialty category. Some of the hospitals in the 1995/96 *Scottish Health Services Costs* had the same HRG score. To deal with this an average rank was assigned to hospitals with the same score. The order of the hospitals has changed from one year to the next, although not as extreme as for the crude and HRG

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[3] Miscellaneous hospitals which by function are not individually comparable with any other unit and where costs would not be expected to run parallel with any other hospital in the full list.

comparisons. The change in rankings here shows that not only does case-mix differ between hospitals, it also differs within hospitals from year to year.

Hospital	Year 91/92	Year 92/93	Year 93/94	Year 94/95	Year 95/96*
A	97(93)	97(94)	98(91)	98(93)	86(92)
B	109(103)	107(95)	92(83)	82(79)	85(77)
C	97(92)	93(101)	93(106)	88(94)	87(68)
D	95(91)	103(94)	101(88)	89(80)	86(89)
E	101(95)	103(97)	105(100)	102(100)	100(96)
F	82(77)	88(86)	93(91)	95(84)	100(93)
G	102(107)	110(111)	97(98)	101(110)	105(105)
H	82(81)	86(81)	105(96)	102(92)	97(86)
1	123(138)	123(141)	120(127)	125(144)	140(151)
2	-	83(84)	80(81)	82(84)	73(82)
3	116(129)	117(117)	125(128)	121(126)	125(127)
4	102(94)	103(98)	114(98)	114(106)	133(112)
5	92(91)	103(98)	106(100)	108(105)	106(104)
6	112(109)	107(109)	109(126)	128(124)	136(127)
7	-	-	96(96)	103(103)	100(105)
8	95(96)	100(95)	99(91)	107(79)	109(89)
9	106 (88)	104(91)	105(100)	113(113)	109(111)
10	59(61)	62(68)	66(71)	64(84)	67(74)
11	103(94)	106(93)	103(86)	110(89)	103(103)
12	85(85)	92(91)	96(89)	102(98)	103(101)
13	110(136)	112(131)	116(133)	111(134)	106(135)
14	121(123)	123(114)	120(115)	124(112)	112(92)
15	132(139)	116(120)	125(127)	128(129)	129(125)
16	81(83)	81(84)	80(94)	77(97)	86(104)
17	96(98)	93(94)	101(104)	102(101)	110(112)
18	102(100)	101(96)	90(87)	99(98)	98(96)

Table 3.2: Comparison HRG adjusted and (crude) scores for 26 Scottish Hospitals: financial years 1991/92 to 1995/96 – general medicine and associated sub-specialties: Scotland = 100

Note: *1995/96 scores were taken from the Scottish Health Services Costs

Hospital	Year 91/92	Year 92/93	Year 93/94	Year 94/95	Year 95/96*
A	99(107)	106(117)	112(120)	115(123)	117(129)
B	104(107)	103(111)	105(113)	100(111)	101(104)
C	96(100)	93(96)	93(92)	90(89)	90(84)
D	97(98)	97(102)	93(95)	88(87)	91(82)
E	101(102)	100(100)	99(92)	98(100)	101(105)
F	91(103)	90(100)	95(101)	102(107)	102(104)
G	110(112)	118(122)	114(120)	119(119)	123(118)
H	97(81)	99(85)	102(86)	101(92)	105(89)
1	113(129)	111(111)	98(88)	100(84)	107(86)
2	-	122(117)	117(117)	117(107)	87(96)
3	103(108)	111(123)	105(117)	105(122)	107(121)
4	94(81)	88(86)	88(84)	87(94)	94(103)
5	95(98)	82(87)	83(86)	87(92)	93(96)
6	129(110)	119(109)	107(105)	108(102)	107(95)
7	-	-	109(113)	100(99)	108(118)
8	101(95)	101(94)	97(90)	94(94)	91(93)
9	95(95)	97(99)	94(93)	101(113)	101(97)
10	81(73)	78(72)	81(80)	78(74)	73(71)
11	92(84)	94(88)	99(79)	93(94)	90(101)
12	97(93)	97(91)	103(89)	104(88)	111(82)
13	85(115)	83(197)	88(107)	95(119)	95(115)
14	130(126)	113(117)	114(123)	120(123)	114(127)
15	95(86)	108(103)	106(101)	105(95)	104(97)
16	100(104)	87(96)	93(111)	99(105)	99(105)
17	82(92)	84(102)	85(92)	87(90)	82(74)
18	108(94)	108(99)	103(97)	97(93)	94(98)

Table 3.3: Comparison HRG adjusted and (crude) scores for 26 Scottish Hospitals: financial years 1991/92 to 1995/96 – ENT, gynaecology, ophthalmology: Scotland =100

Note: *1995/96 scores were taken from the Scottish Health Services Costs

Hospital	Ranking based on Crude LOS	Ranking based on HRG adjusted LOS
8	1	16
B	2	4
D	3	6
10	4	1
F	5	7
2	6	3
11	7	18
H	8	12
A	9	8
C	10	5
16	11	2
18	12	9
12	13	11
E	14	13
17	15	14
7	16	15
5	17	17
4	18	21
G	19	10
14	20	23
9	21	20
6	22	25
3	23	22
15	24	26
13	25	19
1	26	24

Table 3.4: Comparison of the ranking for 26 Scottish hospitals relative to Scottish average for crude and HRG adjusted scores: financial year 1994/95 – general medicine and associated sub -specialties

Hospital	Ranking based on Crude LOS	Ranking based on HRG adjusted LOS
10	1	1
1	2	15
D	3	5
12	4	19
C	5	6
17	6	3
H	7	16
5	8	4
18	9	10
11	10	7
8	11	8
4	12	2
15	13	20
7	14	13
E	15	11
6	16	22
16	17	12
F	18	18
2	19	24
B	20	14
9	21	17
G	22	25
13	23	9
3	24	21
A	25	23
14	26	26

Table 3.5: Comparison of the ranking for 26 Scottish hospitals relative to Scottish average for crude and HRG adjusted scores: financial year 1994/95 – ENT, gynaecology, ophthalmology

Hospital	Ranking based on HRG adjusted LOS 1994/95	Ranking based on HRG adjusted LOS 1995/96
10	1	1
16	2	5
2	3	2
B	4	3
C	5	7
D	6	5
F	7	11
A	8	5
18	9	9
G	10	15
12	11	13.5
H	12	8
E	13	11
17	14	20
7	15	11
8	16	18.5
5	17	16.5
11	18	13.5
13	19	16.5
9	20	18.5
4	21	24
3	22	22
14	23	21
1	24	26
6	25	25
15	26	23

Table 3.6: Comparison of the ranking for 26 Scottish hospitals relative to Scottish average HRG adjusted scores: financial year 1994/95 and 1995/96 – general medicine and associated sub-specialties

Hospital	Ranking based on HRG adjusted LOS 1994/95	Ranking based on HRG adjusted LOS 1995/96
10	1	1
4	2	9.5
17	3	2
5	4	8
D	5	6.5
C	6	4.5
11	7	4.5
8	8	6.5
13	9	11
18	10	9.5
E	11	14
16	12	12
7	13	22
B	14	14
1	15	20
H	16	18
9	17	14
F	18	16
12	19	23
15	20	17
3	21	20
6	22	20
A	23	25
2	24	3
G	25	26
14	26	24

Table 3.7: Comparison of the ranking for 26 Scottish hospitals relative to Scottish average HRG adjusted scores: financial year 1994/95 and 1995/96 – ENT, gynaecology, ophthalmology

Pearsons correlation coefficients were calculated between the crude and adjusted LOS scores for both specialty groupings (see Table 3.6). The association was much stronger within the two specialties than between them, although each correlation was found to be statistically significant at the 0.01 level.

		High Occupancy		*Low Occupancy*	
		Crude LOS	*Adjusted LOS*	*Crude LOS*	*Adjusted LOS*
High Occupancy	*Crude LOS*	***1.000***			
	Adjusted LOS	0.828 (0.000)	***1.000***		
Low Occupancy	*Crude LOS*	0.346 (0.000)	0.300 (0.001)	***1.000***	
	Adjusted LOS	0.282 (0.001)	0.354 (0.000)	0.676 (0.000)	***1.000***

Table 3.8: Correlations (p-values) between crude and adjusted LOS for high and low occupancy specialty groupings: financial years 1991/92-1995/96

3.5 Summary

There were two main aims to this chapter. First to illustrate the use of HRGs and second to emphasis the importance of first taking account of case-mix differences between hospitals before making any judgements or comparisons concerning their apparent performances. Figures 3.1 and 3.2 showed the variation in procedures carried out by each of the eight hospitals using HRG groupings. Noticeable differences in the workloads of each hospital were seen even under the wide HRG headings.

Large variations were also seen both over time and between the HRG adjusted and crude LOS scores for many of the hospitals. Tables 3.4 and 3.5 then demonstrated how adjusting for case-mix can greatly change the rating of a hospital relative to the Scottish average, the purpose being to show that crude measurements can be misleading.

There was also some evidence from the correlations that those hospitals over or under performing in one specialty grouping might behave similarly in the other. In the following chapter which describes the econometric analysis of bed occupancy and cost per case further inferences are made between the crude and adjusted lengths of stay.

However HRGs are not without their weaknesses or limitations, as other case-mix tools. To date HRGs cannot adjust for severity of illness, other than distinguishing between cases with or without complications or comorbidities for some HRGs. Therefore hospitals with seemingly identical diagnostic-mix may in actual fact be treating patients of varying degrees of illness, thus affecting length of stay. Other factors outwith the capabilities of HRGs can also affect length of stay, such as bed management practices and clinical preferences. It is well known that consultants and surgeons have their own views on appropriate lengths of stay for common complaints (Audit Commission, 1992). These points will be discussed in greater detail in Chapter 6.

Chapter 4: Econometric study of bed occupancy and specialty costs

4.1 Introduction

The previous two chapters provided an informal look at differences in bed occupancy rates and lengths of stay between the hospitals. The econometric study described in this chapter sought to establish the effects of differences in bed occupancy rates on hospitals' unit costs and hence the possible costs and benefits associated with different levels of bed occupancy through means of a more formal statistical analysis. The method proposed was a form of regression analysis – multilevel analysis – to identify the relationship between unit inpatient costs for acute specialties and a range of variables thought to influence unit costs in addition to bed occupancy, such as length of stay and teaching status.

Data published in the *Scottish Health Service Costs* (the "Blue Book") for the past five financial years (1991/92-1995/96) were used for this analysis[1]. Of interest were the two specialty groupings: general medicine and its associated sub-specialties (such as cardiology or gastroenterology) as a high occupancy, high emergency admission category and a combination of ophthalmology, ear nose and throat, and gynaecology as a lower occupancy, high elective admission category. The reason for this distinction was to determine whether the relationship between unit costs and bed occupancy was the same for specialties with differing pressures on beds.

Direct cost[2] per case and total cost per case were the measures of unit costs employed. Both were used separately to attempt to identify whether the relationships between unit costs and the various explanatory variables differed according to the definition of cost used. It might be expected, for example, that occupancy would have a stronger negative relationship with total cost per case, because direct costs exclude certain elements of fixed costs (such as heating and cleaning costs), which would be spread over more cases if occupancy rates were increased through added admissions, thus reducing average total cost per case. Ideally it would have been preferred, if data had been available for the whole time period, to have further broken

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[1] The HRG adjusted lengths of stay were derived from SMR1 data (for details see Chapter 3 and Appendix G).
[2] Costs of medical and nursing staff, pharmacy, PAMs, theatres, laboratory and other direct care costs.

the costs down into the sub-components of direct costs (such as nursing and theatre costs).

Tables 4.1 and 4.2 below provide a summary to show how some of the key variables included in the cost models have changed between 1991/92 and 1995/96. Despite there being an obvious decrease in average length of stay, occupancy has remained fairly constant for both specialty groupings. The number of inpatient discharges for the medical, high occupancy specialty grouping has increased, while the number of beds has remained more or less the same. In contrast the lower occupancy grouping has shown a decline in the number of inpatient discharges and averaged staffed beds, which may be a consequence of more day and outpatient cases. The pattern of cost per case also differs for the two specialty groupings. For the lower occupancy specialties average direct and total cost per case has been increasing over the five year period; however, average cost per case appears to have begun to decrease for the medical grouping[3].

Averages	**1991/92**	**1992/93**	**1993/94**	**1994/95**	**1995/96**
Length of stay	7.7	7.2	6.8	6.3	6.1
Occupancy	84.77	84.24	84.57	83.06	84.60
Discharges	6283	6672	6840	7367	7915
Staffed beds	150	149	145	148	151
Direct cost per case	701.00	750.47	741.44	741.19	725.19
Total cost per case	1071.43	1157.41	1173.37	1169.05	1103.28

Table 4.1: Summary statistics for 26 hospitals for high occupancy grouping of general medicine and its associated sub-specialties

[3] The costs have not been adjusted for inflation.

Averages	1991/92	1992/93	1993/94	1994/95	1995/96
Length of stay	3.5	3.3	3.1	2.9	2.8
Occupancy	58.63	57.64	56.17	56.70	56.96
Discharges	4142	4204	3848	3640	3492
Staffed beds	68	65	58	52	47
Direct cost per case	511.20	547.01	614.06	669.30	673.55
Total cost per case	779.94	831.21	964.21	980.33	965.04

Table 4.2: Summary statistics for 26 hospitals for lower occupancy grouping of ENT, gynaecology and ophthalmology

4.2 Selection Criteria

26 hospitals were used for this analysis and were selected on the basis of the following criteria in order to ensure that each was comparable:

- inpatients in both specialty groupings,
- at least 18 averaged staffed beds[4] in the lower occupancy specialty for each of the five years respectively (or as many years as the hospital was fully operational),
- one of three hospital classifications[5] (1) Large general major teaching hospital covering a full range of services (other than maternity in some cases) and with some special units, (2) General hospital with some teaching units, but not necessarily wholly teaching, (11& 12) Mixed specialist hospital. No special units. Consultant type surgery undertaken (with or without maternity).

[4] Two hospitals were excluded from the analysis for having too small a number of beds (12 or less for each year). 18 was therefore the cut-off point as this was the lowest number of beds any of the hospitals included in the study had.

[5] The bracketed numbers refer to the general description of hospital functional classification used in Scottish Health Service Costs (see Appendix B)

Although data were not available for all five years for two of the hospitals (one was not fully opened for one year and another for two years), it was still considered of benefit to include them in the model. There were therefore 127 data points in the sample (24 hospitals with five observations, one hospital with four observations and the remaining hospital with three observations). Many of the more traditional methods used to analyse repeated measures data could not have handled an unbalanced design such as this. However, by considering the data, within a multilevel framework any pattern of measurements is permitted while still giving "statistically efficient parameter estimation"; the estimates produced are more reliable, as information is not being lost through having to delete observations or hospitals in order to maintain a balanced structure (Goldstein, 1995).

4.3 Definition of variables

$$\text{(i) average occupancy ratio \%} = \frac{\text{occupied bed days}}{\text{staffed bed days}} \text{ x } 100$$

$$\text{(ii) crude mean length of stay} = \frac{\text{occupied bed days}}{\text{number of discharges}}$$

$$\text{(iii) direct cost per case} = \frac{\text{direct costs}}{\text{number of discharges}}$$

$$\text{(iv) total cost per case} = \frac{\text{total costs}}{\text{number of discharges}}$$

$$\text{(v) } \textit{adjusted length of stay hospital } i = \frac{\overline{LOS_i}}{Expected(\overline{LOS_i})} \text{ x } \overline{LOS}$$

$$Expected\left(\overline{LOS_i}\right) = \frac{\sum_i n_{ij} \overline{LOS_i}}{\sum_i n_{ij}}$$

$\overline{LOS_i}$ = *mean length of stay for hospital i*

$\overline{LOS_j}$ = *mean length of stay for HRG j*

n= number of cases

Variable	*Description*	*Average*	*Range*
Direct cost per case	average direct cost per inpatient case for a year (pounds)	732	(434-1306)
Total cost per case	average total cost per inpatient case for a year (pounds)	1135	(687-1983)
Occupancy	average percentage of available staffed beds occupied by inpatients for a year	84	(73-105)
Crude length of stay	average length of stay for a year (days)	6.81	(4.1-10.7)
Adjusted length of stay	average length of stay adjusting for diagnostic mix (in terms of HRGs) for a year	6.87	(3.95-10.19)
Discharges	number of inpatient discharges for a year	7030	(1760-19454)
Staffed beds	average number of (available) staffed beds for a year	148	(64-371)
Staffed bed days	number of staffed bed days in a year	54199	(23465-1.35e+05)
Occupied bed days	number of days in which (available) beds are being used in a year	45602	(17291-1.17e+05)

Table 4.3: Description of continuous variables used in cost models for high occupancy (general medicine and associated sub-specialties) grouping: financial year 1994/95

Variable	*Description*	*Average*	*Range*
Direct cost per case	average direct cost per inpatient case for a year (pounds)	605	(331-1022)
Total cost per case	average total cost per inpatient case for a year (pounds)	907	(480-1314)
Occupancy	average percentage of available staffed beds occupied by inpatients for a year	57	(41-78)
Crude length of stay	average length of stay for a year (days)	3.10	(2.00-4.50)
Adjusted length of stay	average length of stay adjusting for diagnostic mix (in terms of HRGs) for a year	3.08	(2.03-4.56)
Discharges	number of inpatient discharges for a year	3858	(1239-10921)
Staffed beds	average number of (available) staffed beds for a year	58	(18-174)
Staffed bed days	number of staffed bed days in a year	21059	(6441-63474)
Occupied bed days	number of days in which (available) beds are being used in a year	12147	(3572-40888)

Table 4.4: Description of continuous variables used in cost models for low occupancy (ENT, gynaecology and ophthalmology) grouping: financial year 994/95

4.4 Methods

4.4. 1 Model selection and criteria

For reasons already discussed in section 1.5.5, multilevel regression was the chosen method used to identify the factors that influence observed average inpatient costs. Multilevel regression techniques, as described by Rice and Leyland (1996) can identify differences both between hospitals and within hospitals over a period of time. Four separate models were estimated for each specialty grouping in which direct cost per case or total cost per case were regressed on average bed occupancy, length of stay, dummy variables for type of hospital and years and any additional variables and interactions which appeared to influence cost per case (see Tables 4.3 and 4.4). General hospitals with some teaching and the financial year 1995/96 were the reference categories. Interactions were estimated by fitting multiples of the variables. Within each specialty grouping, there were two models estimated for both direct and total cost per case, since it was of interest to compare each model including either a crude measure of average length of stay or a case-mix adjusted length of stay; using HRG-mix (see Chapter 3 for details). The reason for this was that, in the past case-mix has been shown to have a substantial effect on a hospitals' average cost per case (for example, see Butler, 1995; Söderlund et al, 1995 and Watts and Klastorin, 1980).

The models were constructed in two stages. Firstly, the fixed part of the model was built using forward stepwise methods. In each of the eight models estimated bed occupancy, length of stay (crude or HRG adjusted) and the dummies for the financial year and hospital type were included in the models regardless of whether or not they were statistically significant, since it was of interest to compare their estimates for each specification of the cost model. All other variables were added one at a time to the models and only retained if found to be statistically significant or approaching statistical significance at the 0.05 level[6]. Once the fixed part of each model was

[6] When interactions with LGMTH were significant the interaction with MSH was also included in the fixed part of the model even though generally non-significant, to allow comparisons between the different hospital types (see for example Table 4.5).

selected, the same process was used to model the random part of the models, although this time only significant variables were included.

It should also be noted that the estimates for bed occupancy and length of stay were centred around their sample means to make interpretation of the models simpler; zero percent occupancy and a length of stay of zero days would make little sense (for greater discussion on centring see, for example, Bryk and Raudenbush (1992)).

4.4.2 Multilevel Model

This section summaries the multilevel model used for the econometric analysis in this chapter, for greater detail see for example Goldstein (1995). The model used takes the form of a two-level repeated measures model with years at level 1 nested within hospitals at level 2. The response variable for each model is either direct or total cost per case. The hierarchy in place is therefore that of repeated measures made on individual hospitals. At level one there is one financial year of data made on each hospital and since there are five financial years of data there are five observations for each individual hospital (with the exception of the two hospitals already mentioned in section 4.2).

First consider a basic ordinary least squares (OLS) regression model for the observed direct or total cost per case for the i^{th} year in the j^{th} hospital y_{ij} $(i = 1,..,5; j = 1,..,26)$:

$$y_{ij} = \beta_0 + \sum_{p=1}^{P} \beta_p x_{pij} + e_{ij}$$

where β_0 is the point at which the regression line intercepts the y-axis i.e. the mean intercept (or constant) for the regression equation.

$\{x_{1j}, x_{2j} ..., x_{Pj}\}$ are a set of predictor or explanatory variables (such as bed occupancy, length of stay and teaching status[7]) for each hospital and $\{\beta_1, \beta_2,..., \beta_P\}$ are the corresponding regression coefficients.

e_{ij} is the error term or residual i.e. the differences between the observed and predicted values $(y_{ij} - \hat{y}_{ij})$.

However in the case of the multilevel model the error term or residual is split into two parts e_{ij} and u_j such that:

$$y_{ij} = \beta_0 + \sum_{p=1}^{P} \beta_p x_{pij} + u_j + e_{ij}$$

where u_j is the effect or residual for each hospital i.e. the departure of the j^{th} hospital's intercept from the overall mean cost per case. If both the explanatory variables and u_j were zero then the observed cost per case would equal the value for β_0. It is therefore the added effect u_j that differs from the basic OLS regression model.

Both e_{ij} and u_j are assumed to have a mean of zero, and to be independently distributed, with a Normal distribution.

$$u_j \sim N(0, \sigma_u^2)$$
$$e_{ij} \sim N(0, \sigma_e^2)$$

σ_u^2 and σ_e^2 are assumed to be constant where σ_u^2 is the level 2 variance (i.e. between hospital) and σ_e^2 is the level 1 variance (i.e. between years within hospitals) such that the total variance is:

[7] Generally teaching status would be a time-invariant regressor i.e. x_j. However within the time period of this study a couple of hospitals changed their functional classification.

$$ar\left(y_{j}\right) = \sigma_{u}^{2} + \sigma_{e}^{2}$$

u_j and $e_{.j}$ are assumed to be uncorrelated such that the covariance is:

$$cov\left(e_{.j,}u_{j}\right) = 0$$

The explanatory variables $\{x_{1.j}, x_{2.j} ..., x_{P.j}\}$ are also assumed to be uncorrelated with both u_j and $e_{.j}$.

The variances σ_u^2 and σ_e^2 are referred to as random parameters of the model while β_0 and $\{\beta_1, \beta_2, ..., \beta_P\}$ are known as the fixed parameters.

4.4.3 Intra-hospital correlation

The amount of variation attributed to each level can be calculated using the formula for intra- unit correlation or in the case of this study intra -hospital correlation.

$$\rho = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_e^2}$$

For this model ρ is the proportion of the total variance which arises due to differences between hospitals and $1-\rho$ is therefore the proportion of variation attributed to year-on-year differences within hospitals. When $\rho = 0$ the model suggests that there is no variation between hospitals and that the observed differences in cost per case can be explained by the fixed parameters and by year-on-year variations. In this case the multilevel model is also equivalent to an OLS regression model.

To give an example model A in Table 4.5 can be written as:

$$y_{ij} = \beta_0 + \sum_{p=1}^{10} \beta_p x_{pij} + u_j + e_{ij}$$

such that:

$$\begin{aligned} direct\ cost\ per\ case_{ij} = \beta_{0ij}cons\ &+ \beta_1 1991/92_{ij} + \beta_2 1992/93_{ij} + \beta_3\ 1993/94_{ij} \\ &+ \beta_4 1994/95_{ij} + \beta_5 LGMTH_{ij} + \beta_6 MSH_{ij} + \beta_7 AOR_{ij} \\ &+ \beta_8 CRUDELOS_{ij} + \beta_9 LGMTH{*}CRUDELOS_{ij} \\ &+ \beta_{10} MSH{*}CRUDELOS_{ij} \end{aligned}$$

where

$$\beta_{0ij} = \beta_0 + u_{0j} + e_{0ij} \qquad \begin{array}{l} [u_{0j}] \sim N(0, \sigma^2_{u0}) \\ [e_{0ij}] \sim N(0, \sigma^2_{e0}) \end{array}$$

The intra -hospital correlation for this model would then be:

$$\rho = \frac{level2(\sigma^2_u)}{level2(\sigma^2_u) + level1(\sigma^2_e)}$$

$$\rho = \frac{9057}{9057 + 4891}$$

$$\rho = 0.6493$$

This means that the proportion of the total variance in cost per case, which is between hospitals, is 65%. A model such as this is often termed a variance components model, since the total variance is the sum of intercept variances at level 1 and level 2. The estimates for the level 1 and level 2 variances can also be used to produce 95% coverage intervals for the expected cost per case of the hospitals. For the example above, the mean direct cost per case of 95% of the hospitals would be expected to fall within £186.5 ($1.96\sqrt{9057}$) of the total mean cost per case. Likewise 95% of the yearly values for cost per case would be expected to fall within £137.1

($1.96\sqrt{4891}$) of the hospital mean for that year (i.e. taking into account the year dummy).

4.4.4 Complex level 1 variation

Model A above assumes that the total variation in cost per case for each hospital is constant despite any differences in hospital or yearly characteristics. However in practice it is likely that hospitals will have different slopes. For example consider model B in Table 4.5.

$$y_{ij} = \beta_0 + \sum_{p=1}^{10} \beta_p x_{pij} + u_j + e_{0ij} + CRUDELOS_{ij} e_{8ij}$$

$$\begin{aligned} direct\ cost\ per\ case_{ij} = \beta_{0ij}cons &+ \beta_1 1991/92_{ij} + \beta_2 1992/93_{ij} + \beta_3\ 1993/94_{ij} \\ &+ \beta_4 1994/95_{ij} + \beta_5 LGMTH_{ij} + \beta_6 MSH_{ij} + \beta_7 AOR_{ij} \\ &+ \beta_{8i} CRUDELOS_{ij} + \beta_9 LGMTH{*}CRUDELOS_{ij} \\ &+ \beta_{10} MSH{*}CRUDELOS_{ij} \end{aligned}$$

where

$$\beta_{0ij} = \beta_0 + u_{0j} + e_{0ij} \qquad [u_{0j}] \sim N(0, \sigma^2_{u0})$$

$$\beta_{8i} = \beta_8 + e_{8ij} \qquad \begin{bmatrix} e_{0ij} \\ e_{8ij} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{e0} & \sigma_{e08} \\ \sigma_{e08} & \sigma^2_{e8} \end{bmatrix} \right)$$

and $CRUDELOS_{ij}$ is the mean unadjusted length of stay in the j^{th} hospital for the i^{th} year, such that the total variation is:

$$Var(y_{ij}) = \sigma^2_u + \sigma^2_{e0} + 2\sigma_{e08} CRUDELOS_{ij} + \sigma^2_{e8} CRUDELOS^2_{ij}$$

The variance for level 2 is still uniform across hospitals, however the variance for level 1 is now dependent on the unadjusted length of stay from year to year within a hospital (i.e. the variance is a quadratic function of CRUDELOS). If the average length of stay of a hospital was the mean 6.8 days then the level 1 variance would be 4333. However if the average length of stay was 8 days, say, the variation would now be 6923 (4333 + (2 x854.9 x (8-6.8)) + 373.8 x $(8\text{-}6.8)^2$). This has consequences for the intra-hospital correlation which reduces from 0.6730 to 0.5629 when the length of stay increases from 6.8 days to 8 days. A model such as this is known as a random coefficient model.

e.g.

LOS 6.8 days

$$\rho = \frac{8917}{8917 + 4333}$$

$$\rho = 0.6730$$

LOS 8 days

$$\rho = \frac{8917}{8917 + 6923}$$

$$\rho = 0.5629$$

4.4.5 Significance testing

For the fixed part of a multilevel model, it is usually sufficient to compare the parameter estimates to their associated standard error to judge their significance, since their distribution should be approximately normal (parameter estimate $\geq$ 2 times standard error). However, for the random part of the model, the distribution of the parameter estimates often depart considerably from normality, especially when the sample size is small, as in this study. A better test is to use the likelihood ratio statistic -2(log-likelihood). Under the null hypothesis the difference in the likelihood of two models, known as a deviance statistic, follows a chi-squared distribution with degrees of freedom equal to the number of extra parameters added to the model.

4.4.6 Confidence Intervals

The 95% confidence intervals (CI) for the hospital residuals or 'effects' plotted in Figures 4.4-4.11 were calculated using the following formula:

$$\hat{u}_i \pm 1.96\, \sigma_i$$

where $\hat{u}_i$ = *residual for hospital i*

σ_i = *standard error for hospital i*

The standard width $\pm 1.96\, \sigma$ was chosen for the intervals, since interested lay only in comparing each hospital to the overall mean cost per case. If however, we had been interested in pairwise comparisons across hospitals, $\pm 1.39\, \sigma$ would have been a more appropriate interval width (see Goldstein and Healy, 1995).

4.4.7 Model Checking

As for any other regression method using a normal model assumptions of constant variance and normality should be checked. This will be demonstrated for model A in Table 4.5. Figure 4.1 firstly checks the assumption of constant variance by plotting the standardised level 1 residuals against the predicted values of the fixed part. The assumption of constant level 1 variance may not be justified as there appears to be a slight increase in variance as the predicted cost per case increase. In fact model B in Table 4.5 shows that level 1 variance is dependent on the hospital's mean unadjusted length of stay.

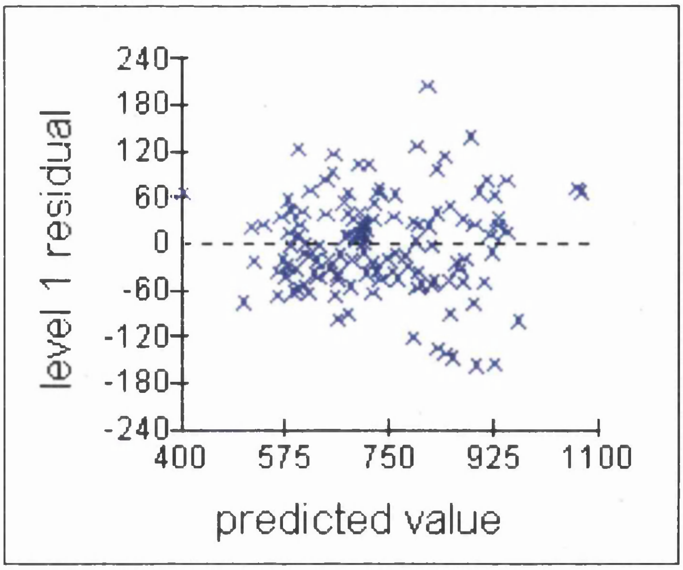

Figure 4.1: Standardised level 1 residuals by predicted values for Table 4.5

Figures 4.2 and 4.3 are plots of the level 1 and level 2 residuals respectively, against their equivalent normal scores. Both are reasonably linear suggesting that the assumption of normality is valid. For a detailed discussion of model checking and outliers in multilevel data see Langford and Lewis (1998).

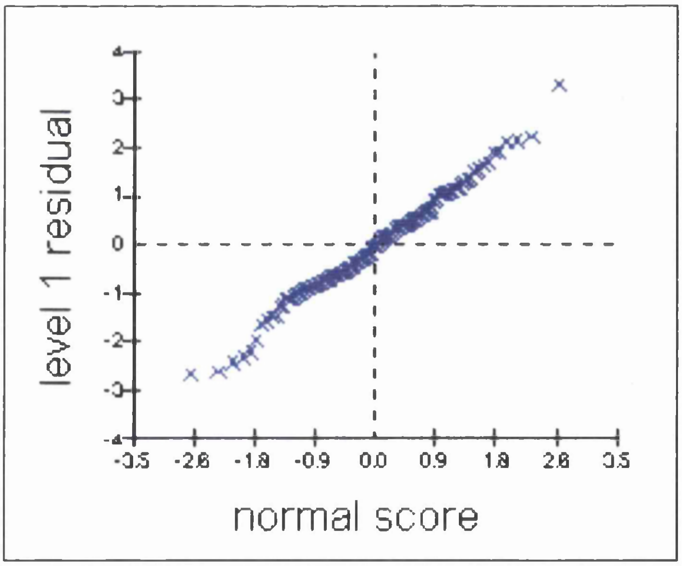

Figure 4.2: Standardised level 1 residuals by normal scores for Table 4.5

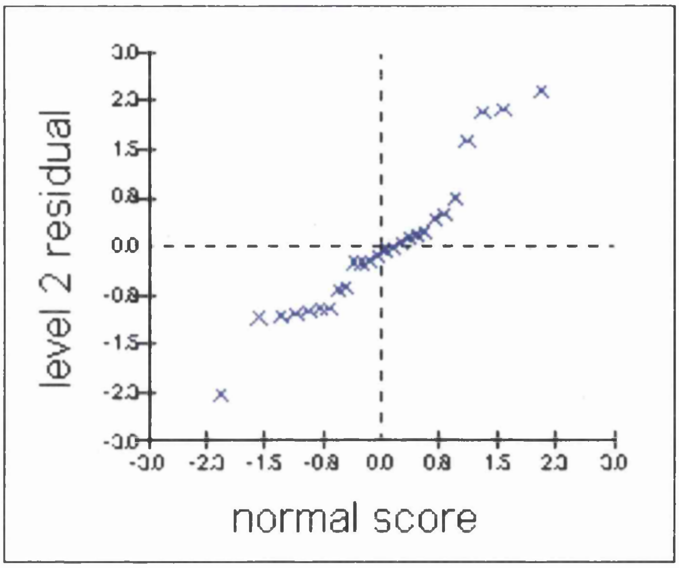

Figure 4.3: Standardised level 2 residuals by normal scores for Table 4.5

4.5 Results

The results for each of the eight specifications of the cost model follow the same format. Tables 4.5-4.12 give the parameter estimates and their associated standard errors for the fixed part and the random part of the best fitting models including the desired explanatory variables. Model A in each of the tables is the variance components model and model B (or B-D in the case of Table 4.6) is the equivalent model allowing for random coefficients at level 1. Random coefficients were also tested at level 2; however, none appeared to be significant and therefore were not retained in the cost models. The random coefficients model in each case produced a lower -2(log-likelihood) than the variance components model and therefore unless otherwise stated the results for this model will be reported. Furthermore plots were produced for the hospital 'effects' of model B (model D for Table 4.6) along with their corresponding 95% confidence intervals for each version of the cost model (Figures 4.4 – 4.11). The eight study hospitals A to H have been highlighted in each of the plots.

4.5.1 Direct cost per case /high occupancy category

Crude length of stay

Initially crude length of stay was fitted to the model for the high occupancy specialty, with direct cost per case as the response variable (see Table 4.5). If we firstly concentrate on the fixed part of model A the constant (or intercept) gives the average estimated direct cost per case in pounds when all other terms in the regression equation equal zero. The variables 1991/92 to 1994/95 are the dummy variables for the financial years. When they all equal zero this gives the estimated cost per case for the reference category – the financial year 1995/96 – otherwise called the baseline year. Likewise, the variables LGMTH and MSH are dummies indicating whether the hospital is a large general major teaching hospital or mixed specialist hospital and the baseline hospital type is a general hospital with some teaching. AOR represents the average occupancy rate and CRUDE LOS represents the average unadjusted length of stay. Both variables are centred around their means, 84% and 6.8 days, respectively. The final two terms are interactions between hospital type and length of stay. Both terms are zero if the hospital type considered is a general hospital with some teaching or the hospital's mean unadjusted length of stay is 6.8 days. The constant (£765.50), therefore represents the predicted direct cost of a medical inpatient in a general hospital with some teaching in 1995/96 with average occupancy rate of 84% and mean length of stay of 6.8 days.

The significance of each explanatory variable can be measured by comparing its estimate to its standard error. If the estimate is twice the standard error then it is consequently thought to be an influencing factor. Looking at model A in more detail average occupancy (AOR) appears not to influence the direct costs of a medical inpatient, although length of stay clearly does, as its estimate is more than twice its standard error. Hospital type has a substantial effect on direct costs with large teaching hospitals (LGMTH) costing (on average) an extra £287.7 per case with an additional £195.84 (£84.54 + £111.30) per extra day the patient stays. The dummies for the financial years 1991/92 – 1993/94 are also significant and since their estimates are negative there is some evidence that costs have been increasing, although flattening out by 1994/95 (direct cost per case £4.50 cheaper than 1995/96). As an example, the predicted direct cost per case in 1992/93 of a large teaching hospital with a length of stay of 8 days (1.2 days longer than average) and an annual occupancy rate of 90% (6% greater than average) would be £1203.49 i.e. relating this back to the equation for model A in section 4.4.3:

$$\begin{aligned}\text{direct cost per case}_{ij} &= 765.5 - 84.26(1992/93_{ij}) + 287.7(\text{LGMTH}_{ij}) - 0.07631(\text{AOR}_{ij}) \\ &\quad + 84.54(\text{CRUDELOS}_{ij}) + 111.3(\text{LGMTH*CRUDELOS}_{ij}) \\ &= 765.5 - 84.26(1) + 287.7(1) - 0.07631(6) \\ &\quad + 84.54(1.2) + 111.3(1.2) = 1203.49.\end{aligned}$$

The estimates for the random part of the model tell us the amount of random variation which is attributable to each level of the model. For model A, the variation between hospital (9057) is approximately twice that of the year-on year variation within hospitals (4891). A more exact calculation of the variation can be derived from the formula for the intra-hospital correlation (see section 4.4.3 for details). In this case the intra-hospital correlation would be 0.6493 (9057/(9057+4891)). This means that approximately 65% of the total "unexplained" variation in average direct cost per case can be attributed to differences between hospitals as opposed to year-on-year variation within hospitals. However, for model B the proportion of random variation attributable to each level is also dependent on a hospital's mean unadjusted length of stay for different financial years. If a hospital's length of stay is equivalent to the mean length of stay (6.8 days) then the proportion of the total variation at each level is calculated in the same manner [i.e. the intra-hospital correlation would be 0.6730 (8917/(8917+4333))]. If, however the hospital's length of stay was 8 days, the level 1 random variation increases from 4333 to 6923 [(4333+2x(8-6.8)x854.9+$(8-6.8)^2$x373.8)]. The intra-hospital correlation would subsequently decrease to 0.5629, implying that the longer the mean unadjusted length of stay is, the smaller the variation in direct cost per case between hospitals is likely to be.

To test whether the fit of the model has improved by adding the covariance (CRUDE LOS/CONS) and variance of the unadjusted length of stay (CRUDE LOS/CRUDE LOS), the reduction in the likelihood ratio statistic -2(log-likelihood) from model A to B is compared (see section 4.4.5 for details). The deviance is 9.92 and is referred to a chi-squared distribution of two degrees of freedom, since two new parameters were added to the model, which is significant at the 0.05 level ($p=0.007$) and therefore the parameters should be retained in the model.

The level 2 residuals or hospital 'effects' were then plotted for model B because it was the "best" fitting model (Figure 4.4). These 'effects' can be interpreted as a increase or decrease in pounds in cost per case relative to the average hospital (Scottish average) after taking account of hospital and yearly characteristics. The hospitals have been ranked in increasing order of their residuals (the centre box on each vertical line).The vertical lines represent the corresponding 95% confidence intervals for their expected direct cost per case (see section 4.4.6). It can be seen that the direct cost per case for the 26 hospitals ranges from £180 less to £200 greater than the Scottish average for the five years. The horizontal line on the graph provides a means for testing the statistical significance of these 'effects'. If the 95% confidence interval for a hospital does not across this line then the expected cost per case of that hospital is significantly different from the average. In total, eight hospitals differed significantly, five of which were study hospitals. The expected direct cost per case for hospitals A, D and G is less than the Scottish average, while hospitals C and B is greater.

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	765.5(31.55)	774.7(30.56)
1991/92	-182.9(27.15)	-197.1(24.97)
1992/93	-84.26(23.59)	-98.99(21.91)
1993/94	-57.58(21.1)	-72.12(18.77)
1994/95	-4.505(20.04)	-12.39(17.05)
LGMTH	287.7(55.48)	289.7(54.38)
MSH	-28.4(37.15)	-28.63(36.28)
AOR	-0.07631(2.104)	-1.586(1.978)
CRUDE LOS	84.54(15.63)	89.87(16.13)
LGMTH*CRUDE LOS	111.3(24.09)	108(21.66)
MSH*CRUDE LOS	-5.03(17.47)	2.179(18.36)
Random:		
Between hospitals: CONS/CONS	9057(2797)	8917(2734)
Between years: CONS/CONS	4891(688.2)	4333(764.1)
CRUDE LOS/CONS		854.9(341.5)
CRUDE LOS/CRUDE LOS		373.8(370.1)
-2(log-likelihood):	1499.19	1489.27

Table 4.5: Models for direct cost per case for high occupancy specialty grouping with crude length of stay

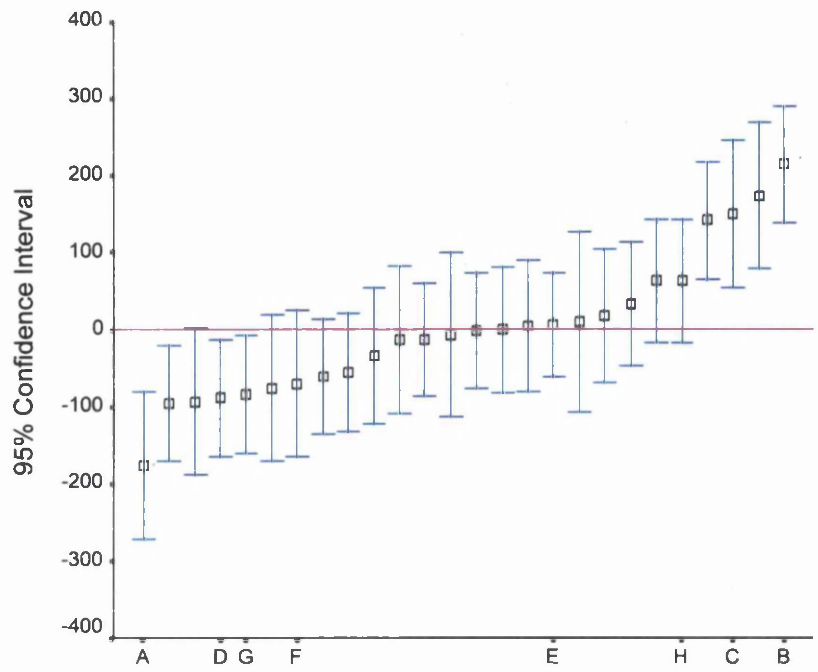

Figure 4.4: Hospital 'effects' on direct cost per case for model B of high occupancy specialty grouping with crude length of stay

Adjusted length of stay

The number of discharges (inverse) has been included in models A-D below since it appears to influence direct cost per case when length of stay has been adjusted for HRG-mix (ADJUSTED LOS). The number of averaged staffed beds, staffed bed days and occupied bed days could be used as alternatives to the number of discharges as indicators of hospital size, as they were also significant, although they are not as good predicators of direct cost per case. Furthermore they could not be included in the model along with the number of discharges, as they are all highly correlated (see Appendix H). The positive sign for the inverse of the number of discharges means there are economies of scale, since the average cost per case is reduced as the number of discharges increases. Adjusting length of stay has subsequently changed the sign of the estimate for average bed occupancy which is now positively associated with direct cost per case (a 1% increase in occupancy on average would increase the cost of a medical case by £4.74 (model D)). The effect of length of stay has also been suppressed after adjusting for HRG-mix and is no longer dependent on hospital type.

The random variation at level 1 is more complex here than for the crude length of stay. The level 1 variation can be modelled in two different ways, first we will concentrate on model B. Part of the variation in direct cost per case is also explained by hospital type; year-on-year variation within large teaching hospitals is much higher than general hospitals, while the variation is significantly lower for mixed specialist hospitals (MSH). The amount of variation in direct cost per case within hospitals also depends on the mean occupancy for that hospital. For example, the intra-hospital correlation for a general hospital with mean occupancy 90% would be 0.628 compared with 0.3672 for a hospital with mean occupancy 75%. However if the hospital with 90% occupancy was a teaching hospital, the value for its intra-hospital correlation would be 0.2976. It is also important to remember that, although the proportion of the variation attributable to year-on-year differences changes as described above, the actual amount of variation between hospitals is the same for all types.

Alternatively, the level 1 variation could be modelled as for model D, which has a lower -2(log-likelihood) ratio than model B. In model D the year-on-year variation is dependent on length of stay. The variation for large teaching hospitals is also larger than the other hospital types. The purpose of model C is to show the large effect adding LGMTH in addition to the ADJUSTED LOS as a random coefficient to level 1 has. The likelihood reduced significantly by 26.62. For a large teaching hospital the level 1 variation would increase by 19056 (2x9528) reducing the intra-hospital correlation from 0.7310 to 0.2896. However, if length of stay was reduced from the mean of 6.9 days to 6 days the intra-class correlation would increase for larger teaching hospitals to 0.3010 and 0.8082 for the other hospitals. Generally, as length of stay decreases the proportion of variation in cost per case between hospitals becomes larger, although for large teaching hospitals year-on-year differences with each hospital are still greater.

For the adjusted length of stay model the hospital 'effects' have been plotted for model D, since it had the lowest -2(log-likelihood). Six hospitals have an expected direct cost per case significantly different from the average hospital (four above and two below). It is also worth noting that the confidence intervals of a further two hospitals only just contain zero. Hospitals B and C still have an expected direct cost per case greater than the average and hospital D lower.

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	634.3(58.21)	631.5(51.06)
1991/92	-141.5(33.77)	-144.3(26.81)
1992/93	-51.44(29.45)	-63.82(22.35)
1993/94	-39.27(26.56)	-35.58(21.07)
1994/95	4.531(24.77)	-0.7878(18.58)
LGMTH	264.1(63.62)	267.7(63.26)
MSH	-73.98(41.92)	-74.81(34.2)
AOR	4.734(2.476)	4.505(2.294)
ADJUSTED LOS	58.95(16.33)	53.55(13.47)
1/DISCHARGES	6.10e+05(2.35e+05)	6.21e+05(2.04e+05)
Random:		
Between hospitals: CONS/CONS	9425(3051)	8281(2683)
Between years: CONS/CONS	7543(1062)	5550(1383)
AOR/CONS		-226(99.45)
AOR/AOR		57.4(28.69)
LGMTH/CONS		7319(3315)
MSH/CONS		-1716(738.2)
-2(log-likelihood):	1545.2	1516.78

Table 4.6(a) : Models of direct cost per case for high occupancy specialty grouping with adjusted length of stay

Parameter	Estimate(s . e) Model C	Estimate(s . e) Model D
Fixed:		
CONSTANT	577.6(61.71)	583.9(52.21)
1991/92	-153.7(31.65)	-161.5(27.01)
1992/93	-61.21(27.44)	-73.21(23.67)
1993/94	-52.45(24.22)	-62.9(20.2)
1994/95	8.066(22.74)	3.607(17.14)
LGMTH	310.1(71.91)	299.3(65.77)
MSH	-77.87(41.6)	-74.91(36.42)
AOR	6.322(2.095)	4.739(1.968)
ADJUSTED LOS	58.46(16.77)	49.03(13.54)
1/DISCHARGES	8.93e+05(2.53e+05)	8.98e+05(2.15e+05)
Random:		
Between hospitals: CONS/CONS	1.28e+04(3930)	9141(2890)
Between years: CONS/CONS	3210(867.3)	3364(640.4)
ADJUSTED LOS/CONS	-456.3(627.8)	891.7(357.3)
ADJUSTED LOS/ADJUSTED LOS	3728(1225)	506(346.9)
LGMTH/CONS		9528(3414)
-2(log-likelihood):	1538.36	1511.74

Table 4.6(b) : Models of direct cost per case for high occupancy specialty grouping with adjusted length of stay

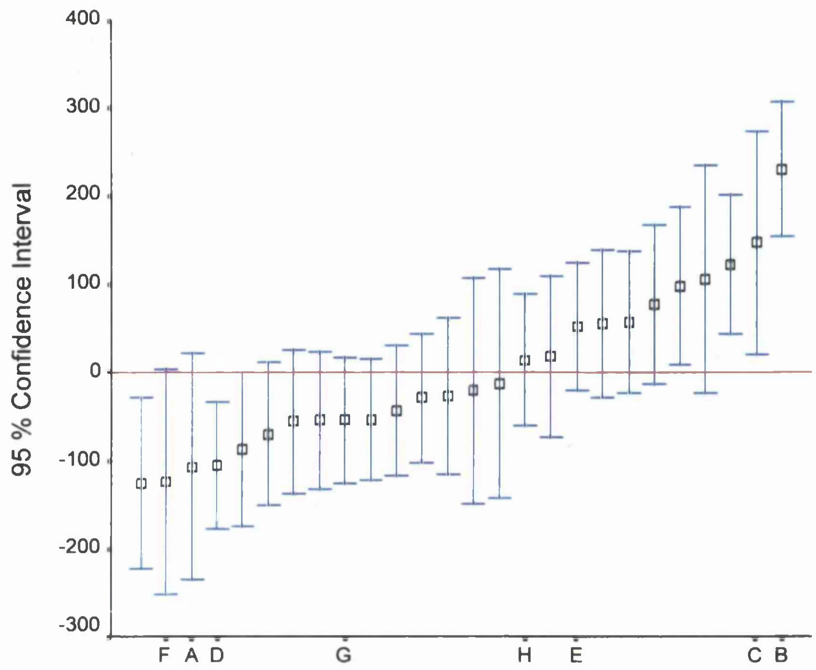

Figure 4.5: Hospital 'effects' on direct cost per case for model D of high occupancy specialty grouping with adjusted length of stay

4.5.2 Direct cost per case /low occupancy category

Crude length of stay

The next two Tables (4.7 and 4.8) compare equivalent models for the low occupancy grouping of ENT, gynaecology and ophthalmology. For this grouping the mean occupancy rate is 57% and the mean crude length of stay is 3.1 days. From the estimates of the dummy variables for the financial years it seems that direct cost per case has been increasing over the past five financial years. Here the dummies for hospital type are not significant, although the association of direct cost per case and occupancy ratio is dependent on hospital type; costs increase with occupancy ratio for large teaching hospitals (£9.08 per case for every 1% increase) and decrease for hospitals with little or no teaching (£5.61 for general hospitals; £4.48 for MSH). Further the increase in direct cost per case for every additional day in a patient's stay above the mean of 3.1 days is £101.90. For example, from model B the predicted cost per case in 1992/93 of a large teaching hospital with 4-day length of stay (0.9 days greater than average) and annual occupancy 65% (8% greater than the average) would be £705.18 (e.g. 695.9-156.1 +1.042 +(8x (-5.611)+(0.9x101.9)+(8x14.69)= 705.18).

From model A it appears that the random variation is approximately equal for level 1(i.e. year-on-year within hospitals) and level 2 (between hospitals). However model B shows that the amount of variation attributable to each level is dependent on hospital type. The intra-hospital correlation for mixed specialist hospitals is 0.3949 and 0.6680 for larger teaching hospitals and general hospitals with some teaching. This means that there is greater year-on-year variation in direct cost per case within mixed specialist hospitals compared to inter-hospital differences. This is the opposite of the high occupancy specialty grouping where the variation year-on-year is less for mixed specialist hospitals.

For both the model with crude length of stay and adjusted length of stay hospital B has a considerably higher average direct cost per case than any of the other hospitals for the low occupancy specialty grouping (see Figures 4.6 and 4.7). Although this difference may be more evident for this specialty grouping, it should be recognised that hospital B has a consistently higher cost per case for all of the cost models. Hospital A is the only other study hospital to differ significantly from the average in figure 4.6. Hospital A has an expected direct cost per case £100.03 (95%CI; (-188.35, -11.71) less than the average. Once length of stay has been adjusted for HRG-mix hospital A's direct cost per case no longer appears to be significantly different (95% CI; (-146.82,30.10)) (see Figure 4.7).

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	710.6(30.82)	695.9(28.97)
1991/92	-234.6(29.34)	-201(26.19)
1992/93	-180(25.54)	-156.1(22.34)
1993/94	-106.3(23.56)	-88.84(20.57)
1994/95	-23.58(22.1)	-10.21(19.04)
LGMTH	3.368(51.12)	1.042(48.26)
MSH	-21.36(36.29)	-24.25(37.22)
AOR	-5.13(2.155)	-5.611(1.687)
CRUDE LOS	123.3(27.82)	101.9(27.9)
LGMTH*AOR	14.23(5.6)	14.69(4.435)
MSH*AOR	0.07831(3.137)	1.13(3.269)
Random:		
Between hospitals: CONS/CONS	6711(2203)	6712(2189)
Between years: CONS/CONS	6038(850.7)	3309(603.8)
MSH/CONS		3487(1173)
-2(log-likelihood):	1514.35	1499.68

Table 4.7: Models of direct cost per case for low occupancy specialty grouping with crude length of stay

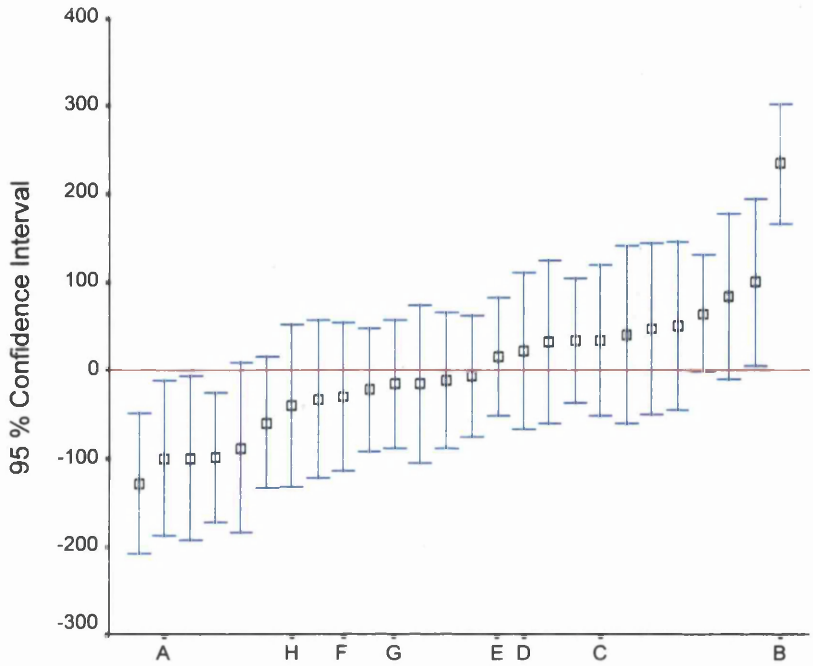

Figure 4.6: Hospital 'effects' on direct cost per case for model B of low occupancy specialty grouping with crude length of stay

Adjusted length of stay

After adjusting for HRG-mix length of stay no longer appears to influence direct cost per case. The rest of the model is still similar to the model including crude length of stay, with the relationship between direct cost per case and occupancy again dependent on hospital type; for large teaching hospitals an increase of £8.02 per case for every 1% increase in occupancy and £5.24 decrease per case for every 1% increase for the other two classifications of hospital. The year on year variation of direct cost per case is also still much greater within mixed specialist hospitals. The intra-hospital correlation for the mixed specialist hospitals is 0.3504 compared to 0.6617 for the other hospitals, which are close to the values for the model with crude length of stay in Table 4.7 (0.3949 and 0.6680 – model B).

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	683.5(32.57)	675.3(30.67)
1991/92	-175.4(35.91)	-152.5(30.63)
1992/93	-138.5(28.58)	-123.4(23.53)
1993/94	-76.67(26.68)	-66.24(22.42)
1994/95	-7.514(24.06)	2.235(29.58)
LGMTH	12.54(50.28)	6.378(48.69)
MSH	-21.57(36.64)	-25.29(38.91)
AOR	-4.123(2.341)	-5.239(1.773)
ADJUSTED LOS	33.42(37.58)	27.15(37.08)
LGMTH*AOR	11.46(5.957)	13.26(4.602)
MSH*AOR	1.084(3.336)	2.4(3.47)
Random:		
Between hospitals: CONS/CONS	5590(2074)	6780(2249)
Between years: CONS/CONS	7259(1023)	3466(632.6)
MSH/CONS		4551(1418)
-2(log-likelihood):	1531.36	1511.47

Table 4.8: Models of direct cost per case for low occupancy specialty grouping with adjusted length of stay

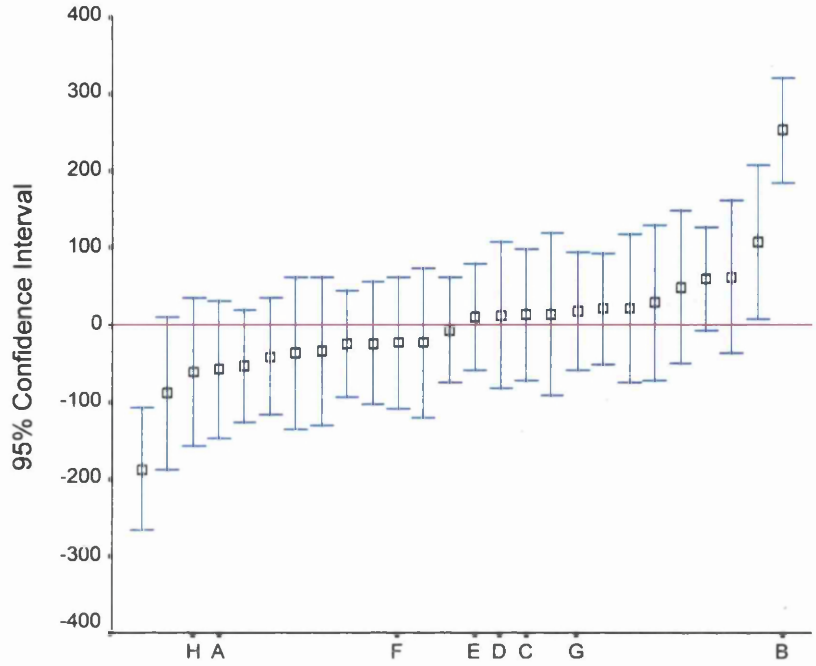

Figure 4.7: Hospital 'effect' on direct cost per case for model B of low occupancy specialty grouping with adjusted length of stay

4.5.3 Total cost per case/high occupancy category

Crude length of stay

The models for total cost per case are comparable to that for direct cost per case, although in addition occupied bed days (inverse) is significant in this model Occupied bed days is just a measure of hospital size and can be interpreted as follows. The difference in cost per case between two hospitals – one with 50,000 occupied bed days and the other with 100,000 – would be (1/50,000 – 1/100,000) x 8.36 x 10^6 = £83.60. This assumes that everything else is held constant; for occupancy to remain the same when the number of occupied bed days doubles, the number of available beds must double (i.e. a hospital twice the size).

If we consider the same in section 4.5.1 describing total cost per case using model A, the predicted total cost per case in 1992/93 of a large teaching hospital with a length of stay of 8 days (1.2 days longer than average) and an annual occupancy rate of 90% (6% greater than average) would be £1671.60 (e.g. 946.8-98.86+488.7+(6x-0.7538)+(1.2x120.1)+(1.2x162.8)=1671.60). The difference between the total and direct cost per case is therefore £468.11 (1671.60-1203.49).

The size of the variation at each level is much larger than it was for the direct cost per case model, approximately twice the between hospital and three times the within hospital. As for the direct cost model there is a significant reduction in the likelihood when adding CRUDE LOS to the random part of model at level 1 and should be included in the model (likelihood ratio statistic = 11.03, 2 degrees of freedom, p=0.004). The value for the intra-hospital correlation is therefore dependent on the unadjusted length of stay. For example, the average length of stay of the hospitals in the sample in 1991/92 was 7.7 days compared to 6.1 days in 1995/96. This gives intra-hospital correlations of 0.5154 and 0.6738, respectively and suggests that as length of stay has decreased the proportion of the total variation in total cost per case between hospitals has increased.

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	946.8(99.49)	934.9(96.17)
1991/92	-246.9(44.96)	-272.2(41.31)
1992/93	-98.86(39.48)	-123(36.34)
1993/94	-40.77(35.85)	-66.98(31.4)
1994/95	24.59(34.21)	0.882(28.29)
LGMTH	488.7(98.64)	510.5(98.24)
MSH	-50.42(58.52)	-52.9(58.03)
AOR	-0.7538(3.635)	-2.09(3.402)
CRUDE LOS	120.1(15.2)	118.7(26.06)
1/OCCUPIED BED DAYS	7.39e+06(2.98e+06)	8.36e+06(2.88e+06)
LGMTH*CRUDE LOS	162.8(40.77)	166.5(35.23)
MSH*CRUDE LOS	-23.43(29.13)	-4.804(30.19)
Random:		
Between hospitals: CONS/CONS	1.86e+04(6003)	1.95e+04(6140)
Between years: CONS/CONS	1.42e+04(2017)	1.27e+04(2177)
CRUDE LOS/CONS		2680(985.9)
CRUDE LOS/CRUDE LOS		1004(1027)
-2(log-likelihood):	1626.97	1615.94

Table 4.9: Models of total cost per case for high occupancy specialty grouping with crude length of stay

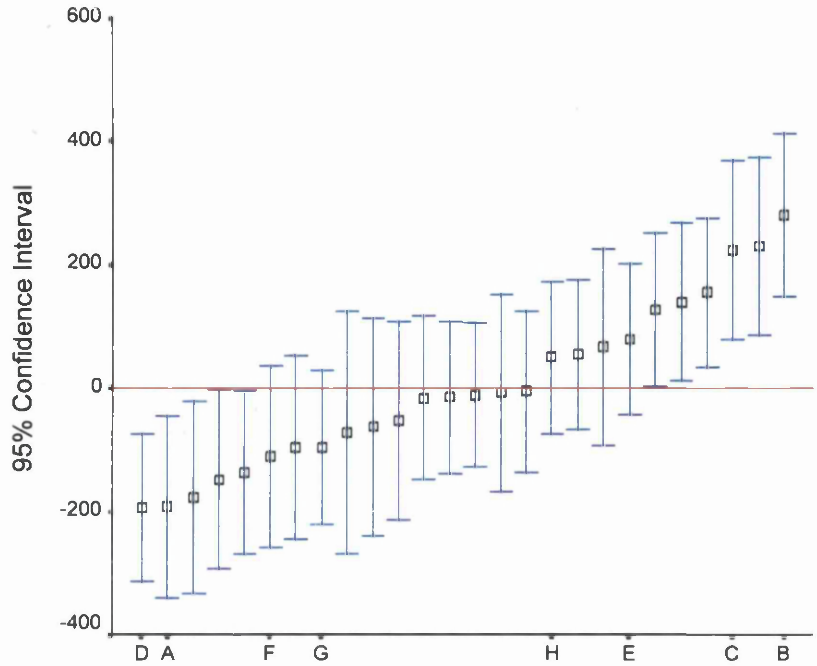

Figure 4.8: Hospital 'effects' on total cost per case for model B of high occupancy specialty grouping with crude length of stay

Adjusted length of stay

The model for total cost per case is similar to that of direct cost per case in respect of direction of the parameter estimates. Average bed occupancy although also positively associated with total cost per case is not significant here (Table 4.10). In the previous model the effect of crude length of stay was dependent on hospital type, which is not the case for the HRG adjusted length of stay. Unlike previous models where costs appear to be flattening out by the financial year 1994/95, total cost per case decreased between 1994/95 and 1995/96 .

In the random part of the model the inclusion of adjusted length of stay and the dummy for large general teaching hospitals produce a significant reduction in the likelihood (likelihood ratio statistic =14.71, 3 degrees of freedom, p=0.002) as for the model of direct cost per case. If length of stay is assumed to be the mean (6.9 days) the intra-hospital correlation for large teaching hospitals would be 0.2404 and for the other hospitals would be 0.5280. That is, for large teaching hospitals, year-on-year variation in total cost per case is greater than inter-hospitals difference. This variation is approximately equal for other types of hospitals. If the length of stay also increased to 8 days, the corresponding intra-hospital correlations would be 0.2159 for large teaching hospitals and 0.4226 for the rest. In summary, the proportion of the total variation attributable to differences in the total cost per case between hospitals decreases as the adjusted length of stay increases. This is due to the amount of inter-hospital variation year-on-year increasing as adjusted length of stay increases.

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	941.1(85.19)	914.6(78.2)
1991/92	-179.6(53.73)	-210.6(47.99)
1992/93	-44.59(47.48)	-79.57(42.72)
1993/94	-4.542(43.36)	-39.99(37.65)
1994/95	43.27(40.92)	34.42(33.48)
LGMTH	332.1(89.55)	357.8(89.77)
MSH	-91.88(61.4)	-87.77(55.35)
AOR	3.251(3.958)	2.768(3.59)
ADJUSTED LOS	70.83(24.98)	66.26(22.58)
1/DISCHARGES	1.04e+06(3.43e+05)	1.26e+06(3.22e+05)
Random:		
Between hospitals: CONS/CONS	1.72e+04(5963)	1.51e+04(5264)
Between years: CONS/CONS	2.08e+04(2924)	1.35e+04(2569)
ADJUSTED LOS/CONS		2604(1242)
ADJUSTED LOS/ADJUSTED LOS		1155(1223)
LGMTH/CONS		1.71e+04(7164)
-2(log-likelihood):	1664.89	1650.18

Table 4.10: Models of total cost per case for high occupancy specialty grouping with adjusted length of stay

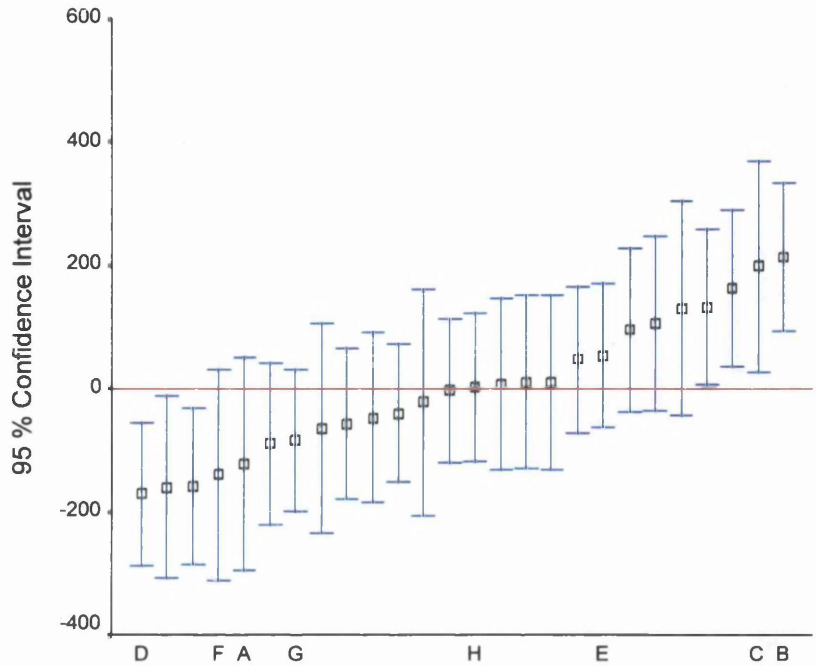

Figure 4.9: Hospital 'effects' on total cost per case for model B of high occupancy specialty grouping with adjusted length of stay

4.5.4 Total cost per case/low occupancy category

Crude length of stay

Unlike direct costs, the relationship between total cost per case and occupancy does not appear to be dependent on the type of hospital; total cost per case decreases as occupancy increases regardless of hospital type (for a 1% increase, there was £4.74 decrease in cost per case). The dummy for large teaching hospitals is nearly significant here with the total cost on average being £99.65 greater per case. For large teaching hospitals and general hospitals with some teaching the variation in total cost per case is approximately equal between hospitals and year-on-year costs within hospitals (49:51). For mixed specialist hospitals the variation is much greater year-on-year (21328 (7870+(2x6729)) compared to 7583 between hospitals i.e. 74% compared to 26%).

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	982(38.08)	968.4(35.29)
1991/92	-262.9(41.54)	-240.1(37.74)
1992/93	-191.7(36.51)	-176(32.86)
1993/94	-44.28(33.96)	-23.17(30.29)
1994/95	-6.881(32.45)	8.924(28.83)
LGMTH	100.3(54.81)	99.65(51.61)
MSH	12.19(43.45)	8.743(43.83)
AOR	-4.556(2.098)	-4.745(1.934)
CRUDE LOS	128.6(36.76)	122.1(36.77)
Random:		
Between hospitals: CONS/CONS	7673(2909)	7583(2809)
Between years: CONS/CONS	1.32e+04(1857)	7870(1434)
MSH/CONS		6729(2441)
-2(log-likelihood):	1600.29	1588.17

Table 4.11: Models of total cost per case for low occupancy specialty grouping with crude length of stay

From the plot of the hospital 'effects' (Figure 4.10) hospital B is the only study hospital to have a predicted total cost per case significantly different from the average; £230.54 greater (95%CI; (144.07,317.02)). Two other hospitals also have a predicted total cost per case significantly greater than the average.

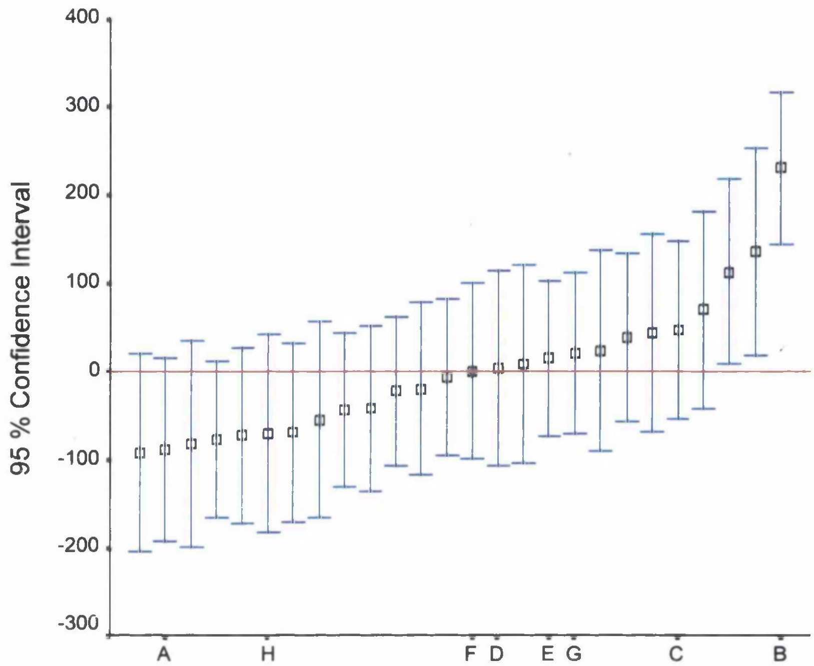

Figure 4.10: Hospital 'effects' on total cost per case for model B of low occupancy specialty grouping with crude length of stay

Adjusted length of stay

As in the previous models (Table 4.11) the direction of bed occupancy is no longer dependent on hospital type, a 1% increase in bed occupancy is associated with £4.09 decrease in the total cost of each case (Table 4.12). However, as for the direct cost model, length of stay no longer appears to influence total cost per case after it has been adjusted for HRG-mix. Finally, the addition of the dummy for mixed specialist hospitals (MSH) to level 1 once more produces a significant reduction in the likelihood. The intra-hospital correlation for mixed specialist hospitals was 0.2431 compared to 0.4726.

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	956.3(40.58)	945.3(37.71)
1991/92	-204(48.59)	-184.3(43.67)
1992/93	-149.2(39.1)	-137.3(34.61)
1993/94	-16.17(36.8)	2.212(32.67)
1994/95	10.25(34.02)	23.94(29.88)
LGMTH	98.99(54.93)	98.79(52.22)
MSH	5.517(44.42)	1.378(45.38)
AOR	-3.539(2.207)	-4.087(2.044)
ADJUSTED LOS	41.75(48.71)	36.11(48.56)
Random:		
Between hospitals: CONS/CONS	7360(2910)	7636(2889)
Between years: CONS/CONS	1.47e+04(2069)	8522(1552)
MSH/CONS		7628(2708)
-2(log-likelihood):	1611.16	1598.17

Table 4.12: Models of total cost per case for low occupancy specialty grouping with adjusted length of stay

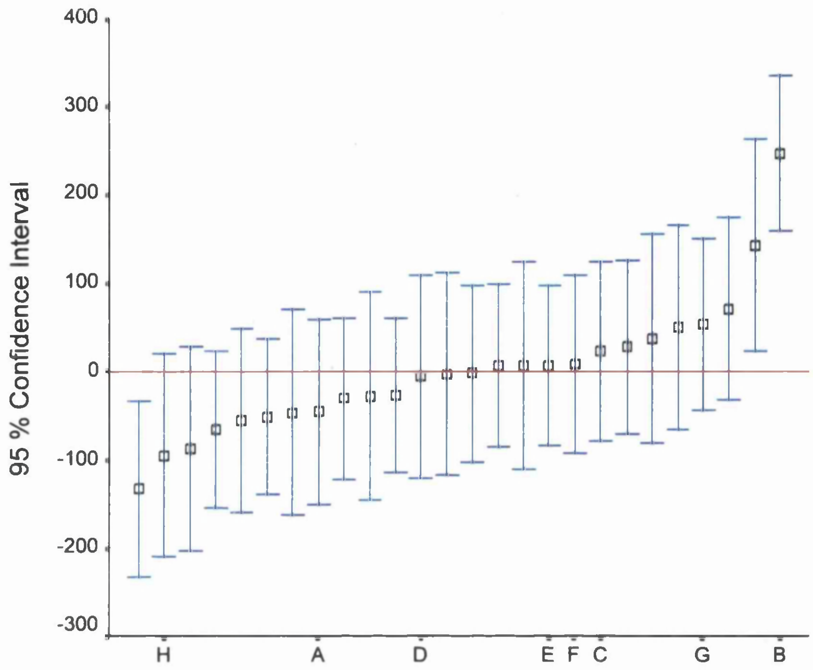

Figure 4.11: Hospital 'effects' on total cost per case for model B of low occupancy specialty grouping with adjusted length of stay

4.5.5 Hospital residuals

The residuals for the direct and total cost models are given in Tables 4.13 and 4.14. Each hospital is also ranked in increasing order of its residual for each model. It is of interest to compare the models. It would perhaps be expected that if a hospital average cost per case was higher in one specialty grouping, then the same would be true for the other. In order to test this hypothesis correlations were calculated between the residuals of each of the eight cost models (see Table 4.15). The strongest relationships are seen between the crude and adjusted length of stay models within the same specialty grouping and cost category, although the correlation coefficents are also high irrespective of length of stay and cost type. This is not surprising since direct costs are a proportion of total costs. Comparing the residuals across specialties produces weaker associations. For total costs, the correlations are significant, although smaller than those for the within specialty relationships, while the correlations for direct costs are non-significant. The stronger relationship for total costs is expected, since a proportion of total costs are fixed across a hospital, while direct costs are likely to differ considerably from one specialty to the next.

Hospital	High Occupancy Grouping		Low Occupancy Grouping	
	Crude LOS	HRG Adjusted LOS	Crude LOS	HRG Adjusted LOS
A	-175.83 (1)	-106.77 (3)	-100.03 (2)	-58.36 (4)
B	213.67 (26)	229.88 (26)	234.10 (26)	252.51 (26)
C	149.47 (24)	146.33 (25)	33.19 (19)	12.64 (16)
D	-88.40 (4)	-105.18 (4)	21.00 (16)	12.22 (15)
E	5.31 (17)	51.45 (18)	15.48 (15)	8.73 (14)
F	-70.66 (7)	-124.02 (2)	-29.73 (9)	-23.57 (11)
G	-83.67 (5)	-54.02 (10)	-15.84 (11)	17.89 (18)
H	62.36 (22)	13.59 (16)	-39.89 (7)	-61.29 (3)
1	10.34 (18)	-13.43 (15)	-99.96 (3)	-88.48 (2)
2	32.17 (20)	56.98 (20)	99.56 (25)	107.08 (25)
3	-13.22 (11)	76.61 (21)	-98.80 (4)	-54.42 (5)
4	141.11 (23)	122.48 (24)	-15.42 (12)	-33.67 (8)
5	-61.48 (8)	-43.77 (11)	-12.39 (13)	-24.22 (10)
6	-34.64 (10)	97.31 (22)	-33.20 (8)	-23.39 (12)
7	-0.24 (15)	-87.75 (5)	-59.83 (6)	-41.44 (6)
8	4.07 (16)	-70.22 (6)	40.34 (20)	13.41 (17)
9	-95.62 (2)	-56.21 (7)	63.90 (23)	60.21 (23)
10	16.46 (19)	-26.83 (13)	-128.74 (11)	-186.83 (1)
11	172.86 (25)	105.62 (23)	50.14 (22)	21.15 (20)
12	-13.06 (12)	-53.66 (9)	32.88 (18)	-6.79 (13)
13	-7.17 (13)	17.35 (17)	-22.24 (10)	20.46 (19)
14	62.27 (21)	54.94 (19)	-88.42 (5)	-37.31 (7)
15	-93.26 (3)	-126.32 (1)	83.11 (24)	61.92 (24)
16	-75.84 (6)	-21.16 (14)	46.44 (21)	48.14 (22)
17	-1.48 (14)	-28.84 (12)	30.87 (17)	28.10 (21)
18	-55.51 (9)	-54.35 (8)	-6.51 (14)	-24.70 (9)

Table 4.13: Hospital residuals (rankings) for direct cost per case models

Hospital	High Occupancy Grouping		Low Occupancy Grouping	
	Crude LOS	HRG Adjusted LOS	Crude LOS	HRG Adjusted LOS
A	-192.39 (2)	-121.89 (5)	-89.52 (2)	-46.25 (8)
B	280.02 (26)	211.97 (26)	230.54 (26)	246.39 (26)
C	222.87 (24)	197.65 (25)	45.97 (22)	22.90 (19)
D	-195.08 (1)	-171.38 (1)	2.98 (15)	-5.35 (12)
E	79.34 (20)	52.80 (19)	14.57 (17)	7.17 (17)
F	-111.17 (6)	-139.42 (4)	0.40 (14)	7.86 (18)
G	-95.67 (8)	-83.33 (7)	20.56 (18)	53.12 (23)
H	48.85 (17)	2.30 (14)	-70.72 (6)	-95.05 (2)
1	-72.36 (9)	-23.06 (12)	-92.12 (1)	-87.06 (3)
2	126.20 (21)	162.56 (24)	134.97 (25)	142.89 (25)
3	65.50 (19)	104.50 (21)	-41.88 (9)	5.78 (15)
4	153.84 (23)	132.26 (23)	69.48 (23)	49.52 (22)
5	53.40 (18)	46.22 (18)	38.45 (20)	27.50 (20)
6	-52.63 (11)	10.19 (17)	-54.78 (8)	-46.64 (7)
7	-8.15 (15)	6.83 (15)	-19.68 (12)	-2.09 (14)
8	-16.69 (12)	-89.40 (6)	22.82 (18)	6.24 (16)
9	-136.61 (5)	-158.23 (3)	-22.65 (11)	-27.02 (11)
10	-95.96 (7)	-47.17 (10)	-73.05 (5)	-133.19 (1)
11	228.56 (25)	128.95 (22)	112.49 (24)	70.91 (24)
12	-11.66 (14)	-39.98 (11)	-7.20 (13)	-51.73 (6)
13	-63.01 (10)	9.55 (16)	-77.36 (4)	-31.05 (9)
14	139.46 (22)	94.27 (20)	-82.59 (3)	-28.19 (10)
15	-177.23 (3)	-160.08 (2)	8.68 (16)	-2.89 (13)
16	-147.87 (4)	-65.28 (8)	-69.34 (7)	-55.43 (5)
17	-15.78 (13)	-3.61 (13)	43.05 (21)	37.04 (21)
18	-5.74 (16)	-57.20 (9)	-44.07 (10)	-65.38 (4)

Table 4.14: Hospital residuals (rankings) for total cost per case models

			Direct Costs				Total Costs			
			High Occupancy		Low Occupancy		High Occupancy		Low Occupancy	
			Crude LOS	Adj LOS	Crude LOS	Adj LOS	Crude LOS	Adj LOS	Crude LOS	Adj LOS
Direct Costs	High Occupancy	Crude LOS	1.00							
		Adj LOS	0.84 (0.00)	1.00						
	Low Occupancy	Crude LOS	0.33 (0.10)	0.32 (0.12)	1.00					
		Adj LOS	0.27 (0.19)	0.35 (0.08)	0.94 (0.00)	1.00				
Total Costs	High Occupancy	Crude LOS	0.90 (0.00)	0.84 (0.00)	0.33 (0.10)	0.32 (0.11)	1.00			
		Adj LOS	0.84 (0.00)	0.90 (0.00)	0.23 (0.27)	0.27 (0.19)	0.94 (0.00)	1.00		
	Low Occupancy	Crude LOS	0.58 (0.00)	0.49 (0.01)	0.80 (0.00)	0.74 (0.00)	0.63 (0.00)	0.53 (0.01)	1.00	
		Adj LOS	0.48 (0.01)	0.51 (0.01)	0.74 (0.00)	0.81 (0.00)	0.59 (0.00)	0.55 (0.00)	0.93 (0.00)	1.00

Table 4.15: Correlations (P-values) of hospital residuals of cost models for direct and total costs, high occupancy and low occupancy specialty groupings, and models including crude and adjusted length of stay

4.6 Summary of results

4.6.1 Relationship between cost per case and bed occupancy

The relationship between cost per case and bed occupancy was different for the two specialty groupings. In the low occupancy grouping of ENT, gynaecology and ophthalmology total cost per case fell as occupancy increased, although for direct cost per case the relationship was dependent on hospital type. Costs increased with occupancy for large teaching hospitals and decreased for hospitals with little or no teaching. In the higher occupancy grouping the relationship between occupancy and cost per case was uncertain, although there was some evidence suggesting that an increase in occupancy was associated with an increase in cost per case (at most a 1% increase was associated with an increase of £5 per case). One possible explanation for these differences could be that the direction of the association between unit costs and bed occupancy is dependent on the level of occupancy reached in a particular hospital. In the medical grouping where average occupancy is approximately 84%, with daily fluctuations frequently exceeding 100%, there is perhaps little room to increase occupancy without additional staff and equipment, which will inevitably produce a rise in unit costs. In the lower specialty grouping, where average occupancy is nearly 30% less (57%), there may be some scope to treat more patients with present resources. In the case of teaching hospitals, more complex (thus more costly) patients within HRGs may account for the positive relationship between unit costs and occupancy.

4.6.2 Cost per case and length of stay

In general, costs increased with length of stay for both specialty groupings, although the relationship was weaker when length of stay was adjusted for HRG-mix and was not always significant for the low occupancy grouping. The reason the relationship is weaker between unit costs and length of stay after taking account of HRG-mix is because the variation in length of stay (and thus unit costs) attributable to patient differences has been removed.

However, the crude and adjusted lengths of stay had different effects on which other factors were significant in the model. When the adjusted length of stay was fitted increasing the number of discharges, averaged staffed beds, staffed bed days and occupied bed days all reduced both direct and total cost per case for the medical specialties, yet only occupied bed days reduced total cost per case for the crude length of stay. None of these indicators of hospital activity influenced the cost of an inpatient in the lower occupancy specialty.

For the high occupancy specialty, adjusted LOS is related to the year and could mean one of two things. Firstly, that variation in cost per case has simply decreased between 1991/92-1995/96. Alternatively, that variation in cost per case increases as LOS (adjusted for HRG-mix) increases; for some hospitals, long LOS is the result of a high number of severely ill patients and therefore high costs, while for other hospitals longer stays maybe unnecessary and are therefore associated with lower costs, widening the gap between the two.

4.6.3 Cost per case and teaching status

Teaching hospitals tended to have a higher cost per case even when lengths of stay and bed occupancy were taken into account. The variation in both direct and total costs was greater among large teaching hospitals for the high occupancy group and among mixed specialist hospitals in the lower occupancy group.

4.6.4 Cost Variation

Adjusting length of stay for HRG-mix reduced some of the cost variation between hospitals. In general, between-hospitals the variation was greater than year-on-year differences, within each hospital except for large general teaching hospitals in the high occupancy grouping and mixed specialist hospitals in the low occupancy grouping. The plots of the 'hospital effects' suggested that outliers changed according to the specification of different models, although hospital B had an average cost per case consistently above the other hospitals.

4.7 Further analysis

From the cost analysis, crude length of stay appeared to be a better predictor of cost per case than the HRG-adjusted length of stay. This suggests that adjusting LOS for HRG-mix was perhaps not an appropriate method of taking account of case-mix differences. The following chapter illustrates an alternative method of case-mix adjustment and discusses whether this would have been a better approach to use.

Chapter 5: Alternative adjustment for HRG-mix

5.1 Introduction

The importance of case-mix adjustment when carrying out hospital cost analysis has already been discussed in previous chapters of this thesis. In the econometric analysis in Chapter 4 the length of stay in each hospital was adjusted for its HRG-mix, however this appeared to explain less of the cost variation than crude length of stay. Ideally both average cost per case and length of stay would have been standardised for HRG-mix. However information was not available on the cost of individual patient episodes and therefore adding a case-mix adjuster was the best possible method. A possible alternative to the method used in Chapter 4 could be to calculate the proportion of discharges within each hospital which fall within the Healthcare Resource Groups (HRGs) with the longest average lengths of stay within Scotland. The rationale being that those HRGs with the longest LOS may depict the more severe and thus more costly cases and therefore hospitals with greater proportions of such cases will likely have greater than average unit costs.

5.2 Method

For the purpose of this illustration we will concentrate only on modelling direct cost per case within the high occupancy specialty grouping. For this analysis only four years of data could be used (financial year 1991/92-1994/95), as information on individual discharges was not available for the financial year 1995/96. Consequently this reduced the data set from 127 time points to 101.

From the HRG-adjusted length of stay calculations, the yearly mean LOS of each HRG in Scotland is already known. However a decision had to be made about where the cut off point for the longest LOS would be. It was proposed to compare two separate variables, one which took account of 10% of Scottish discharges for each year and the other 25%. After the 10% and 25% of discharges with the longest mean HRG LOS were selected, the number within each hospital was calculated. Finally these numbers were divided by the hospitals total number of discharges to give the proportion of discharges within each hospital, which fell into each of the two categories.

The mean and range of the new case-mix variables are given in Table 5.1. It would be expected that each hospital would have proportions near 10% and 25% for the two variables. Correlations between the two new variables and the other variables used in the analysis can be see in Appendix H (Table H3).

Variables	*Mean*	*Range*
HRG PROP10	10.09%	(6.76-16.69%)
HRG PROP25	25.35%	(18.69-40.80%)
CRUDE LOS	6.99 days	(4.70-10.70 days)
AOR	84.15%	(73.0-105.0%)

Table 5.1: Mean and range of new case-mix variables, length of stay and occupancy

5.3 Results

The results are reported in a similar format to Chapter 4. In order to allow for comparisons the models in Table 4.5 on page 96 have been repeated using the reduced data set (see Table 5.2). Figure 5.1 shows the hospital 'effects' for model B in Table 5.2. In Table 5.3 crude length of stay has been substituted by each of the new HRG variables in turn. The two new variables HRG PROP10 and HRG PROP25 are both centred around their means. Replacing length of stay with theses two variables resulted in both the average occupancy ratio (AOR) and number of discharges becoming significant. This similarly happened when adjusted length of stay was added to the model (see Table 4.6 page 100). The affect here is greater though, a 1% increase in occupancy on average would increase the cost per case by £8.35 instead of £4.73 (model A)).

Now concentrating on the actual estimates for the new variables, the variable representing 10% (HRG PROP10) is not significant while the variable for 25% (HRG PROP25) is. The sign of each variable is also different, although the interaction term between large teaching hospitals (LGMTH) and HRG PROP10 is negative as for HRG PROP25. The negative relationship between cost per case and these two variables is perhaps surprising, as it would probably be expect that an increase in cases with longer lengths of stay would lead to an increase in average cost per case. One possible explanation is that some hospitals may have a high proportion of long stay cases with low costs such as geriatric. Looking at the HRG-mix of the study hospitals for HRG PROP25 for the financial year 1994/95 (see Appendix I) this explanation does appear plausible, as a large percentage of the cases are under the HRG chapters nervous system, respiratory and urinary tract and male reproductive system which are likely to include a number of elderly long stay patients.

The models in Table 5.3 have no significant random coefficients. The intra-hospital correlations for the models are 82% (model A) and 75% (model B). This suggests that 82% and 75% of the "unexplained" variation in unit costs is explained by between hospital differences. In comparison the intra-hospital correlation for the crude length of stay (model A) in Table 5.2 was 66%. This suggests that crude LOS differences explain more variation than these simple indicators of diagnostic (HRG) mix.

The level 2 residuals or hospital 'effects' have been plotted for model B in Table 5.3 (see Figure 5.2). Here ten hospitals have an expected direct cost per case significantly different from the average of which five are study hospitals. Unlike all the model specifications in Chapter 4 hospital B does not have the highest expected cost per case, here hospital C does. However this is not an unexpected finding as the expected cost per case of hospital C in each of the high occupancy category models was consistently close to the expected cost of hospital B.

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	781(33.36)	784.2(31.96)
1991/92	-178.6(27.1)	-181.9(23.8)
1992/93	-80.56(23.21)	-87.34(20.86)
1993/94	-56.36(20.99)	64.99(17.96)
LGMTH	584.8(231.8)	295.9(59.68)
MSH	-23.89(150.6)	-31.11(38.91)
AOR	1.658(2.437)	0.5915(2.236)
CRUDE LOS	79.21(17.62)	78.96(17.33)
LGMTH*CRUDE LOS	126.6(35.05)	118.7(30.74)
MSH*CRUDE LOS	-0.9949(20.68)	12.88(20.85)
Random:		
Between hospitals: CONS/CONS	9979(3139)	9601(3002)
Between years: CONS/CONS	5026(820.8)	4828(936.9)
CRUDE LOS/CONS		942.5(384.4)
CRUDE LOS/CRUDE LOS		168.5(400)
-2(log-likelihood):	1203.51	1195.23

Table 5.2: Crude length of stay models

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	582(79.14)	541.1(74.24)
1991/92	-102.6(24.71)	-79.59(24.82)
1992/93	-17.16(22.77)	-21.99(23.43)
1993/94	-29.95(21.19)	-21.58(22.33)
LGMTH	268.1(97.02)	273.7(86.45)
MSH	-65.52(53.65)	-89.73(52.03)
AOR	9.385(2.556)	8.347(2.624)
HRG PROP10	17.89(15.3)	
HRG PROP25		-9.796(4.793)
LGMTH*HRG PROP10	-55.69(19.84)	
MSH*HRG PROP10	-13.8(19.82)	
1/DISCHARGES	7.95e+005(3.17e+005)	1.02e+006(3.09e+005)
Random:		
Between hospitals: CONS/CONS	2.50e+004(7318)	1.88e+004(5701)
Between years: CONS/CONS	5341(872.1)	6141(1001)
-2(log-likelihood):	1230.11	1233.93

Table 5.3: Comparison of models for HRG PROP10 and HRG PROP25

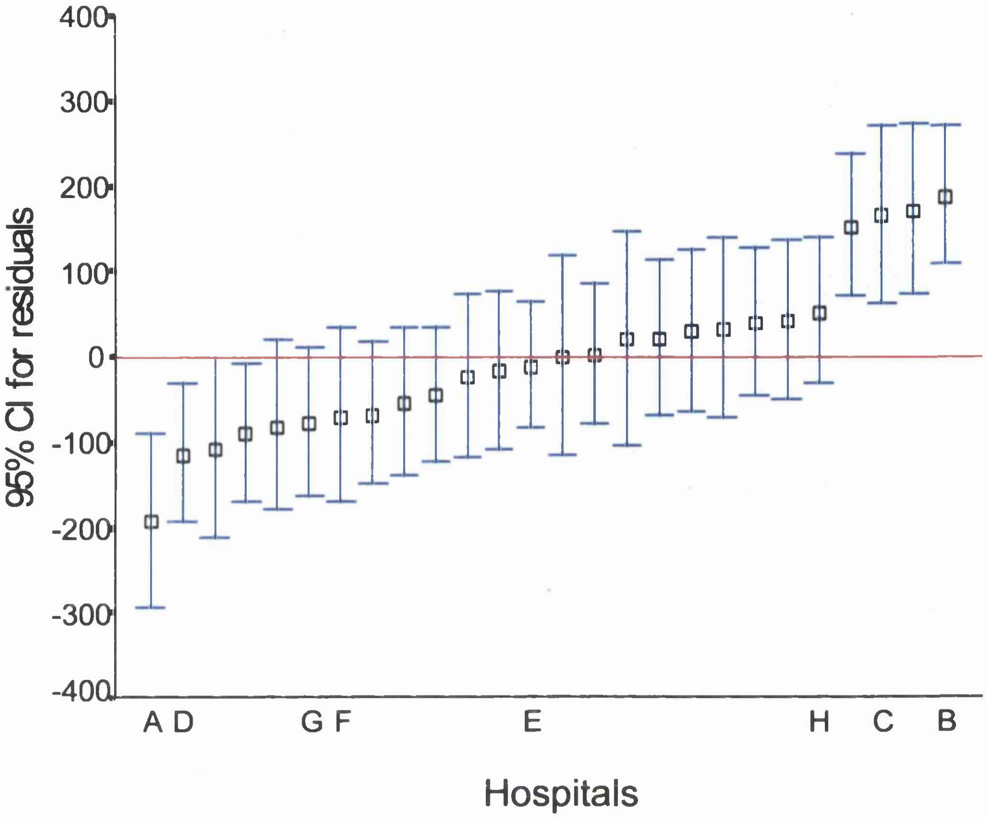

Figure 5.1: Hospital 'effects' for model B in Table 5.2

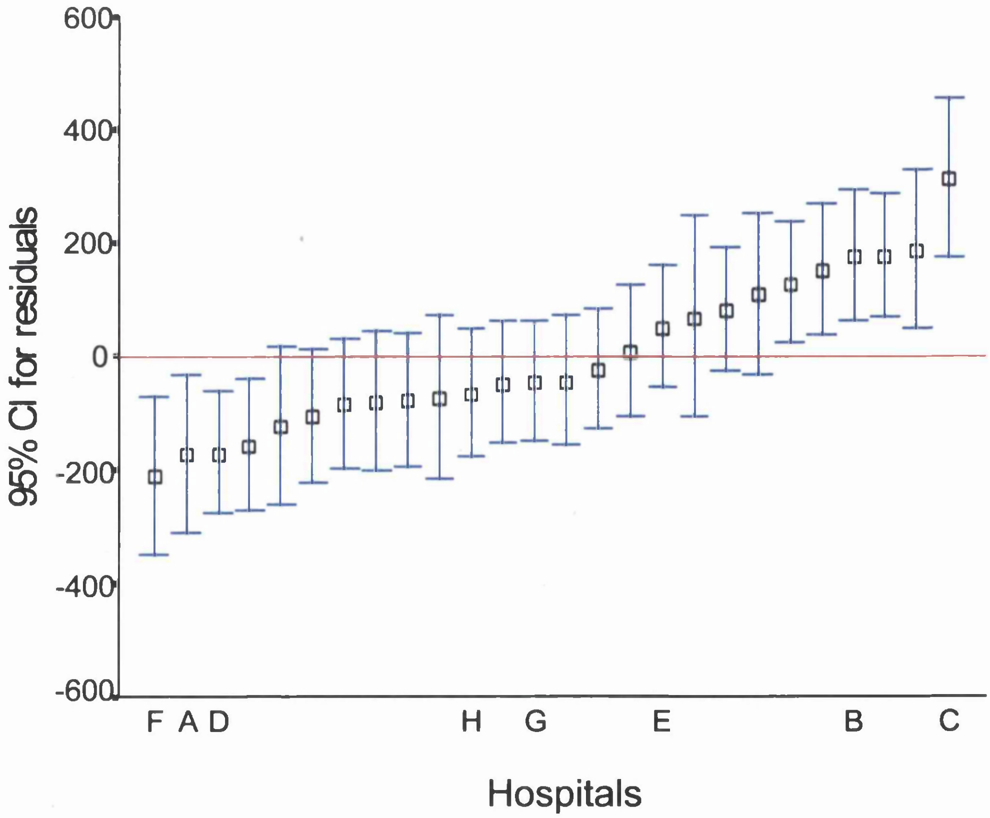

Figure 5. 2: Hospital 'effects' for model B in Table 5.3

Crude length of stay and the two new case-mix variables were also included within the same models (see Tables 5.4 and 5.5). Firstly, we concentrated on modelling only the fixed part of the model and compared models for the two case-mix variables (see Table 5. 4). Again PROP10 was not significant and will therefore be discarded from the rest of the analysis. PROP25 was nearly significant so further investigation was thought worthwhile. Furthermore, after adding LOS back into the model occupancy and the number of discharges were no longer significant. This suggests that crude length of stay has a greater effect on cost per case than either of theses two measures.

In Table 5.5 the random part of model B in Table 5.4 has been modelled. Two different models produced a significant reduction in the likelihood. In model A the variance and covariance of HRG PROP25 has been added to level 1. Adding these two terms produced a significant reduction in the –2 (log-likelihood) (joint chi square test =6.06, 2 degrees of freedom, p=0.048). If HRG PROP25 was assumed to be its mean (25.35%) then the intra-hospital correlation would be 0.8138. However if a hospital had a proportion 5% above the mean then its intra-hospital correlation would decrease to 0.7609.

Adding the variance and covariance of CRUDE LOS[1] and the dummy for large teaching hospitals to level 1 (see model B) produced a greater reduction in the likelihood (joint chi square test = 8.984, 3 degrees of freedom, p=0.029). If we compare this model to the model without HRG PROP25 (see model B, Table 5.2) most of the variable estimates are similar, although a 1 day increase in length of stay has increased from £78.96 to £93.32. This increase is perhaps compensating the negative estimate for HRG PROP25.

The hospital 'effects' of both models A and B have been plotted (see Figures 5.3 and 5.4). The expected cost per case of hospital C has remained higher than hospital B even after adding length of stay back into the model.

[1] Adding only the variance and covariance of CRUDE LOS did not produce a significant reduction in the –2(log-likelihood).

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	780.6(33.75)	788.8(34.14)
1991/92	-178.3(27.45)	-177.4(26.67)
1992/93	-80.22(23.81)	-86.81(23.07)
1993/94	-56.23(21.1)	-56.99(20.46)
LGMTH	300.3(61.5)	286(63.25)
MSH	-29.98(40.55)	-42.25(41.04)
AOR	1.65(2.438)	1.462(2.416)
HRG PROP10	0.4843(127.2)	
HRG PROP25		-6.401(3.896)
CRUDE LOS	78.93(18.05)	84.19(17.8)
LGMTH*CRUDE LOS	127.2(36.02)	118.9(34.46)
MSH*CRUDE LOS	-0.9287(20.67)	1.421(20.51)
Random:		
Between hospitals: CONS/CONS	9931(3125)	1.08e+004(3340)
Between years: CONS/CONS	5033(822)	4757(776.5)
-2(log-likelihood):	1203.51	1200.98

Table 5.4: Comparison of HRG PROP10 and HRG PROP25 length of stay models

Parameter	Estimate(s . e) Model A	Estimate(s . e) Model B
Fixed:		
CONSTANT	787.8(33.2)	799.9(31.59)
1991/92	-160.8(24.64)	-189.1(22.12)
1992/93	-75.18(21.72)	-104.2(18.58)
1993/94	-51.06(17.93)	-69.23(15.21)
LGMTH	273.8(62.89)	286.1(63.87)
MSH	-53.65(37.88)	-50.44(36.81)
AOR	1.788(2.144)	0.4085(2.088)
HRG PROP25	-4.85(4.114)	-8.626(3.703)
CRUDE LOS	95.01(17.52)	93.32(17.46)
LGMTH*CRUDE LOS	107.6(30.49)	116.3(34.48)
MSH*CRUDE LOS	-13.63(19.95)	18.45(20.79)
Random:		
Between hospitals: CONS/CONS	1.18e+004(3580)	1.12e+004(3411)
Between years: CONS/CONS	2699(659.9)	2809(665.3)
HRG PROP25/CONS	-256.7(142.3)	
HRG PROP25/HRG PROP25	143(62.79)	
CRUDE LOS/CONS		1132(430.5)
CRUDE LOS/CRUDE LOS		968.1(475)
LGMTH/CONS		1405(910.2)
-2(log-likelihood):	1194.85	1186.08

Table 5.5: Random coefficient models for HRG PROP25 and crude length of stay

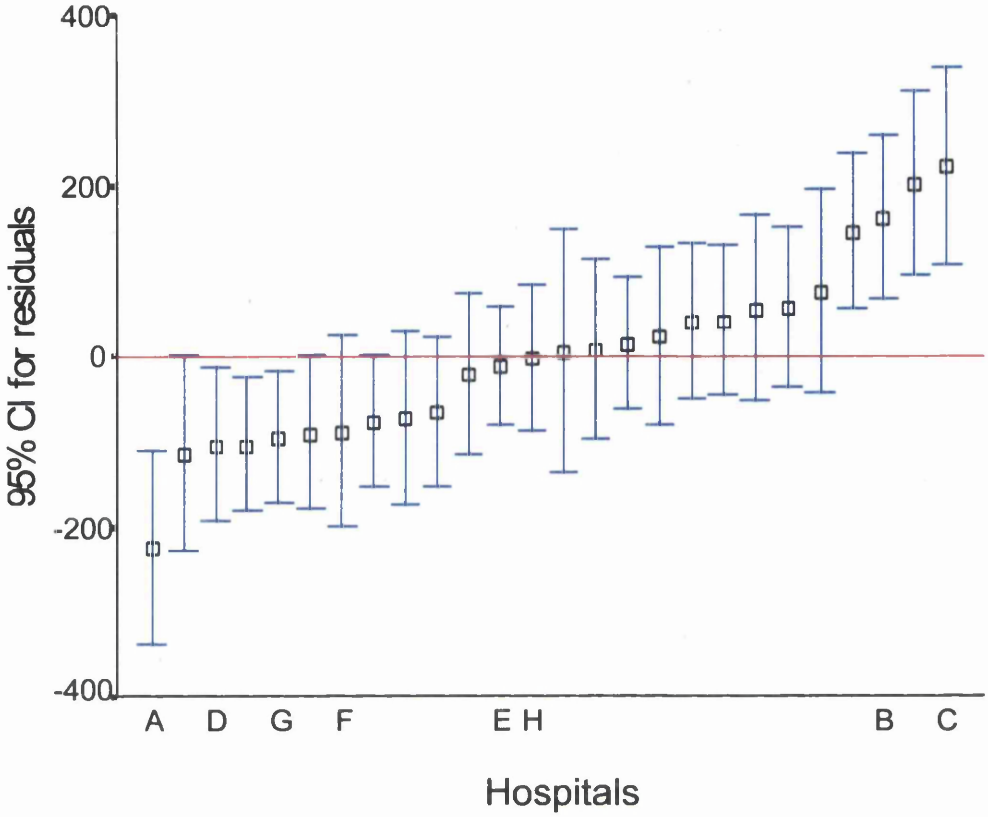

Figure 5.3: Hospital 'effects' for model A Table 5.5

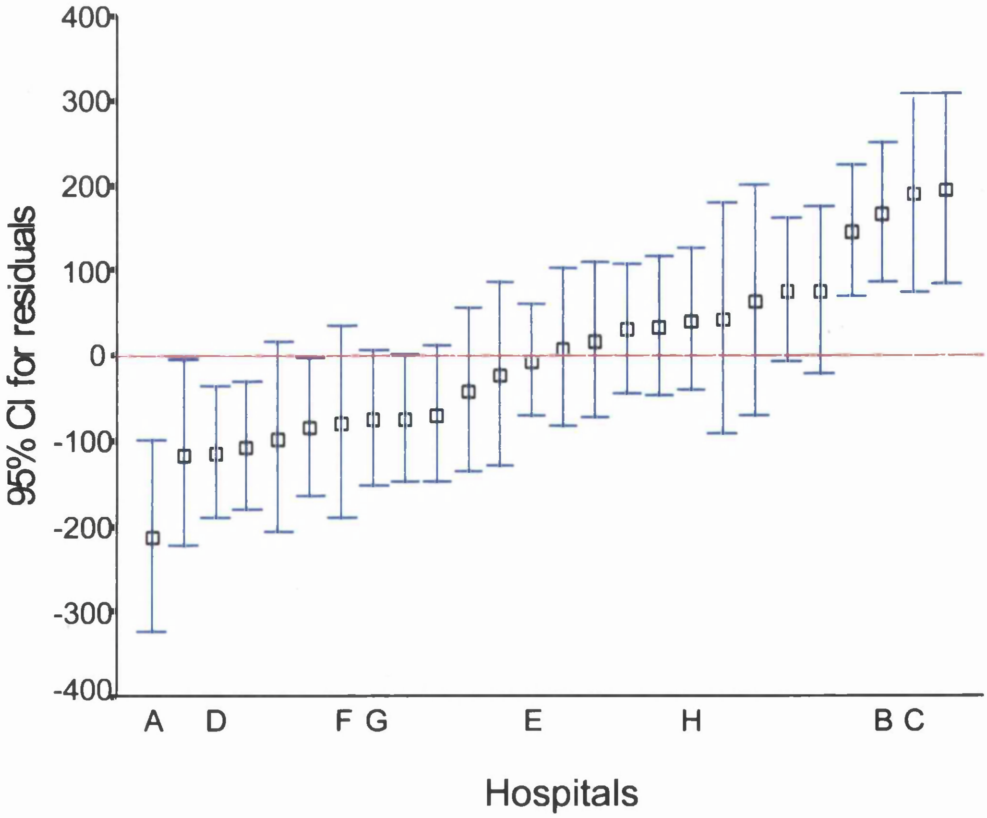

Figure 5.4: Hospital 'effects' for model B Table 5.5

5.4 Conclusions and discussion

The alternative adjustment for case-mix (HRG-mix) outlined in this chapter has also failed to explain more of the cost variation than the crude length of stay models. This could either be because the case-mix adjustment used is still too crude a measure or that the cost data have been poorly distributed across specialty and are therefore a poor reflection of the actual costs incurred by individual specialties. If the latter is true then it is questionable whether or not any other adjustment for case-mix within the context of this data would produce dissimilar results.

Ideally if information on the cost of individual cases or diagnoses had been available then case-mix adjusted costs could have instead been fitted to the model. In the future this may be possible as data is currently being collected from English hospitals to construct cost weights for HRGs, similar to those developed in the US for DRGs (Söderlund, 1994 and Söderlund et al, 1995). However some caution may be required in transferring these weights to Scottish data, since Finished Consultant Episodes (FCE) are used in England to describe patient care rather than specialty discharges (for greater discussion of this see section 6.3.2).

Relative cost weights such as these are usually derived from local cost data and the average cost of all episodes is generally given a weight of one. A DRG or HRG twice as costly as the average would therefore be given a weight of two and half as costly a weight of 0.5 and so on. The recommend method of obtaining these cost weights by the UK National Steering Group was to cost actual patient episodes and aggregate them up to obtain average estimates for each HRG. Söderlund (1994) identified potential problems with this method. One being that a bottom up approach such as this requires vast amounts of resource information collected over a long period of time before reliable estimates can be created. Consequently, Söderlund (1994) highlighted that because initial benefits would be limited hospitals may be discouraged from taking part.

Further, it could be argued that weights should be given to individual diagnoses rather than HRGs, as there is still likely to be considerable differences in costs between some diagnoses within HRG groups. However in practical terms the numbers would be too large and extremely hard to manage. This was one of the main reasons HRGs were adapted in the first place, to create smaller more manageable units of healthcare, which could be priced and cost.

Alternatively mortality rates or readmission rates could have been calculated from the linked SMR1 data set, to produce indicators of effectiveness or efficiency. Which may either determine differences in the service or the quality of care provide by hospitals or simply identify differences in the patient populations arriving at hospitals (such as age, severity). For example a hospital with a large number of readmission may have a shorter than average lengths of stay due to patients being discharged early and thus decreased average cost per case. This could be misleading, on the surface the hospital may look to be running efficiently when in actual fact they are providing a poor standard of care. On the other hand high mortality rates may reflect a sicker population or be an indication of patient severity. Hospitals with more severe or complex cases are likely to have higher mortality which could explain higher patient costs.

Chapter 6: Discussion and conclusions

6.1 Introduction

The analyses in this thesis have attempted to explain at least some of the wide variation in bed occupancy and patient costs seen across hospitals. It was found that an increase in bed occupancy did not necessarily equate to a decrease in average cost per case and that perhaps length of stay was a more influential determinant of both. However, the conclusions that can be drawn may be limited by doubts about the quality and validity of some of the available data. This chapter will firstly discuss the conclusions, which can be reached from Chapters 2-5 separately, and then any inferences which can be made from the research as a whole, along with recommendations for future work.

6.2 Daily variations in bed occupancy

The analysis in Chapter 2 has reinforced the argument that crude annual averages such as bed occupancy figures cannot alone reflect the efficient use of hospital resources. It was demonstrated that they fail to reflect daily, weekly and seasonal variations in demand, which in turn give no indication of the day to day pressures encountered by hospitals. Crude annual averages fail to take into consideration the amount of spare capacity required for the random arrival of emergency admissions or disruptions to the system, such as flu epidemics (Edwards and Werneke, 1994) and thus the resources and the number of appropriately skilled staff needed. Further, they ignore the natural differences in the case-mix and the diagnostic mix of hospitals that result from the different populations they serve. For example teaching hospitals traditionally have higher bed occupancy than non-teaching hospitals since they generally treat more complex cases which require longer stays. Perhaps the most important reason, however, is simply that bed occupancy can be a manifestation of longer lengths of stay rather than an increased number of admissions (or discharges).

6.2.1 Variation in bed occupancy by day of the week

The descriptive analysis attempted to investigate the feasibility of using short term trends in bed occupancy (such as day of the week and seasons) as a tool to aid the planning of elective admissions. The results suggested that this is possible since bed occupancy varied by day of the week, with an obvious decline at the weekend. The lower rates at the weekend (especially for the elective specialties) are, however, likely to also reflect the use of five day wards.

6.2.2 Seasonality of bed occupancy

The seasonal trend for bed occupancy was less clear: there was not a distinct pattern across hospitals for each specialty as there was for day of the week. Other than a higher rate between January and March for general medical wards each of the specialties appeared to have a dip in July and December. The decline in December was particularly sharp for the elective specialties. These lower rates in July and December are most likely to reflect holiday arrangements. Interviews from the larger study highlighted the observation that elective surgery in some hospitals can grind to a near halt for part of the summer as consultants and surgeons take concurrent leave. Pressure to stagger holidays, would ease the pressure in other periods or increase the number of patients who could be treated (providing of course there are available resources to match the increased activity). It is also probable, however that this decline is partly due to patients themselves preferring not to have routine surgery during the summer or over the festive season.

6.2.3 Elective, emergency and transfer admissions

Large differences in the elective/emergency/transfer ratio were found between the eight study hospitals even within the same specialty grouping, illustrating the uniqueness of each hospital (as well as each specialty). This finding further emphasises the importance of each hospital (or specialty) having internal management and monitoring systems to achieve efficient use of their own resources and time. For example, in a 'high' elective specialty such as ophthalmology where emergency admissions are likely to be minimal, introducing a five day ward may be a practical option, while this would not be sensible for a 'high' emergency specialty such as general medicine.

The marked differences between the proportions of elective, transfer and emergency admissions, especially in general medicine, may raise doubts about the ways in which these categories are recorded from one hospital to another, rather than actual large differences in admission type. This in turn raises the question of what constitutes an emergency or elective admission. This is a somewhat grey area; for example 10 percent of the medical inpatients in 1994/95 were recorded as having a length of stay of zero days. ISD's definition of an inpatient states that "an inpatient is a patient who occupies an available staffed bed in hospital and remains overnight. A mother who delivers in hospital and a patient who is admitted as an emergency are also regarded as inpatients regardless of how long they stay" (ISD, 1991-1996). However further investigation of discharges recorded as having a stay of zero, showed that 17.5 percent were not admitted as an emergency. It appears likely that some hospitals may be recording day cases discharges wrongly as inpatients (or emergencies as elective or transferred).

6.2.4 Bed occupancy and emergency admissions

For the eight study hospitals there appeared to be some relationship between the number of emergency admissions and bed occupancy for general medical beds. Hospitals with larger numbers of emergency admissions tended to have a higher average rate of bed occupancy. In a previous study, Kendrick et al (1997) found the number of emergency admissions in Scotland generally to be higher from January to March. In this study a similar pattern was found for bed occupancy.

6.2.5 Periods of pressure

The descriptive analyses of daily occupancy rates revealed the wide daily fluctuations disguised by annual occupancy rates, with levels frequently in excess of 100%, providing some insight into the implications of different annual occupancy rates. Hospitals in the study with average occupancy approaching 90% (such as G and H) are obviously under stress, which suggests that it would at most take a 10%

increase in average occupancy for most of the other hospitals to be under similar strain. This indicates an upper limit which a hospital cannot exceed without detriment to the effectiveness of its staff and the quality of care its patients receive. Chapter 2 provided some evidence that bed borrowing was (is) common practice in all of the study hospitals (Figures 2.18 and 2.19). This is likely to be the case in the majority of other acute Scottish hospitals. Although the practice of boarding patients in the beds of other specialties provides a solution when a patient needs to be admitted, it can have adverse implications on the quality of care that is given. For example, the ward where the patient has been boarded may not be equipped with the necessary resources and staff to cope with individual needs. Bed borrowing can be impractical from the point of ward rounds, as unnecessary amounts of medical staff time can be consumed chasing round hospitals to see patients. This can result in patients being overlooked. These problems are also likely to have financial consequences.

The pressure on beds is likely to be greater than that described in Chapter 2, since it only takes account of inpatients. In practice inpatient beds are often used for day cases and many hospitals operate five day wards, such that the amount of spare capacity available has probably been overestimated in at least some hospitals. Bed occupancy calculations do not take turnover intervals between patients in to consideration. A better indicator would include the time recorded between one patient and another, although such information would be difficult to obtain in practice.

A further consideration is that a hospital or specialty is unlikely to be able to utilise all its spare capacity for two reasons. Firstly, they may not have the available resources and secondly because of the separate provision needed for female, male and child admissions (Yates, 1982). Pooling beds between genders could provide a partial solution. There is also the added problem of 'Bed Blockers'[1] who obstruct the use of beds for their intended purpose (Coid and Crome, 1986). For example, a study

[1] The generally accepted definition of a 'Bed Blocker' is someone who has been in hospital for more than a month and of whom medical and nursing staff agree is no longer in need of such medical attention (Rubin and Davis, 1975).

of Edinburgh hospitals found that approximately 13% of acute general medical beds there blocked (Namdaran, Burnet and Munroe, 1992).

Finally, the number of (available) average staffed beds was also a very crude estimate taken from *Scottish Health Services Costs*, which assumed that each specialty within each hospital had the same number of beds on each day of the year. This is obviously not the case in practice. High elective specialties such as ENT and gynaecology frequently have beds released to general medicine during periods of high demand, especially in the winter. Some elective specialties are also likely to have wards closed at weekends or holidays.

6.3 Healthcare resource groups

The application of Healthcare resource groups (HRGs) and the necessity of taking account of case-mix when comparing hospital activity or performance was illustrated in Chapter 3. It was shown, first, that wide variations in HRG-mix existed among the eight study hospitals even within the same specialty grouping. Secondly, the effect of case-mix on length of stay and thus the perceived efficiency of a hospital was demonstrated by comparing crude and HRG adjusted length of stay scores for all 26 hospitals over the five year time period.

6.3.1 Crude and HRG adjusted lengths of stay

There were large variations both over time and between the crude and HRG adjusted LOS scores for a number of the hospitals. While variation between the crude and HRG adjusted LOS emphasised the need to adjust for case-mix, differences from one year to the next may instead relate to change in bed management practices or clinical protocols during the five years of the study period. Understanding differences in the type and number of patients treated between and within hospitals is one of the first steps in improving resource management.

It is also important to remember that, while adjusting for case-mix is essential, variations in length of stay (or bed occupancy) cannot be explained by differences in case-mix (or in this case HRG-mix) alone. Bed management practices and clinical preferences, as well as access to community and social work services can all affect length of stay. A lack of theatre space, the availability of diagnostic facilities, the timing of ward rounds and inadequate support from community and social work services can all delay discharge, resulting in increased length of stay. It has also been known for staff themselves to keep patients longer than necessary in order to save beds for planned admissions (Yates, 1982).

6.3.2 Limitations and weaknesses

Like any other currently available case-mix tool, HRGs are not without limitations or weaknesses. Their usefulness is dependent on the accuracy of the data provided. Comparisons across organisations may also be limited, because the interpretation of an episode of care can differ from one hospital to the next. This is especially a problem within England and Wales when Finished Consultant Episodes (FCE)[2] are used (NCMO, 1997a). This, is unlikely to be a problem within Scotland, where a separate discharge summary (form SMR1) is completed for every transfer between specialties whether internal or external.

A further criticism, is that the element of severity included in the HRG grouping system[3], does not provide a satisfactory adjustment for patient severity. The reason one hospital is more costly than another, may simply be that they treat more severely ill patients within each HRG grouping. This was also a concern with the use of DRGs in the United States. Methods for measuring the severity of illness such as the Severity of Illness Index and Disease Staging were adopted. The Severity of Illness Index described by Horn, Sharkey and Bertram (1983) would not have been suitable for this study since it requires information that is not routinely available in the UK such as the level of patient dependency and the rate of response to therapy (Söderlund, 1994). On the other hand the information required for Disease Staging can be derived from NHS data (McKee and Petticrew, 1993). Studies comparing DRGs to Disease Staging, have found little empirical evidence to support using

[2] There is little agreement on the interpretation of a FCE. In one hospital an admission to A&E, then a transfer to a medical ward would be counted as two FCEs, while another hospital would count internal transfers as part of the same FCE.

Disease Staging instead of DRGs except for the case of a few diagnostic categories (Söderlund, 1994). Disease staging has been found to explain less of the variation in costs than DRGs (Calore and Iezzoni, 1987). This is not surprising, because the cost of treatments received by more severely ill patients is not always greater (Calore and Iezzoni, 1987). For example, a patient in the advance stages of lung cancer may receive only fairly inexpensive palliative care such as pain control, while a patient with early breast cancer may receive more expensive treatments such as chemotherapy, radiotherapy and surgery.

Although HRGs are unable to reflect the true severity of patients within a specialty, they are still a better representation of the workload carried out within the NHS than any of the alternative methods. HRGs are continually under development, so it is likely that the degree to which they reflect severity will improve along with the internal homogeneity of HRG groups.

6.3.3 Potential problems

Many problems with DRGs were experienced in the US within the Medicare system. DRGs were used to reimburse hospitals at an average rate. Hospitals with more severely ill patients thus received less money than the cost of their patients. This led to specially severe patients being referred elsewhere by some hospitals, with other patients being diagnosed and even treated as if they were more severely ill in order to place them in a DRG which was reimbursed at a higher rate (Sanderson et al, 1986). This phenomenon has become known as a "DRG-creep" (Carter, Newhouse and Relles, 1990). If HRGs were to be used in similar ways in Britain, these practices may also become a problem; even the use of HRGs in "costing for contracts" may produce similar problems. If HRGs are to be a useful tool for aiding the contracting process then it is important that information on discharge records are recorded accurately: otherwise, the costing of HRGs will not reflect actual resource use and contracts will fail to reflect the needs of the population served by the hospital or Trust. This however, may prove to be less important following the abolition of the

[3] The HRG grouping method provides some degree of adjustment for severity, by currently including 120 diagnose categories which have a HRG for both with and without complications and/or comorbidities.

internal market announced in the recent white paper "Designed to Care: Renewing the National Health Service in Scotland" (Scottish Office Department of Health: Edinburgh, 1997).

6.4 Econometric analysis of bed occupancy and specialty costs

In Chapter 4 a multilevel regression analysis was undertaken in order to explore the relationships between cost per case, bed occupancy and length of stay, taking account of known influences such as teaching status and case-mix for 26 Scottish hospitals between 1991/92 – 1995/96. A separate analysis was carried out for both total and direct cost per case. It was anticipated that an increase in bed occupancy and a decrease in length of stay, would likely decrease cost per case if all other factors such as case-mix were equal. The following sections go on to discuss the associations found within the cost models.

6.4.1 Trends 1991-1996

There was relatively little change in the average bed occupancy of acute specialties in Scottish hospitals between 1975/76 and 1991/92 (Munro, 1994). This pattern has continued for the period 1991/92 to 1995/96 (Chapter 4). Instead change has occurred in the length of stay, number of staffed beds and the number of patients. This suggests that pressure on beds is dealt with by shortening lengths of stay rather than increasing bed occupancy and that length of stay is a better indicator of efficiency and thus a more suitable target variable. It should not be forgotten, however, that comparisons of crude lengths of stay can also be misleading (Tables 3.4 and 3.5).

Although length of stay has decreased for both the 'high' and 'low' occupancy groupings average cost per case has increased for the latter. This may be because length of stay in the 'low' occupancy specialties has decreased to a point where patients are only staying in hospital for the most costly part of their treatment. Furthermore, the increasing tendency towards day case treatments removes those inpatient cases with the shortest lengths of stay. During the five year time period real cost per case fell by 11.1% for the high occupancy category and rose by 6.8% for the low category[4].

6.4.2 Relationship between cost per case and bed occupancy

The initial objective of the econometric study in Chapter 4 was to examine the relationship between bed occupancy and costs and the implications of different average occupancy rates for the cost per case of acute hospitals in Scotland, for the two distinct specialty groupings. In general, only a weak relationship was found between occupancy and cost per case, and in some versions of the model, the association was not negative as expected. This association was particularly weak for the high occupancy group, indicating that once a certain level of occupancy is reached there is little room for manoeuvre without additional resources. With everything else remaining equal, cost per case will thus remain constant. The slight positive association found in some of the models for the high occupancy specialty is probably a reflection of the additional staff and beds required when the average occupancy of a hospital exceeds this 'optimum' level. This observation would also explain why the relationship between occupancy and costs was seen to be stronger in the lower occupancy grouping, since the potential to increase bed occupancy without added costs is much greater.

It should also be noted that for the lower occupancy specialty group the direction of the association between occupancy and direct costs was dependent on hospital type. One possible reason might be that, as well as teaching hospitals having a more complex case-mix, they treat more severely ill patients within HRG groupings thus resulting in a higher average cost per case.

6.4.3 Relationship between cost per case and length of stay

In general, length of stay – regardless of whether or not it was adjusted for case-mix – had a positive and significant effect on cost per case for both the high and low occupancy specialty group. After adjusting for HRG-mix this association became

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[4] Real cost per case was derived using the Pay and Prices Index for hospitals and community services (Department of Health, 1995).

weaker. This is not surprising, since obviously part of the variation in costs among hospitals can be explained by differences in length of stay due to case-mix differences. However, the –2 log (likelihood) was lower for the unadjusted length of stay models, suggesting better model fit and that perhaps adjusting length of stay for HRG-mix was not a adequate adjustment for case-mix. The alternative approach illustrated in Chapter 5 (see also section 6.5), produced similar results.

6.4.4 Relationship between cost per case and teaching status

Teaching hospitals tended to have a higher cost per case even after bed occupancy and length of stay were accounted for. This was still the case after adjusting for case-mix (in the form of HRGs) as found in previous studies. The available data meant that it was not possible to determine why this should be the case, although it is likely that indirect costs of medical training and/or teaching hospitals having a more severely ill patient mix within HRGs are contributing factors. Goldfarb and Coffey (1987) suggested that the higher cost of teaching hospitals could simply be that they consume more resources to treat "medically similar patients" and are more likely to use more expensive treatments.

6.4.5 Cost variation

Although in general the teaching hospitals in the study had a higher cost per case, the variation in cost per case was greatest among the mixed specialist hospitals, for the lower occupancy grouping. However, this may simply be due to the way this grouping was combined (see section 6.6.3). The hospitals which had an average cost per case above or below the Scottish average appeared to differ for each specification of the cost model, although one hospital (hospital B) consistently had the highest average cost per case. However, it should be noted that for the alternative cost models in Chapter 5 hospital C had the highest average cost per case.

However, correlations of the hospital residuals showed strong associations for all cost models within each specialty grouping regardless of which length of stay score or cost category was specified (Table 4.15). Across specialties the relationship was weaker, although still significant for the total cost models. The lack of association between the direct costs of the two specialty groupings may reflect variation in the type and amount of resources consumed by each or more simply that the proportion of direct costs that make up the total costs are determined differently from one specialty to another.

6.5 Alternative adjustment of HRG-mix

In the econometric analysis in Chapter 4 it was found that the unadjusted length of stay explain the cost variation across hospitals better than the HRG-adjusted length of stay. It was therefore decided to try and add a separate case-mix indicator to the cost models (see Chapter 5). This was done by calculating the proportion of discharges within each hospital which fell within HRGs with the longest average lengths of stay within Scotland. Two separate variables were tested representing 10% and 25% of HRGs with the longest lengths of stay. The relationship between cost per case and the 10% and 25% HRG proportions were found to be different. For 10% the association was dependent on hospital type. Costs decreased with a higher proportion of cases with longer lengths of stay for teaching hospitals and increased for hospitals with little or no teaching. While for 25% the relationship for all hospital was the same as teaching hospitals in the 10% category. These negative associations at first seemed surprising as it would be expected that hospitals with a greater proportion of cases within HRGs with longer lengths of stay would have higher average cost per case. However, further investigation revealed that a large proportion were probably elderly long stay cases (see section 5.3 and Appendix I).

The other key results were similar to the HRG adjusted model and the addition of the separate case-mix variable still failed to explain the variation in costs better than the unadjusted length of stay. It is therefore, unlikely that any adjustment for case-mix without being able to also standardised costs will produce dissimilar results.

6.6 Methodology and data quality

6.6.1 Appropriateness of multilevel analysis

In the introduction reasons for employing a multilevel analysis over traditional regression techniques were briefly discussed (section 1.5.5). The need for these methods were emphasised by the results of the econometric analysis as discussed below.

First, the data were unbalanced which many traditional repeated measures techniques would have failed to cope with. Secondly, the intra-hospital correlation (i.e. between hospital variance) for each of the cost models was considerably greater than zero indicating that a single level approach such as OLS would have been inapplicable. Irrespective of the intra-hospital correlation, however, nothing is lost from analysing the data within a multilevel structure because an intra-hospital correlation of zero produces a model equivalent to an OLS model. Third, the assumptions of constant level 1 variance and independence required for OLS regression do not hold. For example, for model B in Table 4.5 the proportion of the variation in the expected cost per case attributable to year-on-year inter-hospital differences, increased as mean length of stay increased. Within a multilevel analysis, interest lies with such 'variance heterogeneity' – modelling it explicitly – instead of attempting to eliminate it through procedures such as 'variance stabilising' transformations (Goldstein, 1987). Last, if conventional single level methods had been used, the statistical significance of the explanatory variables included within the model would have been overestimated due to ignoring the hierarchy and so violating assumptions of independence (see, for example, Goldstein, 1995).

Within the multilevel repeated measures model the hospitals were modelled using random effects. Alternatively the hospitals in the sample could have been modelled using fixed effects. The benefit of treating higher level unit as fixed or random effects has been discussed in literature on Panel data (for instance, see Hsiao, 1996). In the case of the data in this study fitting a separate fixed effect for each hospital would have produced less reliable estimates because of considerable loss of degrees of freedom resulting from adding an additional parameter to the model for each hospital. A fixed effects approach only allows inferences to be made for each hospital separately, whereas treating the hospitals as random effects allows variation between hospitals to be explored. More exact estimates are produced if the hospitals are treated as random effects, because data from all hospitals within the sample are utilised when generating the estimates for each hospital. Goldstein (1995) has emphasised the importance of using this approach when analysing repeated measures data where there are few level 1 units for each level 2 unit.

Translog cost functions and data envelopment analysis (DEA) were identified as possible alternative methods (section 1.5). Scott and Parkin (1995) used translog cost functions in an analysis of the same data as this study (although only for financial year 1992/93) and concluded that this was probably not an appropriate method and suggested that non-parametric techniques such as DEA should be explored. Hollingsworth and Parkin (1995) used DEA on the same data, suggesting that DEA would have been a suitable tool if interested in comparing the relative efficiency of one hospital with another. However, DEA could not have answered the questions posed in this study, because interest lay primarily with attempts to explain the large variation in unit costs.

It should, be noted that although multilevel analysis has many methodological advantages in this context, limitations of the available data, meant that the explanatory variables were still added to the model in an *"ad hoc"* manner and so that interpretation of the relationships described may still be ambiguous. For example, there is no *a priori* reason why the relationship between bed occupancy, length of stay and unit costs should differ from one specialty to the next. It is not possible to tell whether the positive and negative relationships between bed occupancy and unit costs derive from increased admissions or longer stays.

6.6.2 Multicollinearity

The unstable nature of some of the estimates suggests that multicollinearity might have been an underlying problem in the data. Before the analysis was carried out the potential for multicollinearity was reduced by not including highly correlated variables together in the model. Although the other variables did not appear to be highly correlated many still produced statistically significant correlation coefficients (that is, $p<0.05$) using Pearson's correlation test (see Appendix H). A further test for multicollinearity is the deletion of observations from the data set. If multicollinearity was not present it would be expected that the size and direction of the estimates would remain stable. However, this was not the case when the models in Table 4.5 were repeated with only four years data, estimates for some of the variables changed significantly (see Table 5.2).

6.6.3 Small sample size

It may not have been appropriate to group together ENT, gynaecology and ophthalmology because of their differences in admission types (see Figures 2.15-2.17). If a hospital only had two out of the three specialties (such as hospitals E and H, which do not have an ophthalmology department), then average occupancy or cost per case may be higher or lower than other hospitals simply for this reason. This decision was a trade–off between uniformity and sample size which was already small because of the relatively few acute hospitals in Scotland with a reasonably large bed complement in each specialty group.

6.6.4 Validity of data

The variability of the results in the cost analyses (such as the changeable direction of bed occupancy) suggests that some of the problems encountered in other cost studies are also evident here. This may indicate that it is the usefulness of the available cost data which is questionable rather than the methods that were used. Scott and Parkin (1995) have also questioned the appropriateness of *Scottish Health Services Cost* data since it may just be an artefact of accounting procedures – a balancing of the books exercise – rather than a random process. There was no way of investigating how hospitals distributed their annual expenditures or whether each hospital attributes the cost of the same facilities and resources to the same cost categories (as divided in *Scottish Health Services Costs*). If cost data were collected directly from the hospitals, then more reliable estimates could be produced.

It would have also been helpful if direct costs had been broken down into their sub-components for the full five year period, so that the effects of nursing staff, theatre and laboratory costs on bed occupancy and vice versa could have been investigated.

6.6.5 Case-mix adjustment

In this thesis two difference case-mix adjusters were added to the cost models and both failed to explain costs better than crude length of stay. There are several possible explanations for this. Firstly, that length of stay is the main driving force behind unit costs and that perhaps unadjusted length of stay is acting as a proxy for case-mix. For the medical specialties this may be the case, although this is unlike for the elective specialties where the range for length of stay is very small (for time period 2-4.5 days). Secondly, the case-mix adjustments used may still be too crude a measure. To make a true adjustment for case-mix both sides of the equation need to be standardised (i.e. unit costs as well as length of stay), which was not possible here (see Chapter 5). Thirdly, costs may be poorly distributed across specialties and therefore be a poor reflection of actual resource use. For instance how accurately is the cost of theatre or laboratory use divided among specialties. Concerns about the validity of the data have also been discussed in 6.6.4. Furthermore if the latter is true then it is questionable whether any adjustment for case-mix within the context of this data would explain the cost variation better than length of stay.

6.7 Conclusions and future recommendations

The first obvious conclusion is that annual bed occupancy rates do not, or do not necessarily reflect or indicate efficient hospital resource use and are not a useful way of making comparisons between hospitals. Better measures of efficiency need to be found, although more accurate patient-focussed data are required first. On the other hand, there is some use for daily bed occupancy rates at a local level. They can be useful internally within a trust or hospital as a way of monitoring bed use to enable more effective management of beds.

It was also apparent from the econometric study that bed occupancy is not a suitable target variable for reducing unit costs (at most a probable 1% increase would reduce cost per case by £5). One reason is that desired levels of bed occupancy can be achieved in two different ways: either by increasing admissions or by treating more severely ill patients with longer lengths of stay. Both of which will inevitably affect average cost per case differently. There was some evidence from the analyses carried out in Chapters 2 and 4 that there may be an upper level of bed occupancy which cannot be exceeded without additional resources and manpower (thus resulting in increased cost per case).

As in other analyses of hospital costs, doubts about the quality of the available data have undermined attempts to explain variations in unit costs across hospitals. If better cost data are not created in the future, unreliable estimates will continue to be produced no matter how sophisticated the methods of analysis become. The models that are constructed can only be as good as or as accurate as the data they employ.

In summary, as expected, considerable differences existed between the two specialty groupings, in the type, cost and length of stay of their admissions. In the lower occupancy 'elective' specialties there appeared to be some scope for reducing bed numbers to improve efficiency. For the higher occupancy, medical specialties, many hospitals appeared to be already working to their limits, frequently having to borrow beds from other specialties in order to cope with the demand for their beds. Despite these differences there was evidence that hospitals which were over-or under-performing in one specialty group behaved similarly for the other group. This suggests, that in order to improve efficiency, hospital or trust wide policies are also needed.

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Appendices

Appendix A: Functional classification of 26 hospitals

Hospital	Hospital type
A	Large general major teaching hospital
B	General hospital with some teaching units
C	Large general major teaching hospital
D	Mixed specialist hospitals with maternity
E	General hospital with some teaching units
F	Large general major teaching hospital
G	General hospital with some teaching units
H	Mixed specialist hospitals without maternity
1	Mixed specialist hospitals without maternity
2	Mixed specialist hospitals without maternity
3	General hospital with some teaching units
4	Mixed specialist hospitals with maternity
5	General hospital with some teaching units
6	Mixed specialist hospitals with maternity
7	General hospital with some teaching units
8	Mixed specialist hospitals without maternity
9	General hospital with some teaching units
10	General hospital with some teaching units
11	Large general major teaching hospital
12	General hospital with some teaching units
13	General hospital with some teaching units
14	Mixed specialist hospitals without maternity
15	Mixed specialist hospitals with maternity
16	Large general major teaching hospital
17	Mixed specialist hospitals with maternity
18	General hospital with some teaching units

Appendix B: General description of functional classification

	Hospital description
01	Large general major teaching hospital covering a full range of services (other than maternity in some cases) and with special units.
02	General hospital with some teaching units but not necessarily wholly teaching.
03	Hospitals providing some local general services but excluding a high proportion of highly specialised units.
04	Small general hospitals with some specialist staff including a surgical unit. No maternity.
05	Small general hospitals with some specialist staff including a surgical unit but with maternity.
06	General non-teaching hospitals but not covering a full range of work within the main specialties.
07	Large teaching hospital for children covering full range of medicine and surgery.
08	General practitioner cottage hospitals with no maternity units and limited surgery done either by general practitioner or visiting consultant. Centres for consulting clinics.
09	General practitioner cottage hospitals with maternity units and limited surgery done either by general practitioner or visiting consultant. Centres for consulting clinics.
10	General practitioner cottage hospitals with maternity units and visiting consultant clinics but with a surgery of any kind.
11	Mixed specialist hospitals with maternity. No special units. Consultant type surgery undertaken.
12	Mixed specialist hospitals without maternity units. No special units. Consultant type surgery undertaken.
13	Hospitals with medical and/or surgical units but with a large chronic sick element.
14	Special orthopaedic units with active surgery. Adults and children.
15	Consultant staffed units in which surgery and accident work predominate.
16	Totally geriatric with assessment units. High geriatrician activity.
17	Long stay geriatric units controlled by geriatrician. May be with or without young chronic sick but no major assessment unit.
18	General practitioner hospitals with some long stay cases. No maternity or surgery.
19	General practitioner staffed small long stay units with small turnover. No assessment units.
20	Long stay geriatric units.
21	Consultant staffed general medical and geriatric units.
22	Major teaching maternity units covering the full range of maternity work.
23	Non-teaching maternity units. Consultant controlled and taking mainly normal midwifery.

	Hospital description
24	General practitioner maternity units doing normal midwifery only. Visiting consultant on request.
25	Non-teaching and non-GP maternity units with operating facilities. Not confined to normal midwifery.
26	Units for gynaecology only.
27	Large ex-ID hospitals still having major interest in ID having at least some other variable non-surgical acute activity.
28	ID hospitals with other special acute activities including a surgical one.
29	Hospital still dealing essentially with medical tuberculosis and other chest cases. No thoracic surgery.
30	Units for fever and tuberculosis only.
31	Recovery units for early pre-convalescence.
32	Convalescent units adults only.
33	Convalescent units without any special activity. Children only.
34	Mental hospitals with major teaching or research units giving a full range of treatment.
35	Non-teaching mental hospitals giving a full range of treatment.
36	Mental hospitals wholly or largely providing for amenity or private patients.
37	Mental units of small nursing home type.
38	Mental handicap units. Children only.
39	Mental handicap units providing full range of service. Adults only.
40	Mental handicap units providing full range of services. Mixed adults and children.
41	Large teaching specialist hospitals.
42	Small non-teaching specialist hospitals.
43	Dental hospitals.
44	Miscellaneous hospitals which by function are not individually comparable with any other unit and where costs would not be expected to run parallel with any other hospital in the full list.
45	Hospitals subject to cost but not open during the year and hospitals open for part of the year only.
46	Day hospitals.
47	Limb fitting and appliance centres.
48	Hospital clinics.
49	Mass radiography units.

Appendix C: Scottish Morbidity Record 1 (SMR1) form

isd | Information & Statistics Division
National Health Service in Scotland

Medical In Confidence
Inpatient/Day Case Record

Coppish SMR 01
I/A/D/C

Patient Identification

Hospital

Health Records System ID

Patient Identifier

Coppish SMR Episode Record Key

Surname

First Forename

Second Forename

Previous Surname

Date of Birth

Sex (Gender)

Marital Status

Central Index (CI)/CHI Number

NHS Number

Alternative Case Ref. Number

Patient's Address

Postcode

Ethnic Group

GP Practice Code

GMC No. of Referring GP/GDP/Consultant

Episode Management

Spell/ Care Package ID

Location/ Hospital

Admission Date

Specialty/ Discipline

Admission Type

Significant Facility

Admission Reason

Clinical Facility Start

Admission /Transfer From

Consultant/HCP Responsible for Care

Admission /Transfer From — Location

Management of Patient

GP Referral Letter Number

Patient Category

Waiting List Guarantee Exception Code

Waiting List Date

Waiting List Type

Contract Identifier: Provider, Purchaser, Contract Serial Number, Contract Service Number, Iso Resource Group, Invoice Number, Invoice Line

Contract Charge

General Clinical

Main Condition/ Principal Diagnosis/ Problem Managed - ICD 10

Other Condition/ Comorbidity/ Complication - ICD 10 - 2

Other Condition/ Comorbidity/ Complication - ICD 10 - 3

Other Condition/ Comorbidity/ Complication - ICD 10 - 4

Other Condition/ Comorbidity/ Complication - ICD 10 - 5

Other Condition/ Comorbidity/ Complication - ICD 10 - 6

Discharge Data

Ready for Discharge Date

Clinical Facility End

Discharge Date

Discharge Type

Discharge/Transfer To

Discharge/Transfer To — Location

Operation/Procedure

Main Operation/Procedure

Date Main Operation

Clinician Responsible

Other Operation/Procedure (OPP2)

Date (OPP2)

Clinician Responsible (2)

Other Operation/Procedure (OPP3)

Date (OPP3)

Clinician Responsible (3)

Other Operation/Procedure (OPP4)

Date (OPP4)

Clinician Responsible (4)

Development data

Chronic Sick/Disabled

Clinical Problem of Spell/Care Package

Lifestyle Risk Factors 1 — 2

Outcome Measures 1 — 2

Dependency/Severity Measures 1 — 2

1/96

Appendix D1: Details of Scottish Health Service cost categories post 1993/1994

Direct Costs

Medical and Dental	Medical and Dental staff
Nursing	Nursing staff
Pharmacy	Pharmacy staff and direct supplies i.e. drugs, dressings, instruments and sundries.
PAM	PAM staff directly involved in patient direct care and direct supplies i.e. radiography, physiotherapy, occupational therapy, chiropody, paramedical equipment purchase, rental and repair
Other Direct Care	Other direct care staff and supplies i.e. surgical appliances, medical/surgical equipment purchase, rental and repair.
Theatre	Theatre staff and theatre supplies
Laboratories	Laboratory costs are likely to emanate from a trading account which will include the costs of direct staff and supplies and allocated costs such premises costs, heat, light and depreciation.
Allocated Costs	All other costs not included as direct costs i.e. Administration Nurse teaching Catering – patients and staff Bedding and linen Patients Clothing Uniforms Laundry Portering Residences Waste Disposal Transport and Travel Property maintenance Cleaning Heating Rent and Rates Furniture and other equipment purchase, rental and repairs Depreciation Notional interest Miscellaneous Income – catering and other

Appendix D2: Details of Scottish Health Service cost categories pre 1993/1994

Direct Patient Care

Medical and dental staff
Nursing staff
Professional and technical staff (PAMs)
Pharmacy staff
Other direct care staff
Medical and surgical etc. equipment
    purchase and rental (not on capital charges)
    repair
Surgical appliances
Mental patients allowances

Hotel Services

Catering – patients
Linen services
Cleaning
Portering

Property Costs

Maintenance (buildings, engineering and grounds)
Heat, light and power
Rent and rates

Running Expenses

Administration (medical, nursing, general and agency)
Catering – staff
General Services
Nurse teaching
Residences
Transport and travel staff
Uniforms
Furniture etc.
    Purchase and rental (not on capital charge)
    Repair
Direct credits

Capital Charges

Depreciation and interest

Appendix E: Summary statistics for daily occupancy rates

Hospital	Mean	Standard Deviation	Minimum	Maximum	Percentiles	
					5th	95th
A	76.45	6.84	55.11	98.01	66.42	88.12
B	77.63	8.10	54.49	95.19	63.88	90.06
C	80.21	7.34	51.69	98.12	67.86	91.99
D	81.82	9.58	44.71	110.00	63.71	95.71
E	82.22	9.22	61.42	104.32	67.06	95.99
F	83.37	7.38	56.72	102.99	72.21	95.77
G	87.28	11.17	56.45	116.53	67.98	105.24
H	90.43	8.36	56.67	114.44	76.11	103.33
1	74.64	10.09	42.97	92.97	55.70	88.28
2	76.58	7.62	51.55	99.48	51.22	98.78
3	76.63	7.38	52.33	97.09	63.75	88.28
4	78.06	12.12	41.30	106.52	58.15	96.74
5	78.88	8.48	48.29	96.58	62.42	90.60
6	79.82	7.21	61.21	97.13	68.56	91.38
7	80.14	14.03	50.00	116.92	60.77	108.23
8	80.94	10.60	47.03	103.47	61.88	96.88
9	81.27	7.30	59.41	100.59	69.50	92.35
10	81.66	10.02	47.44	105.13	65.38	98.72
11	81.98	6.83	57.41	99.31	71.41	93.91
12	82.36	8.68	58.67	105.10	67.86	98.32
13	84.00	12.36	49.34	115.13	63.82	106.58
14	84.49	6.19	62.39	97.44	73.50	93.16
15	88.31	9.89	60.00	112.67	72.00	104.467
16	88.56	9.54	56.95	108.86	75.01	105.04
17	89.00	10.76	50.63	113.92	69.37	105.06
18	90.73	10.84	64.58	112.50	72.62	106.46

Table E1: Summary statistics for daily bed occupancy for medical specialty grouping: financial year 1994/95

Hospital	Mean	Standard Deviation	Minimum	Maximum	Percentiles	
					5th	95th
A	59.82	18.45	12.86	105.71	26.14	88.14
B	59.22	21.77	7.89	113.16	21.05	94.74
C	69.25	21.48	21.15	134.62	32.69	103.85
D	43.50	17.37	2.63	100.00	18.42	76.32
E	58.10	21.67	13.51	109.46	24.32	93.24
F	60.00	19.96	13.51	108.11	28.78	91.89
G	65.03	18.48	9.62	107.69	33.27	96.15
H	47.69	17.12	7.89	94.74	21.05	76.32
1	35.83	23.01	0.00	120.83	0.00	75.00
2	-	-	-	-	-	-
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	46.72	25.79	0.00	123.08	8.85	88.46
6	36.53	16.60	5.00	95.00	12.50	67.50
7	-	-	-	-	-	-
8	52.21	34.65	0.00	168.75	6.25	118.75
9	50.23	22.65	5.26	118.42	15.79	91.32
10	44.99	26.14	0.00	109.38	6.25	86.56
11	77.67	83.79	0.00	400.00	0.00	250.00
12	62.10	21.40	6.25	118.75	25.00	97.29
13	-	-	-	-	-	-
14	-	-	-	-	-	-
15	4.45	24.21	0.00	300.00	0.00	25.00
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	64.04	27.14	10.00	135.00	21.67	108.33

Table E2: Summary statistics for daily bed occupancy for ENT surgery: financial year 1994/95

Hospital	Mean	Standard Deviation	Minimum	Maximum	Percentiles	
					5th	95th
A	60.04	13.24	24.12	94.12	37.06	80.59
B	71.53	16.45	34.85	113.64	44.39	99.55
C	70.63	17.07	17.39	115.22	41.30	97.83
D	46.44	11.40	12.00	74.00	28.60	66.00
E	59.90	16.21	14.63	104.88	29.63	85.00
F	53.25	18.08	8.33	101.67	23.33	81.67
G	76.06	20.06	23.91	128.26	36.96	106.52
H	51.76	15.55	4.55	92.42	26.21	75.76
1	-	-	-	-	-	-
2	-	-	-	-	-	-
3	51.62	17.55	5.88	91.18	23.53	79.41
4	58.15	17.87	18.42	105.26	31.58	86.84
5	53.51	15.97	12.50	93.75	25.00	81.25
6	65.07	22.91	10.00	133.33	26.67	105.67
7	69.77	25.46	8.33	145.83	30.42	108.33
8	70.47	18.06	19.05	119.05	38.09	100.00
9	61.59	19.10	9.72	116.67	30.56	94.44
10	64.44	20.17	19.44	119.44	30.56	97.22
11	64.14	16.29	7.41	101.85	37.04	90.74
12	59.39	51.58	0.00	165.4	0.00	130.77
13	64.39	18.34	4.00	112.00	34.00	92.00
14	52.51	15.07	9.46	86.49	21.62	77.03
15	54.25	17.69	4.76	107.14	23.81	80.95
16	57.18	14.08	11.70	92.55	32.98	79.79
17	58.58	18.90	11.76	105.88	20.59	88.24
18	60.75	14.85	15.00	103.33	36.67	84.50

Table E3: Summary statistics for daily bed occupancy for gynaecology: financial year 1994/95

Hospital	Mean	Standard Deviation	Minimum	Maximum	Percentiles	
					5th	95th
A	51.48	13.82	5.41	81.08	28.38	72.97
B	32.35	16.38	0.00	78.26	8.70	60.87
C	58.08	24.12	6.52	110.87	19.56	95.65
D	47.61	31.77	0.00	129.17	0.00	102.917
E	-	-	-	-	-	-
F	65.46	19.17	8.70	110.87	28.26	95.65
G	66.98	30.29	0.00	141.67	19.44	118.61
H	-	-	-	-	-	-
1	48.80	24.68	0.00	109.52	7.14	88.09
2	47.62	19.29	0.00	93.33	18.33	81.67
3	43.67	12.82	0.00	80.36	21.43	64.29
4	-	-	-	-	-	-
5	37.46	23.40	0.00	95.45	0.00	77.27
6	-	-	-	-	-	-
7	51.53	32.13	0.00	128.57	7.14	113.21
8	54.28	49.16	0.00	200.00	0.00	137.50
9	54.60	28.96	0.00	158.33	8.33	100.00
10	-	-	-	-	-	-
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	-	-	-	-	-	-
15	-	-	-	-	-	-
16	44.65	18.27	2.33	87.21	13.95	74.07
17	37.18	25.69	0.00	108.33	0.00	79.17
18	-	-	-	-	-	-

Table E4: Summary statistics for daily bed occupancy for ophthalmology: financial year 1994/95

Appendix F1: Scottish average monthly bed occupancy rates

Month	Medical	ENT	Gynaecology	Ophthalmology
January	81.83	55.38	63.00	39.72
February	79.52	59.88	68.19	49.97
March	77.34	59.96	66.36	47.25
April	92.43	58.87	54.42	47.91
May	91.41	53.27	57.62	48.89
June	86.09	54.51	57.12	51.34
July	72.82	52.54	56.34	40.80
August	74.48	53.05	57.81	47.33
September	74.68	51.99	58.32	44.41
October	77.24	50.25	57.32	42.44
November	76.39	54.61	68.23	47.56
December	72.19	48.51	53.89	36.68

Table F1: Average monthly bed occupancy of Scottish hospitals for financial year 1994/95

Appendix F2: Scottish average day-to-day bed occupancy rates

Day	Medical	ENT	Gynaecology	Ophthalmology
Monday	80.83	50.73	59.92	43.46
Tuesday	81.92	63.96	62.04	57.91
Wednesday	81.82	68.64	63.56	60.45
Thursday	80.97	68.41	66.32	59.01
Friday	78.12	56.91	63.40	44.67
Saturday	76.15	38.70	52.72	25.97
Sunday	77.90	32.99	50.71	25.59

Table F2: Average day-to-day bed occupancy of Scottish hospitals for financial year 1994/95

Appendix G: Method for calculating Crude and HRG adjusted LOS scores

The formula for the Crude length of stay (LOS) Score for the i^{th} year in the j^{th} hospital *(i=1,.....,5; j=1,...,26)* is:

$$Crude\ LOS\ Score_{ij} = \frac{Observed\ \overline{LOS}_{ij}}{Expected\ \overline{LOS}_{i}} \text{ x } 100$$

where

$$Observed\ \overline{LOS}_{ij} = mean\ length\ of\ stay\ for\ the\ i^{th}\ year\ in\ the\ j^{th}\ hospital$$

$$Expected\ \overline{LOS}_{i} = Scottish\ mean\ length\ of\ stay\ for\ the\ i^{th}\ year$$

The formula for the HRG Adjusted LOS Score for the i^{th} year in the j^{th} hospital *(i=1,.....,5; j=1,...,26)* is:

$$HRG\ Adjusted\ LOS\ Score_{ij} = \frac{Adjusted\ \overline{LOS}_{ij}}{Expected\ \overline{LOS}_{i}} \text{ x } 100$$

where

$$\text{Adjusted}\ \overline{\text{LOS}}_{\text{ij}} = \frac{Observed\ \overline{LOS}_{ij}}{Expected(\overline{LOS}_{ij})} \text{ x } Expected\ \overline{LOS}_{i}$$

$$Expected(\overline{LOS}_{ij}) = \frac{\sum_{k} n_{ijk}\ \overline{LOS}_{k}}{\sum_{k} n_{ijk}}$$

$Expected\ (\overline{LOS}_{ij})\ is\ the\ \exp ected\ mean\ length\ of\ the\ i^{th}\ year\ in\ the\ j^{th}\ hospital\ after$ $taking\ account\ of\ HRG-mix.$

$$\overline{LOS}_{k} = mean\ length\ of\ stay\ for\ k^{th}\ HRG$$

$n = number\ of\ cases\ (i.e.\ SMR1\ records)$

For example, Hospital A's Crude LOS Score in 1994/95 for general medicine and its associated sub-specialties is:

$$Crude\ LOS\ Score_{ij} = \frac{5.79}{6.20} \text{ x } 100 = 93.39$$

Similarly, Hospital A's HRG Adjusted LOS Score is:

$$HRG\ Adjusted\ LOS\ Score_{ij} = \frac{6.08}{6.20} \text{ x } 100 = 98.04$$

Appendix H: Correlation between continuous variables used in econometric study

	Occupancy	*Discharges*	*Average Staffed Beds*	*Occupied Bed Days*	*Staffed Bed Days*	*Crude Length of Stay*	*Adjusted Length of Stay*	*Direct Cost per Case*	*Total Cost per Case*
Occupancy	***1.000***								
Discharges	0.010	***1.000***							
Average Staffed Beds	-0.036	0.959**	***1.000***						
Occupied Bed Days	0.055	0.959**	0.994**	***1.000***					
Staffed Bed Days	-0.036	0.959**	1.000**	0.994**	***1.000***				
Crude Length of Stay	0.063	-0.406**	-0.196*	-0.188*	-0.196*	***1.000***			
Adjusted Length of Stay	0.158*	-0.357**	-0.171*	0.159*	-0.171*	0.867**	***1.000***		
Direct Cost per Case	0.020	0.235**	0.336**	0.346**	0.336**	0.361**	0.292**	***1.000***	
Total Cost per Case	-0.065	0.088	0.182*	0.185*	0.182*	0.345**	0.260**	0.929*	***1.000***

Table H1: Correlation of variables used in econometric analyses for high occupancy specialty (general medicine and its associated sub-specialties)

**Correlation is significant at the 0.01 level(1-tailed)
*Correlation is significant at the 0.05 level(1-tailed)

Note: used Pearson's correlation

	Occupancy	*Discharges*	*Average Staffed Beds*	*Occupied Bed Days*	*Staffed Bed Days*	*Crude Length of Stay*	*Adjusted Length of Stay*	*Direct Cost per Case*	*Total Cost per Case*
Occupancy	***1.000***								
Discharges	0.265**	***1.000***							
Average Staffed Beds	0.114	0.954**	***1.000***						
Occupied Bed Days	0.291**	0.968**	0.980**	***1.000***					
Staffed Bed Days	0.114	0.954**	1.000*	0.980**	***1.000***				
Crude Length of Stay	0.238**	0.160*	0.346**	0.371**	0.346**	***1.000***			
Adjusted Length of Stay	0.223**	0.125	0.261**	0.286**	0.261**	0.761**	***1.000***		
Direct Cost per Case	0.040	0.053	0.027	0.035	0.027	-0.045	-0.230**	***1.000***	
Total Cost per Case	-0.056	0.034	0.036	0.032	0.036	-0.025	-2.10**	0.857**	***1.000***

Table H2: Correlation of variables used in econometric analyses for low occupancy specialties (ENT, Gynaecology and Ophthalmology)

**Correlation is significant at the 0.01 level(1-tailed)
*Correlation is significant at the 0.05 level(1-tailed)

Note: used Pearson's correlation

	Occupancy	*Discharges*	*Average Staffed Beds*	*Occupied Bed Days*	*Staffed Bed Days*	*Crude Length of Stay*	*Direct Cost per Case*	*Total Cost per Case*	*HRG Prop 10%*	*HRG Prop 25%*
Occupancy	***1.000***									
Discharges	0.068	***1.000***								
Average Staffed Beds	0.020	0.968**	***1.000***							
Occupied Bed Days	0.106	0.970**	0.995**	***1.000***						
Staffed Bed Days	0.020	0.968**	1.000**	0.995**	***1.000***					
Crude Length of Stay	0.090	-0.383**	-0.196*	-0.188	-0.196*	***1.000***				
Direct Cost per Case	0.029	0.250*	0.344**	0.351**	0.344**	0.353**	***1.000***			
Total Cost per Case	-0.077	0.110	0.200*	0.199*	0.200*	0.336**	0.939**	***1.000***		
HRG Prop 10%	-0.114	-0.171	-0.133	-0.135	-0.133	0.384**	0.350**	0.384**	***1.000***	
HRG Prop 25%	-0.179	-0.288**	-0.250*	-0.257**	-0.250*	0.396**	0.135	0.205*	0.828**	***1.000***

Table H3: Correlation of variables used in alternative analysis: high occupancy specialty (general medicine and its associated sub-specialties) – financial years 1991/92-1994/95

**Correlation is significant at the 0.01 level(1-tailed)
*Correlation is significant at the 0.05 level(1-tailed)

Note: used Pearson's correlation

Appendix I: HRG-mix

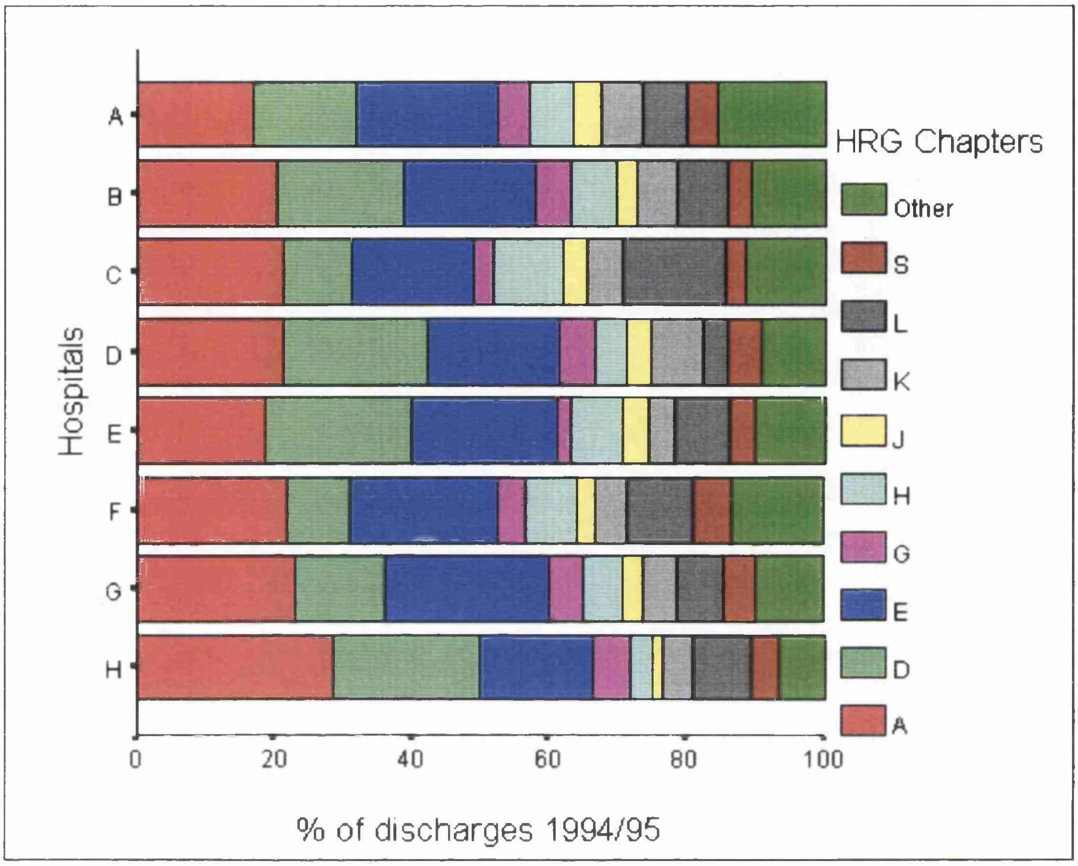

Figure I: HRG-mix of study hospitals for the variable HRG PROP25 (financial year 1994/95)

HRG Chapter	Headings
A	Nervous System
B	Eyes and Periorbita
C	Mouth, Head, Neck and Ears
D	Respiratory System
E	Cardiac Surgery and Primary Cardiac Conditions
F	Digestive System
G	Hepato-biliary and Pancreatic System
H	Musculoskeletal System
J	Skin, Breast and Burns
K	Endocrine and Metabolic System
L	Urinary Tract and Male Reproductive System
M	Female Reproductive System
N	Obstetrics and Neonatal Care
P	Diseases of Childhood
Q	Vascular System
R	Spinal Surgery and Primary Spinal Conditions
S	Haematology, Infectious Diseases, Poisoning and Non-specific Groupings
T	Mental Health
U	Undefined Groups