AN ECONOMETRIC ANALYSIS OF RUNNING COSTS OF SCOTTISH NHS HOSPITALS: A COMPARISON OF TEACHING AND NON-TEACHING HOSPITALS' COST STRUCTURE

by

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TEKLU and *FELEKECH*

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Summary

This study undertook an econometric analysis of total running costs of Scottish hospitals for the fiscal year 1985-86. Its objectives can be classified into two main strands: (a) to search for a means of investigating the higher costs of hospitals involved in teaching and related activities, and (b) to apply this analytical technique to Scottish hospitals data and try to approximate the extent of additional financial resources that might be incurred due to the teaching responsibilities of hospitals.

In order to satisfy the first objective, a detailed review of the literature in this topic was made, which included the methodological aspects and the views taken by these studies about higher costs of teaching hospitals as well as the difficulties encountered in the process. The review showed the various sources that could generate additional costs to teaching hospitals, outwith that involved for the provision of patient care services. It also pointed that econometric approach to be the sole methodology favoured in the analysis of hospital costs.

The study, therefore, selected econometric approach to be the basic tool of analysis. Models were specified for total running costs of hospitals and the several components constituting it, such as, costs for employing medical staff and provision of supplies. The independent variables of the models defined are measures of hospital levels of resources and services provided. The functional relationship postulated between these variables reflects the multi-product nature of hospital operation. Among others, measures of level of teaching activity of hospitals were included in the modelling process, some of which were not tested in the past studies of Scottish hospital costs due to absence of satisfactory data. These are, number of undergraduate medical students and nurses in training, in addition to teaching status of hospitals.

After considering the methodological set-up, the available data on Scottish teaching and non-teaching hospitals were compiled in the required manner, but due to apparent incomparability of some non-teaching hospitals with the teaching ones, specific hospitals were selected to form the sample of hospitals to

be analysed. 81 hospitals, 33 teaching and 48 non-teaching hospitals were chosen among more than 300 present in Scotland.

The following main deductions were made from the analysis of these 81 hospitals total running costs and its cost components:

(a) The analysis gives evidence to the hypothesis that hospitals' level of teaching activity does indeed generate additional running costs. It presented supportive justification for the amount of allowance being made to Scottish hospitals per undergraduate medical students at present.

But, it also shows that allowances should be made for costs incurred for training nurses and the teaching status of hospitals, especially the major teaching hospitals. Therefore,it recommended that to facilitate their teaching responsibility, the major and minor teaching hospitals in Scotland might need to allocate on the average about 14.9 per cent and 12.3 per cent, respectively, of their total running costs based on 1985-86 levels of expenditure. Similarly, it calls on the non-teaching hospitals to make an allowance of 6.4 per cent of their training costs for teaching activity, with particular reference to the 48 hospitals selected as control groups.

(b) Even though the teaching hospitals might have spent a larger part of their resources on teaching activities in comparison to their non-teaching counterparts, the analysis lacked conclusive evidence to suggest that the various types of patient care services, inpatient and non-inpatient care could be provided with differing marginal costs between teaching and non-teaching hospitals studied.

(c) The analysis stressed the possibility that the level of teaching activity of hospitals to significantly influence some specific components of total running costs than others. Thus, the evidence implied that teaching loads of hospitals could possibly create a significant uplift in hospital total costs for employing staff but not for provision of supplies.

(d) The models estimated for total running costs and cost components generally showed that hospital costs could be linearly approximated from variables measuring levels of resources (beds) and services (inpatient cases, patient days, outpatient visits, number of medical students, nurses in training and teaching status), with high explanatory power obtained.

The result, thus questioned the possibility of economic gain or saving in costs in Scottish hospitals from expansion or diversification of services. That is economies of scale and scope may not prevail in Scottish NHS hospitals sector.

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CHAPTER 1

INTRODUCTION: SCOPE OF THE STUDY

1.1. Introduction

The Scottish NHS have at least 300 hospitals, under its management providing health care services to the public, of which 33 of them are designated to facilitate clinical training and other related activities. According to published Scottish Health Service Costs of the 1985-86 Fiscal Year, these few hospitals participating in medical teaching spent nearly half (about 43%) of the expenditure for running almost all the Scottish NHS hospitals. These running costs are not only spent on furnishing patient care services but also the training aspects. The question that comes to mind would be why these teaching hospitals spend much more than the non-teaching hospitals? The answer to that is partially, because they are required to finance their teaching related responsibilities which the other non-teaching hospitals are not fully involved in. Another reason of course may be they are providing health care in a larger scale than the non-teaching hospitals.

The main concern in previous studies of comparison of cost structures between teaching and non-teaching hospitals was to furnish answers for questions such as, how much of these teaching hospitals expenditure was actually devoted to the training activity, and how can this be measured. This study also aspires to examine the higher costs of teaching hospitals, with particular reference to the experience of Scottish hospitals.

The Scottish Home and Health Department, since 1976 have tried to devise a solution that allowed the teaching hospitals to get a fair reimbursement for the expenses incurred to satisfy their teaching commitment. The recommended solution worked out at the time had a parallel with that implemented by the Department of Health and Social Security for hospitals in England and Wales. Working parties appointed under both Departments in Scotland, England and Wales come up with a solution for the funding of teaching costs of hospitals in what was known as a Service Increment for Teaching (SIFT) for hospitals in the latter two regions and a similar one for the former, as reported in SHARE, Scottish Health Authorities Revenue Equalisation. These recommendations calculated the 'excess' costs of teaching hospitals, above that expended on the average, by a selected group of hospitals engaged in only provison of patient care services. This was to be distributed among the teaching hospitals mainly on the basis of the number of medical/dental students they trained.

The solutions have since then been implemented in practice. However, they have become also sources of much of the studies in the area in British NHS expenditure with strong criticisms directed at them. The adequacy of the methodologies used, the recommended solutions, complimented with the form of statistical information used were being questioned. [see Perrin & Magee (1982), Bevan (1982), and Straf (1981)).

One of the intentions for embarking on this study is therefore, to make suggestions as to whether the reimbursement being allowed for teaching hospitals could be justifiable based on empirical evidence obtained from analysis of information available on Scottish hospitals. Furthermore, judging from the available literature in this area the work proposed could have wider scope, because:

(i) of the limited availability of econometric study specifically dealing with higher costs of teaching hospitals in Scotland;

(ii) the extensive development of econometric studies in the hospitals sector in recent years that would entail to make the best use of a more advanced approach; and,

(iii) the presence of adequate data on measures of teaching activity of NHS hospitals at present, which can be advantageous compared with past similar works faced with the scarcity of such information.

1.2 Aims of the Study

The main task of the study is to contribute some explanation to the issue of resource allocation among hospitals engaged in teaching and non-teaching activities. Specifically, we aspire goals for the following objectives of interest:

(i) We search for plausible techniques to help understand the different cost structures of the two types of hospitals. Adequate form of hospital cost model specification and testing them empirically by data analysis is involved. Also, hospital departmental costs and their relation to level of teaching activity are analysed.

(ii) We try to estimate the extra cost of teaching hospitals that may be attributable to their level of teaching responsibility, and also indicate the possible proportional difference between teaching cost of major and minor teaching hospitals. and,

(iii) We infer from the empirical results of data analysed on the possible existence of some economic parameters, like economies of scale and scope, for Scottish hospitals with respect to their use of resources.

1.3 Layout of the Thesis

This thesis is subdivided into nine separate chapters, each with several sections. Chapter 2 briefly reviews past literatures concerned with the study of teaching hospital costs. It will focus on the methodological aspects of these studies and common difficulties arising in a study of hospital costs. The studies reviewed were subdivided into two sections, one dealing with NHS hospitals in Scotland, while the second is a collection of other studies with particular reference to the problem we try to deal with.

Chapter 3 will discuss the elementary concepts of multiple regression theory. It is by no means a complete discussion, but provides information on those parts of the theory of which we have made use. These are mainly, on regression model specification, the assumptions made, and ways of verifying them. Also, principles of variable selection, in addition to the problem of simultaneous equations and methods of estimating regression models in such a case are elaborated on.

In chapter 4, the cost function developed to explain the structure of total running costs of hospitals will be described in detail. It involves describing the form of models used, their specification and definitions of the model variables used. Expected relationships between the endogenous and exogenous variables and their implications in respect of model parameters estimation will be stressed.

Chapter 5 will explain about the sources and reorganisation of the data used in fitting the models. The case of selecting hospitals (to be referred) as control groups is the main concern of one of the sections. Answers will be provided for questions such as, why this selectivity of the non-teaching hospitals is necessary?, how was it done?, its justification and the problems expected in doing so. In another section, some descriptive statistic of the cost model variables will be compared with respect to the teaching status of hospitals and observations will be made.

Empirical results from the models fitted to the data of the Scottish hospitals will be outlined in chapter 6. The model fitting procedure used, devised a model building iterative procedure, due to the large number of variables being considered in relation to the size of sample of hospitals. The first section portrays the process used to search for the 'best' set of explanatory variables for total running costs model. The model fitting is undertaken via a weighted least squares estimation approach. The modeling starts from a 'basic' model with linear independent variables representing inpatient and non-inpatient case activity of hospitals. Next, the results of models adding quadratic and cubic order variables will be presented, which is followed by the addition of the interaction variables. Finally, the influence of variables measuring teaching activity of hospitals will be investigated and a summary of the whole chapter given.

Chapter 7 tests the relationship between level of teaching activity of hospitals and the various cost components constituting the total running costs of hospitals, such as expenditure for salary and other payments on medical staff, nursing staff, and other types of staff employments, as well as expenses on hospital supply provision. This chapter also examines whether the affect of the level of teaching on costs varies among the cost components and in which components is this influence most manifested. Therefore, it tells us about modeling hospital total running cost components; the model, the variables, the data used and some related ideas. This chapter's models are also fitted using a weighted least squares estimation technique.

Chapter 8 also concentrates on modeling of total running costs and its components. The difference between this and the preceding two chapters will be that, the model parameter estimation will incorporate the presence of simultaneous equation relationships between model variables. Explanations will be furnished why this problem might prevail in modeling hospital costs. The models are fitted implementing Two-stage least squares estimation technique. Comparison of empircal results will be made among the present and the last two chapters.

Finally, in chapter 9, a summary of concluding remarks about the whole study will be presented.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Introduction

Having their own specific objectives and areas of interest, most researches undertaken in the past, to investigate the different levels and degrees of expenditure between teaching and non-teaching hospitals or within each type of hospitals were directed at devising techniques that could help explain their varying structures of costs. For instance, Feldstein (1967), Culyer et al. (1978), and Bailey and Ashford (1984) are some of those cited in our references. There are specialised studies devoted to the purpose of presenting a concise review of such hospitals cost studies; for example, Berki (1972), Foster (1987), Cowing et al. (1983) and others. These reviews generally refer us to the first of the next two alternative approaches, to analyse the differences in costs of hospitals. The first, which is widely being followed and discussed uses econometric techniques, while the second, was explained as development of cost accounting systems in the hospital sector.

The econometric technique focusses on the specificiation of regression models for costs, to explain the variability between hospital costs in terms of the outputs they produced, and some times the facilities they used. Hospital outputs were mainly expressed as the measures of levels hospital services provided such as, patient cases, occupied bed days, medical students (and nurses) trained and the like, while the inputs refers to hospital available beds.

The alternative approach to cost modeling, is the cost accounting of the inputs used by each hospital in producing its given services. According to this system, it is suggested that hospital costs may be apportioned assigning fraction of costs to the input components implemented. The cost accounting system approach, though discussed and advocated to be the favourable means of understanding the cost differentials between hospitals, was not practically applied. [see Foster (1987)]. The restriction to its inapplicability rests on the complexities manifested by the operation of the hospital: (i) various services are provided that require estimation of a lot of unit costs, (ii) problem of joint products that still had no complete solution on how to cost inputs used for both products separately, and (iii) the costs of undertaking this task in all NHS hospitals.

This study aspires to embark into analysis of Scottish hospitals costs using the econometric approach. The way forward has been developed extensively, but still this is not also without difficulties. The drawbacks of the technique stems from the fact that (i) the complex nature of hospital operation have not been fully grasped within the mathematical (functional) frameworks already devised in previous studies. (ii) The problem of joint product costing persists here also and, (iii). the definitions and measures of variables to be implemented in the modelling practice were not universally accepted and varies from literature to literature as well as the form of the cost functions proposed. The prevailing problems in the hospital cost studies had been generalised in Berki (1972) and were accepted by others. He summarised (pp.85-86), these problems to refer to:"... the indefiniteiveness of the cost studies" due to: "... the prevalance of multiple and sometimes conflicting conceptualisations ...., conceptual impression resulting in empirical exactitude at the cost of unreality ..., methodological carelessness ..., the relative absence of adequate data ..., and the nature of the hospital sector...".

Bearing in mind that there are such obvious difficult issues in the analysis of hospital costs through econometric methods, it seems the only practical means of study favoured by almost all. Therefore, in the next sections of this chapter a brief review of those studies are presented. We have partitioned the chapter into three sections, the first, comments on the explanations given about the higher cost of teaching hospitals, and lists the problems commonly encountered in undertaking such studies. The second part looks at some studies done on Scottish hospitals, whereas the third, takes care of other studies that are of interest to us, dealing with the comprison of teaching and non-teaching hospital costs.

2.2 Explaining higher costs of teaching hospitals

Generally there is an agreement on the literatures about teaching hospitals requring additional resources due to their higher expenditure on training and research purposes compared with their non-teaching counterparts. The challenge arises in explaining why there is higher costs, its justifiability and how much should be ascertained for it. These points will be dealt with in some detail. The heart of the problem lies in the final part, that is, how to explain variations in teaching and non-teaching hospital costs and to identify the proportion of teaching hospitals costs expended for teach purposes.

2.2.1 Sources of Higher costs of Teaching hospitals

Several studies have been undertaken to explain sources of higher expenditure of teaching hospitals. These include the SHARE (Scottish Health Authorities Revenue equalisation), report produced by the Working Party on Revenue and Resource Allocation (**WPRA**), (SHHD, 1977), on Scottish Hospitals; also Copeman and Drummond (1982), Perrin and Magee (1982), and others. Inspite of the fact that health service system and accounting practices are not identical to those existing in Britain, numerous North American studies, such as Sloan et al.(1983), Hosek and Palmer (1983) and others few known to us had expressed suggestions similar to those summarised below. The sources suggested can be stated under four headings. They are:

(a) Providing Facilities for Teaching Undergraduate Medical Students

According to the report of the WPRA (SHHD, 1977, p24): "The practical parts of [training medical doctors] were and still are, given in teaching hospitals,..." it informs, and states that even though the direct costs of undergraduate training are met by the universities the health service is required to "provide substantial facilities additional to those normally provided in hospitals", which raises extra costs to those participating in teaching activities. Those facilities include extra staff time, teaching rooms, laboratories, catering services and other similar teaching equipment and manpower supply.

(b) Other Training Activities

Under this section falls teaching hospitals responsibilities for training Nurses, Postgraduates (and professions supplementary to medicine) medical staff (like paramedical professionals). In contradistinction to Undergraduate education these activities are also carried out in non-teaching hospitals and hence may not necessarily have a particularly strong influence only on the cost of teaching hospitals as such. However, Copman and Drummond (1982, p7), in their extensive discussion of this topic have expressed that differences in concentration of those training opportunities do exist between the two types of hospitals.

(c) Research Responsibility

Research activity is one of the main undertakings of teaching hospitals for the advancement of medical knowledge. The availabilty of well qualified staff and modern equipment coupled with the teaching environment ensures research to be extensively carried out in the teaching hospitals. Because of this,"in addition to funded research projects, medical staff were normally expected to engage in personal research. ..." (Copeman and Drummond, (1982, p7)), and hence generating costs unaccounted for in the resources allocated to the hospitals. The problem with research activity, as will be noted later, is not its generating of other non-renumerable costs but the difficulty in measuring them.

(d) Other Special Activities

There is accepted general uniformity in the above three sources of higher costs in teaching hospitals by the authors, previously cited. But there are also points of differences between them. According to WPRA's study of Scottish hospitals, the concentration of " some Supra-area specialities " in the teaching hospitals were specified to be " a most important element in the extra costs borne by the teaching centres..." (SHHD, 1977, p24), while Copeman and

Drummond (1982, p10), stresses the treatment of difficult and complex cases that are more costly to provide with the necessary staff and facilities. Their similarity therefore, lies in that highly specialised (or supra-area) units in teaching hospitals are more capable of coping with the extremities of health care.

Other reasons for the costliness of teaching hospitals are likely to include location. For instance the presence of manv of the teaching hospitals in and around the city areas. [Example, Culyer et al, (1978)] But, it is not known whether this applies in Scotland.

2.2.2 Common difficulties encountered in hospital cost studies

Three points can be referred to concerning the problems likely to be encountered in studies similar to what we propose to undertake. They are:

(a) Justifying Higher Cost of Teaching Hospitals

The general problem in studying hospital cost structures is the methodological difficulties arising in distinguishing and measuring the structural differences in the use made of the available resources among the many varieties of hospitals. This will be an agenda for later sections. The point to be made here refers to the conflicting interpretations given towards the sources of higher cost of teaching hospitals.

According to Drummond (1978), there are primarily two parallel explanations being debated about this idea. Those who ascertain that higher spending of teaching hospitals is a result of financing to achieve medical excellence, and others who express dissatisfaction, seeing it as expenditure towards unjustified extravagence. Both sides, as he explained are not easy to prove or disprove. Teaching hospitals could be seen to be centres of excellence, if taken in terms of the quality of staff they employ, the modern technogical hardware they possess as well as the difficult and complex cases they treat. Besides this, the average higher unit costs they incur puts them in the forefront of criticism and invites a judgement of economic inefficiency, their expenditure viewed as extravagant.

These ideas need strict economic analysis to check and are difficult to take sides with. The stance of this study is to assume that systematic differences in expenditure exist between teaching and comparable non-teaching hospitals and that these have econometric interpretations.

(b) Costing Joint Products

The notion of joint products conceives a given firm, say a hospital, producing two or more end-products commonly using the same required inputs. Teaching hospitals are perfect examples. They produce - other than health care for patients - medical doctors, research results, and other related services, sharing the resources available through one channel. In the process of reallocating resources on the basis of hospital activities the question arises on determining what fraction of the expenditure goes to the above outlined sources of costs, complicating the estimation of the extra cost due to teaching and associated responsibilities.

The literatures on this topic doesn't aspire to specify any solutions. There is a harmonious agreement by most on the impossibility of getting an accurate and reliable method of costing joint products in the NHS sector. Others indicate a possibility - though impractical in the near future - to the successful development of a cost accounting system in NHS hospitals, [see Magee and Perrin,(1982)]. There remains only to concentrate on seeking techniques that could be helpful in drawing a line of margin between teaching and non-teaching hospitals' cost structures.

(c) Unquantifiable Aspects of Health Care

Availability of adequate statistical information on various aspects of health care are essential in order to analyse the factors differentiating costs of NHS hospitals. Scale, type, and complexity of activity are some that could be measured and implemented to identify the prevailing variations in hospitals cost structure. But there exist other important variables necessary to distinguish the inherent effects influencing expenditure. Such factors are differences in quality of care and extent of research undertakings as well as training other staff, posing methodological and measurement difficulties to incorporate them in the desired analysis. [see Culyer et al. (1978)]. Capturing relative influences of these factors may be possible but questionable. For instance, teaching hospitals being seen as centres of excellence may imply that they provide high quality of care, which assumes quality of care to be associated with those hospitals having higher unit costs. But, in (a) above we saw that this theory of excellence could be controversial.

2.3 Studies of Scottish Hospital Costs

The main study made in Scottish hospitals and known to us was by the Working party on Revenue and Resource Allocation (WPRA) in 1976, the counterpart official Resource Allocation Working Party (RAWP) in England and Wales.

WPRA studied the general aspect of finances of all Scottish hospitals, including the case of teaching hospitals, which we will concentrate upon. Their main task being to devise a means of distributing resources available on an equitable basis among the 15 Scottish Health Boards, thus undertook the task by identifying key factors indicating the Health Board's need of resources, in order to satisfy the demand for health care. Those factors were the size of population (community) being served, the cross boundary movement of patients, the level of highly specialised services and teaching responsibilities of hospitals at each Health Board. A model was built incorporating all these factors to recommend how the distribution of resources should take place.

The resource share model recommended for the teaching Health Boards and their hospitals follow a cost comparison approach to estimate their additional costs incurred due to the medical/dental training and highly specialised services provided. These costs also known as Excess Costs of teaching was assumed to cover hospital expenses on training, research, and special services (activities), other than on patient care services. This was computed as the difference from the average costs of teaching and a similarly selected group of non-teaching hospitals, called"Equivalent hospitals". (SHHD, 1977, p3). This cost was recommended to be "distributed on the basis of the number of undergraduates [medical/dental students] in their clincal year at each Centre". (Ibid, p24). We have drawn some parallel on selective use of non-teaching hospitals. [See chapter 5].

Since there was little information available on the unit cost of training an undergraduate medical student in Scotland that results obtained from analysis of English hospitals was adopted, assuming some similarity between the two regions. The unit cost of training of medical students in England, estimates used by RAWP (DHSS, 1976) was directly applied in Scotland. Some comments can be made about WPRA's study as presented in Milne et al. (1986, p4). They: (i) suspected the plausibility of "the estimate of the cost of medical education used", (ii) questioned the working party's assumption that the hospitals " level of activity and, not resources, generate costs" and (iii) showed the possibility that, "the estimated extra (teaching) costs depends on which non-teaching hospitals are selected as their equivalent." We think the empirical results of our study might provide some contribution towards the judgement of these criticisms.[see chapter 6- 8].

Stein (1980), Ho (1983) and Milne 1986) are other studies on Scttish hospitals which have influenced our work; however different their area of concern may be. Stein (1980) analysed the variation in unit costs of selected Scottish hospitals employing primarily, measures of case-mix and intensity of specialisation of hospitals. The empircal results he had presented, depicts to what extent these variables, specially case-mix significantly measure the variation in unit costs of hospitals. The technique, employed coincides with such studies by Evans (1971), Feldstein (1967), and others who advocated the use of case-mix variables to differentiate hospital cost structures. However, his conclusion pointed: "... that the case-mix measures based on diagnosis, unit on discharge (speciality) and surgery do not contribute significantly to explaining variation in unit costs." Stein's summary advices us to be critical in our implementation of these variables. [see chapter 4].

Ho (1983) and Milne et al. (1986) studied Scottish hospitals performance through modeling their inpatient costs. The latter summarised the results from the former's analysis highlighting its implications for the problem of equal financing of teaching hospitals. The variables used consists of measures of hospital resources and activities, such as staffed beds, inpatient cases and days, hospital teaching status and proportion of learner Nurses in Training. The functional relationship expressed in the inpatient costs model follows that developed by Bailey and Ashford (1984), in which use of speciality grouping and cost components of hospitals play the major role. We also adhere to this type of cost models set up. [see chapter 4] Their findings gave some insight into the contribution of level of teaching activity in generating hospital costs. However, the data on teaching hospitals was limited due to unavailability of data on the number of medical students. The hospitals' teaching status was used instead, significantly contributing to explain the variations in inpatient costs of hospitals. [Ho (1983, p102)]. That means, among three teaching variables used, two are dummy variables (representing major and minor teaching hospitals) and the other (representing the proportion of nurses in training), to fit a cost model for mixed-DGH type Hospitals, Major teaching had a statistical significant coefficient.

The draw back with these latter three studies lies in the fact that no data on Medical Students, which probably is the majot determinant of teaching hospital costs was used. [Culyer et al. (1978)]. Although, teaching status was included in modeling, this variable is related to variation in factors such as measuring case-mix and quality of cases of hospitals. [Foster, (1987)] In addition, the analysis concentrates on inpatient costs of hospitals, which accordingly ignores the multiproduct aspect of hospitals. [Berki (1972)]. We will try to rectify these problems, in our specification of cost functions. [see chapter 4]

Hence, it seems evident that econometric studies of Scottish hospital costs are a fresh field to be undertaken in view of the limited applicatons known to us, and presented here.

2.4 Other Studies related to Teaching hospital costs

Culyer et al. (1978) perhaps takes the lead in the application of econometric analysis to teaching hospital costs in Britain, with particular reference to hospitals in England and Wales. However, there are numerous studies involving the general aspect of NHS hospitals, for instance, Feldstein (1967), Bailey & Ashford (1984) and others, including the RAWP, (DHHS, 1976). Since there is enough material on their review, we will focus the attention here to the cases of teaching hospitals. The bulk of econometric studies of costs of teaching hospitals, of course were also drawn from North American experience, such as Sloan et al (1983), and Hosek and Palmer (1983). Foster (1987) recently produced a general review of these teaching hospital cost studies, from both areas.

Generally speaking those studies of teaching hospital costs were based on regression analysis, specifying a 'Behavioural' type cost function relationship between costs and outputs. What differentiates them one from the other was mainly the dissimilar definitions and measures used for the variables of hospital costs and outputs. In most cases cost per cases or patient weeks were the dependent variable for which its variability was explained in terms of other variables: for example, Culyer et al. (1978) and Sloan et al. (1983). Other studies were also available incorporating total costs, like Hosek and Palmer(1983).

The independent variables, measuring mainly hospital activities (or outputs) varied also. As a summary Culyer, et al, (1978, p21) had classified and presented them in terms of: extent of patient care, difficulty and specialisation of case-mix, the scale and intensity of hospital activity, quality of care, training of medical students and other staff, research and location of the hospital. With the exception of research activity and quality of care all these variables on different aspects of health care were included in their regression model of hospital inpatient cost per case.It was from their analysis that the unit cost of medical undergraduate students was derived, which in turn helped to formulate the Service Increment for Teaching (SIFT) allowance by RAWP for teaching hospitals in England and Wales . There are questions surrounding the particular inference made in this study , namely the conclusion that, "... an estimate of the extra cost per case attributable to teaching function ... amounts to approximately 75% of the extra cost per case of teaching hospitals." (Ibid, p24). Because it is not clear and not generally understood how this was arrived at. [see, Bevan, 1982, p36].Further investigation of the relationship of teaching activities and their departmental costs, such as staff, catering, drug etc. costs, were performed, from which it was concluded that: " the estimation of individual departments show that there are differences in which the teaching function imposes costs on individual departments affecting unit costs and unit cost per case differentially". Culyer et al.(1978, p79). In this study we will try to confirm with respect to Scottish teaching hospitals. [see chapter 7-8].

Sloan et al. (1983) presents empircal results of a study made about the effects of teaching activity on hospital costs in the U.S.A. The approach was the same as above, defining regression models of costs. What varied was the variables used. Unlike hospitals in British National Health Service, hospitals in North America are partly affected by market forces. Hospitals are expected to get reimbursement for the services rendered to their patients by fixing their own charges and costs. The postgraduate medical education is the main training scheme and the students are partly employed as non-physician personnel receiving wages. Hence, Sloan et al's cost function also incorporates variables related to these factors, for example, Wages and Source of reimbursement for patient care. But this specification was not generally accepted in other similar studies in the sense that no such variables were universally employed. [our views are presented in chapter 4, section 4.2]. His findings mainly points to the higher costs of teaching hospitals due primarily to case-mix and secondorily to teaching demands. [Ibid, p25].

The teaching hospital econometric studies didn't only concentrate on the effects of teaching activities. There are other factors investigated affecting the variability in hospital costs, for example the influence of economies of scale, in the cost functions estimated, which refers to the shape of the cost surve being estimated, U-shaped, L-shaped, etc. It basically indicates the proportional change in costs with respect to the change in size of hospitals. According to Foster (1987)'s summary, "the results reported are confusing and contradictory"; There were studies implying economies of scale's existence and others without success.

Departmental costs (also known as cost components, and cost categories) interactions with teaching load of hospitals was another area of concern. As explained earlier some studies here reported the presence of strong association between Departmental operations of hospitals and their level of teaching activity. Another topic, which was not fully analysed, perhaps, is the effect of interactions within the different types of hospital activities and their influences on use of hospital resources.. For instance, between inpatient and outpatients and/or teaching activities. Hosek and Palmer(1983) had made some investigation between teaching and other types of variables in his model for Radiology department total cost. The empircal results imply that associations may or may not exist. [More details will be provided in chapter 4].

As far as the theoretical (statistical) aspect of the model estimation process was concerned the approach varies. In some cases no mention was made, either to the regression assumptons being satisfied or the actions that was taken. Major hospital studies like Feldstein (1967), Sloan et al. (1983), and Bailey and Ashford (1984), however, had made contributions. The interrelationship between the cost models variables, namely the dependent and independent ones, to indicate simultaneous equations problem was underlined. There were also influences of multicollinearity, hetroscedasticity and other problems of statistical model parameters estimation considered.

Finally, based on the experiences discussed in this chapter, we will develop cost functions for total running costs of hospitals, in Chapter 4. The next chapter, however, outlines, some elementary concepts about multiple regression theory.

CHAPTER 3

THEORY OF MULTIPLE REGRESSION ANALYSIS

3.1 Introduction to Regression Models

The technique of regression analysis is the basic method chosen to investigate the cost structures of Scottish hospital. The main idea is to formulate an adequate regression model of cost, expressing the underlying relationship between hospital costs and the variables potentially generating them, usually measures of resources and activities of hospitals.

Regression models represent the variability in the dependent variable in terms of the independent variables, within some additional assumptions. Hence the objective of this chapter is to present a brief discussion of Regression Models and the assumptions involved. The chapter will concentrate on basic multiple regression analyses concepts mainly about: model specification, estimation, assumptions and their verification. It also refers to techniques of model variable selection and the problem of simultaneous equations encountered in the model set up and the estimation procedure required.

3.2 Specification of Regression Models

Assume a set of p independent variables X's, are available to approximately determine a dependent random variable Y. The multiple regression model specifies a functional relationship in such a way that the random variable Y can be expressed as a linear combination of the X's and an error variable U in the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p Xp + U \quad \dots\dots\dots\dots \quad (3.1)$$

where, β_i's are unknown model parameters, and U is a random error variable accounting for other non-measurable variables predicting Y.

Given data, x_{ij} colleted on the X's, and y_i collected on Y, of n independent observations each, there are n sets of equations of the form (3.1)

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_p x_{ip} + u_i \quad \text{for } i = 1, \dots, n \qquad (3.2)$$

Collecting the n equations and putting them in the Matrix notation gives:

$$\underline{Y} = X\underline{\beta} + \underline{U} \qquad (3.3)$$

where, $\underline{Y}$ is an (nx1) vector, and X is an (n x (p + 1)) matrix of observations y_i and x_{ij}, respectively. $\underline{\beta}$ is a (px1) - Vector of parameters, $\underline{U}$ is an (nx1) - Vector of observation, u_i.

3.3 Assumptions of Regression Models

Given a multiple regression model presented in (3.3) the following assumptions are usually made and their accuracy verified:

(i) $n \geq p + 1$. The sample size is larger than number of independent variables X, in the model.

(ii) $Æ(\underline{U}) = \underline{0}$, implying $Æ(\underline{Y}) = X\underline{\beta}$. Where, Æ means 'expected value of', and $\underline{0}$ is an (nxl) null (zero) vector.

(iii) $Æ(\underline{U}\,\underline{U}^T) = \sigma^2 I$, where $\sigma^2 > 0$, and I, is an (nxn) Identity matrix.

Both (ii) and (iii) imply that the elements of the error Variable u_i have constant variance for all i = 1, ..., n, and are independent of each other. It is also kown as Homoscedasticity. In most cases, $Æ(\underline{U}\,\underline{U}^T) = \sigma^2 V$ is true, which implies non-constant variance or Heteroscedasticity. where V is assumed to be known and an (nxn) positive definite matrix. When V is non-diagonal it shows the u_i's are correlated, indicating Autocorrelaton problem, mostly encountered while using time series data.

(IV) The X's are constant and independent.

That is rank of matrix X is full, equals p + 1. If this is not the case there is said to be Multicollinearity problem. Also assumed that the X's are independent of $\underline{U}$. The problem of simultaneous equation arises when the X's are related to the error variable $\underline{U}$.

(V) $\underline{U}$ has a Multivariate Normal Distribution. Thus simplifying assumptions (ii), (iii) and (v) to give:

$\underline{U} \sim \underline{N}(\underline{0}, \sigma^2 I)$ with Homoscedasticity,

and $\underline{U} \sim \underline{N}(\underline{0}, \sigma^2 V)$ with Hetroscedasticity present in the variance structure of $\underline{U}$'s. (~ means 'distributed as').

The failure of any of assumption (i) to (v) affects the estimation procedure, and the accuracy of the model parameters ($\underline{\beta}$) estimated.

3.4 Estimation of Regression Models

The frequently used estimation technique for the model,

$Y = X\underline{\beta} + \underline{U}$, is through Ordinary least squares (OLS) estimation.

In the event of all the assumptions stated under (i) to (v) satisfied OLS chooses $\hat{\underline{\beta}}$, vector of estimators of $\underline{\beta}$, such that

$$RSS = \hat{\underline{U}}^T\hat{\underline{U}} = (\underline{Y} - X\hat{\underline{\beta}})^T(\underline{Y} - X\hat{\underline{\beta}}), \quad \ldots \ldots \ldots (3.4)$$

the residual sum of squares is minimised. This is achieved by setting:

$$\hat{\underline{\beta}} = (X^TX)^{-1} X^T\underline{Y} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.5)$$

$\hat{\underline{\beta}}$ are known as Best Linear Unbiased Estimators, **BLUE** of $\underline{\beta}$. Also

$$\hat{\underline{\beta}} \sim \underline{N}(\underline{\beta}, \sigma^2(X^TX)^{-1}) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.6)$$

However, constant variance assumption (iii), may not be satisfied in many cases and if ordinary least squares (**OLS**) is applied to estimate $\underline{\beta}$, unbiased but inefficient estimators, or non-BLUE estimators are produced, which leads to make inaccurate inferences about them.

Generalised least square (**GLS**) estimation technique is an alternative means of tackling that problem. Since OLS is a special case of GLS, with V, the covariance matrix being the same as an identity matrix, (I), we will focus the analysis **from now on** with respect to the GLS framework.

Given the above model (3.3), with,

$Æ(\underline{U}\underline{U}^T) = \sigma^2 V$, and V, assumed known, GLS minimises the function,

$$RSS = (\tilde{\underline{U}}^T V^{-1}\tilde{\underline{U}}) = (\underline{Y} - X\tilde{\underline{\beta}})^T V^{-1}(\underline{Y} - X\tilde{\underline{\beta}}) \quad \ldots\ldots \quad (3.7)$$

to derive,

$$\tilde{\underline{\beta}} = (X^TV^{-1}X)^{-1}X^TV^{-1}\underline{Y} \quad \ldots\ldots\ldots\ldots\ldots \quad (3.8)$$

as an unbiased and consistent minimum variance estimator of $\underline{\beta}$, and it follows that,

$$\tilde{\underline{\beta}} \sim \underline{N}(\underline{\beta}, \sigma^2(X^TV^{-1}X)^{-1}) \quad \ldots\ldots\ldots\ldots \quad (3.9)$$

[^ or ~ both signify estimators obtained corresponding to the two assumptions made about Var(U).]

And an unbiased estimator of σ^2 is presented by,

$$\tilde{\sigma}^2 = \frac{RSS}{n-p-1} = (\underline{Y} - X\underline{\tilde{\beta}})^T V^{-1}(\underline{Y} - X\underline{\tilde{\beta}})/(n-p-1) \; , \; . \; . \; . \; . \qquad (3.10)$$

Which has a distribution function of $(X^2{n-p-1})(\sigma^2)/(n-p-1)$ . . . (3.11)

Where, X^2_{n-p-1} denotes a X^2 distribution with (n-p-1) degrees of freedom.

The point estimate of $Æ(\underline{Y})$, expected value of $\underline{Y}$, is $\underline{\tilde{Y}} = X\underline{\tilde{\beta}}$, which have a distribution of $\underline{N}(X\underline{\beta}, \sigma^2(X^T(X^TV^{-1}X)^{-1}X))$ . . . . (3.12)

The predicted estimate of, say Y_f, for given values $\underline{X}_f$, of X's are given by:

$\tilde{Y}_f = \underline{X}^T{}_f \underline{\tilde{\beta}}$, where $X_f{}^T$ is a column vector of p+1 elements, ... (3.13)
also including 1 for the variable corresponding to the intercept (β_0).

under regular conditions, it has been shown that:

$$\tilde{Y}_f \sim N(X_f{}^T\underline{\beta}, \sigma^2((\underline{X}_f{}^T(X^TV^{-1}X)^{-1}\underline{X}_f) + 1)) \; . \; . \; . \; . \; . \; . \; . \; . \qquad (3.14)$$

Equations (3.9) to (3.14) provide a basis for performing some hypothesis tests and constructing confidence intervals about $\underline{\beta}$, Expected or predicted values of $\underline{Y}$, (ie. $Æ(\underline{Y})$ and Y_f), or any functions of them.

3.5 Verification of Assumptions

There are numerous complex statistical tests of hypothesis proposed to investigate the accuracy of assumptions of regression models. Basic references can be found in advanced statistical text books. [Johnston (1984), discusses most]. However, there are also simpler methods of verifying most of the assumptions given in section (3.3). This is through the use of different plots of the estimated residual variable ($\underline{U}$) or its functions which will be discussed below. In Chapter 6, we have also implemented ideas of diagnostic model checking by looking at outliners and influential observations by way of suggested techniques, such as outliner tests, comparing cook's distances, and similar others. Basic reference can be seen in Wersberg (1985) and others.

Suppose $\underline{\tilde{\beta}}$ is the estimator of $\underline{\beta}$ given in equation (3.7) then the estimated residual vector can be given by:

$$\underline{\tilde{U}} = \underline{Y} - X\underline{\tilde{\beta}} = (I - H)\,\underline{U} \quad \ldots \quad (3.15)$$

where $H = X(X^TV^{-1}X)^{-1}X^TV^{-1}$

Since H is an indempotent matix ($H^2 = H$), and has rank $p + 1$, $(I - H)$ is also an idempotent matrix of rank $(n-p-1)$. So $\underline{\tilde{U}}$ is a linear combination of the actual vector of random variable $\underline{U}$.

Therefore, $\underline{\tilde{U}} \sim \underline{N}(\underline{0}, \sigma^2(I - H))$

Taking $H_{ii} = \underline{X}_i(X^TV^{-1}X)\underline{X}_i^TV_{ii}^{-1}$, it can be seen that H_{ii} are not the same for $i = 1,\ldots,n$, which also implies not all variances of u_i, estimated by:

$\tilde{Var}(\tilde{u}_i) = \tilde{\sigma}^2(I - H_{ii})$, are equal, for $i=1,\ldots,n$.
Where, V_{ii} is the i^{th} diagonal element of V.

Then defining,

$$r_i = \frac{\tilde{U}_i}{\tilde{\sigma}(I - H_{ii})^{1/2}} \qquad \text{for, } i = 1, \ldots, n, \quad \ldots \quad (3.16)$$

which are called Standardized (Studentized) residuals, and can be shown to have equal expected variances, *i.e.*, $Var(r_i) = 1$, for $i = 1, \ldots, n$.

Note that $r_i \sim N(0, 1)$, if the u_i's also follow a Normal distribution.

Therefore, r_i is the basis for detecting most of the discrepancies of the model from the stated assumptions by using different plots and also its magnitudes. For instance, if the u_i's are assumed normal, then a 45^0 straight line Normal probability plot of $\underline{r}$, an(nx1) vector of r_i's, indicates Normality assumption might be accepted.

The scatter plots of $\underline{r}$ against $\underline{\tilde{Y}}$ also helps to reveal such problems of Hetroscedasticity, Autocorrelation, Outliner observations, inadequacy of the model fit or miscalculation in the estimation process.

Furthermore, the plots of $\underline{r}$ against any or set of independent variables in the model or some others omitted helps to detect curvilinear relationships or requirement of the omitted variables to be included.

Nevertheless, there are drawbacks in using the plots of $\underline{r}$ because of its observations being pair-wise correlated, even if that of $\underline{U}$ were not. The plots may be distorted due to this influence. Suspicious plots need to be investigated further. There are suggested remedies for that, like transformations of variables.

3.6. Methods of model variable selection

The subject of variable selection in regression analysis arises due to several reasons. The major ones are the availability of more predictor variables than normally needed in the model fitting process, collinearity between the predictor variables and the desire for few predictor variables to simplify the model. The principle in such instances is to choose a subset of predictor variables in such a way that this subset can provide as much explanation as the full set of predictors. The advantage usually lies in simplifying the model and possibly interpretation of the empircal results.

Numerous techniques are available to deal with such problems. The best being the analyst's knowledge about his subject area and the characteristics of each of the variables, including the expected signs and magnitudes of their coefficients. However, in most situations this knowledge needs to be supported by the information the data furnishes based on application of known statistical algorithms. We mainly relied on two versions of principles of stepwise regression:

(i) Forward stepwise regressions.

(ii) All subset stepwise regressions.

Both approaches use various statistics computed from the data in order to arrive at the final decision of selecting a suitable subset such as multiple and partial correlations or their derivations, F-ratios, Mallows Cp, etc.

By method (i) predictor variables are added or omitted at each step of the model fitting process based on some of the above statistical measures as a criterion, until a point is reached where no more variables are required for additon or omission. The statistics usually used as criterion are preassigned values of F-To-Enter, which tests the significance of each variable to be entered at each step.[Actually don't have same properties as the usual F statistics].

All subject stepwise regression, (ii) involves comparing the results of all possible subsets of the predictor variables and selecting the 'best' subset; for example if there are P predictors, 2^P different regression models are fitted for Y. Using such statistics as Mallow's Cp, which is derived from the sum of squares of residuals (RSS_j) from a fitted model ,the independent variables are selected. The Mallow's Cp statistic, for a model with j predictors, denoted by C_j, is computed from the equation:

$$C_j = \frac{RSS_j}{\hat{\sigma}^2} + 2j - n \quad \cdots\cdots\cdots \quad (3.17)$$

where, $\tilde{\sigma}^2$ is a suitable estimate of σ^2, which is often estimated from the model with all P predictor variables included, ie, the estimated squares error of the full model.

Usually the plot or comparison of C_j with j [number of variables included] indicates the 'best' subset of predictors, on the assumption that the residual sum of squares from the j predictors approximates that from the use of all p variables. Hence, a model fitted with j variables indicating: (i) C_j and j near approximates (ie. $C_j \simeq j$) and (ii) preferably its computed C_j being smaller in magnitude compared with that obtained from other alternative possible models may be a good candidate to be chosen as the 'best'. Several models can be found with subsets of j predictors, so the decision lies on the analyst's discretion.

3.7 Problem of simultaneous Equations and Model Estimation

The regression model set up considered in the preceding sections constitutes a single functional relationship between the X's and Y. In section 3.3, assumption (IV) states that none of the independent (exogenous) variables are related to the error variable U. However, most economic variables are identified by several interrelated equations incorporating associations between different dependent (endogenous) variables themselves. For example, the frequently presented modular relationship between consumption expenditure(C_t) , non-consumption expenditure(Z_t) and national income (Y_t). at a given time t, expressed as:

$$C_t = \beta_0 + \beta_1 Y_t + u_t$$

$$Y_t = C_t + Z_t \quad \ldots\ldots\ldots\ldots \quad (3.18)$$

shows this fact.

This model system has two structural equations, two endogenous variables (C_t and Y_t) and one exogeneous variable (Z_t). Here, some of the regression assumptions will not be fulfilled, because C_t and Y_t are both random variables and are not independent of u_t. Then ordinary or generalised least squares estimation techniques will not be applicable, since they produce biased and inconsistent estimators of the parameters (β_0 and β_1). Several techniques were devised and presented to deal with the estimation of simultaneous equations model, such as the use of Instrumental Variables in place of Y_t (which may be related to it but not to U_t), and different estimation procedures, like Indirect least squares (ILS), Two Stage Least Squares (**2SLS**), and others.

The intention of this section is to present the general form of Simultaneous equations model and to consider one method of estimation, preferably Two stage Least Squares, to explain the steps followed in brief detail. Our discussion refers to Johnston (1984. Chapter 11).

Suppose, we have a model containing G linear relationships expressed in the structural equations of the form,

$$\underline{Y}_i \Gamma_i + \underline{X}_i \underline{\beta}_i = \underline{U}_i, \text{ for } i = 1, \ldots, G \quad \ldots\ldots\ldots\ldots \quad (3.19)$$

where, $\underline{Y}_i$ and $\underline{X}_i$ are vectors of endogenous and exogenous variables in the ith structural equations of the model, respectively. $\underline{\Gamma}_i$ and $\underline{\beta}_i$, respectively are vectors of parameter coefficients corresponding to the endogenous and exogenous variables of the ith equation. $\underline{U}_i$ is a random variable for the ith structural equation.

Collecting the G equations together the general matrix notation of the model may be given by:

$$Y\Gamma^T + XB^T = U \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.20)$$

where, Γ and B are matrix of coefficients with G x G and PXG elements, respectively, collected from the G equations in (3.19), assuming G endogenous and P exogenous variables are present, represented in matrices Y and X, respectively, with n observations per column. U is matrix of elements of random variables $\underline{U}_i$.

Given equation (3.20), the **structural form** of the model, its **Reduced form**, expressing the endogenous variables in terms of all exogenous variables may be stated as:

$$Y = X\Pi^{T} + V \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.21)$$

where, $= -B(\Gamma)^{-1}$ and $V = U(\Gamma)^{-1}$.

The 2SLS estimation process makes use of the above two forms of the model, i.e. structural and reduced forms. (We will assume here that the identification problem present in simultaneous equations estimation may be satisfied). [see Johnston (1984) for more detail].

To apply 2SLS estimation, the simplified forms of equations (3.20) and (3.21) are used, as will be explained below. Suppose one of the endogenous variables, ($\underline{Y}$), of interest can be expressed as the function of other endogenous and exogenous variables in the following format:

$$\underline{Y} = Y_1\underline{\gamma} + X_1\underline{\beta} + \underline{U}_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.22)$$

where Y_1 is matrix of nx(g-1) elements of the(g-1) endogenous variables in the structural equation of $\underline{Y}$, X_1 matrix of (nxk) elements of k exogeneous variables in the same equation, $\underline{U}_1$ an (nx1) vector of error variable. $\underline{\gamma}$ and $\underline{\beta}$ are (g-1) and (k) element vectors of coefficients corresponding to Y_1 and X_1, respectively.

Estimation of Equation (3.22) follows two stages, according to 2SLS regression estimation technique:

Stage (1). Using OLS regression , each of the endogenous variables forming Y_1, say ,$\underline{Y}_{1i}$ for, i = 1, ... g-1, are regressed on all P predetermined exogenous variables in X of equation (3.21), say $\underline{X}_1, \ldots, \underline{X}_p$ That means regress, $\underline{Y}_{1i}$ on $\underline{X}_1, \ldots \underline{X}_p$. Then produce predictions of $\underline{Y}_{1i}$ denoted $\tilde{\underline{Y}}_{1i}$, to form $\tilde{Y}_1$.

Stage (2). Replacing Y_1 by $\tilde{Y}_1$ in equation (3.22), and peforming an OLS regression of $\underline{Y}$ on $\tilde{Y}_1$ and X_1. This produces estimators of $\underline{\gamma}$ and $\underline{\beta}$ that are consistent.

Variables included in $\tilde{Y}_1$ are also known as 2SLS instrumental variables, and are assumed to be uncorrelated with $\underline{U}_1$, unlike those in Y_1's.

Similar analytical procedure can then be applied for the remaining endogeneous variables in the simultaneous equations model, re-expressing each $\underline{Y}_i$ in equation (3.20) in the same format of equation (3.22) and applying 2SLS procedure described above.

CHAPTER 4

THE STRUCTURE OF TOTAL RUNNING COSTS OF HOSPITALS

4.1 Introduction

The hospital is seen as a complex organisation producing a variety of services, in which the resources and activities required to produce them are jointly implemented and used. This is a widely accepted notion. For instance, Berki (1972, p.14), defined hospitals as such. The main services are, inpatients care, outpatient (non-inpatient) care, medical training and research, as well as other community related duties.

In most instances, the hospital cost studies were directed at one or two of the above forms of hospital services. The preference of such specific sectors of hospital activity of course depends on the objectives and interests of the study and above all, on available information. Nevertheless, the question arises as to whether it is possible to isolate the effect of certain types of services and centre the study on a few sets of hospital services via the costs assumed to produce them. Effect of teaching activities on hospital costs have usually been assessed through analysis of inpatient costs. It was not clearly stated, however, whether the effect of teaching activities in generating additional costs were borne only in relation to inpatient care activities of hospitals or the hospitals studied only provide these two types of services. As far as the experience of Scotland was concerned, nearly all hospitals do participate at least in inpatient and non-inpatient care services.

There are studies critical of such an attempt. Berki (1972, p.45) had questioned it by saying that "the view of the hospital as a complex organisation producing a variety of services .... is not generally recognised in the empirical studies. The focus of the analysis is on the production of inpatient care...", and recommended that "the discussion of outputs should recognise, and empirical research should explicitly incorporate, the multiplicity of inpatient and non-inpatient focused outputs and their competing demand for the use of hospital resources." This proposal seems general and appropriate. It is evident that the analysis of hospital costs have not reached a point where all intricacies of hospital operation can be fully grasped in the cost functions already formulated. But approximations could lead to better results than ignoring the facts.

The intention of this part of the paper is to present hospital cost functions identified which it is hoped will respond to the above conceptual problems. The cost function is designed to explain structure of total running costs of Scottish hospitals. The total running costs of a given hospital are constituted of all expenditures in a given year, made to facilitate their general operation. They are spendings for inpatient and non-inpatient care, training and other responsibilities. The chapter will devote itself to describing the specification and definition of variables included in the cost function, the role of specialities in formulating the cost functions, and different economic aspects of hospital operation to be investigated, such as economies of scale and scope. It also tries to explain the estimation aspect of this function of cost in relation to the statistical assumptions needed to be satisfied for its parameters estimaton with the available hospitals data.

4.2 Form of the Total Running Costs Function

The various cost functions proposed in the past studies of hospital costs structure mainly concentrated on hospital inpatient costs. They portrayed differences not only on the mathematical set-up of their models but also on the underlying assumptions to specify the factors that are thought to generate hospital costs. The cost function to be specified in this study refers to that applied by Bailey and Ashford (1984) for total inpatient costs of hospitals. Attempt will be made here to extend that framework to a multi-product cost function, to explain the structure of total running costs of hospitals in Scotland. They argued in developing their cost function that factors measuring hospital resources and services provided are the determinants of total inpatient costs, which we think could be true for total running costs of hospitals, since the latter costs constitute hospital expenditures on inpatient and non-inpatient care as well as clinical training services, from which a possible parallel can be drawn.

The cost function proposed assumes that the total inpatient cost of a given hospital is composed of the costs of treatment care, residential care and provision of facilities generated during the inpatient's effective length of stay, (Ibid, p.248). This idea is incorporated to the total running costs of a given hospital to include costs generated also due to treatment care of non-inpatients and provision of facilities for clinical training. These five sources of total running costs reflects, respectively , the number of in-patient cases treated (**IPC**), occupied bed days (**OCD**) and allocated staffed beds (**BED**) corresponding to inpatient costs, in addition to the number of non-inpatient cases treated (**NIP**) and the extent of teaching undertaken measured in terms of number of undergraduate students (**STDN**) and nurses in training (**NURS**) as well as teaching status (**TS**) of hospitals, for the remaining part of total running costs after deducting for inpatients. Thus, total running costs of a given hospital, i, say TC_i can be expressed in functional form as:

$$TC_i = f(BED_i, IPC_i, OCD_i, NIP_i, STDN_i, NURS_i, TS_i, \underline{Pr}) \quad \ldots\ldots\ldots\ldots \quad (4.1)$$

where TS stands for the three teaching status of Scottish hospitals , either major or minor or non-teaching naming given by their Health Boards, **Pr** stands for prices of factors of production of the different hospital services, (seen as a vector of observations).

The total running costs of Scottish hospitals to be analysed excludes capital costs and payment for 'rates' or local authority taxes. Both expenses may be fixed and were thought unrelated to the day to day running of the hospitals to supply the required patient care and teaching services. Capital costs were already omitted in the published costs data of Scottish hospitals (SHHD, 1986).

It is obvious that the relationship identified in equation (4.1) suffers from the common problem of cost functions of hospitals, in such a way that no formal measure of quality of care and research outputs of hospitals can be included. These two factors may be correlated with the teaching variables.

Economic cost functions at best require the incorporation of prices (P_r) of factors of production specified in the equation, which poses another problem in the cost studies of hospitals. In the British NHS system no market prices are available for hospital factors of production. Official bodies nationally negotiate for wages and salaries of the labour force employed in the hospital sector. Thus, prices referring to labour (manpower) costs are usually assumed the same among hospitals as far as the specification of the cost function was concerned. The remaining part of TC_i, non-labour (supply) costs, may have prices specific to hospitals. But at the time of this study no such information was available. In general, it was presumed - in the Scottish context - national prices may prevail and would be unrelated with the level of outputs of hospitals.

Equation (4.1) does not allow for differences in unit costs of patient treatments within various hospital specialties. We will discuss this in the next section.

4.3 Role of Speciality Groups

Hospital activities are centred around various speciality treatments they provide. These specialities are listed in Appendix 1 for Scottish hospitals. In 1985/86 there were over 50 recognised speciality patient care services available all over hospitals in Scotland. Each speciality service provision utilizes different amounts of resources, in staff time, medical supply, (drugs, dressings, etc.), laboratory tests, etc. Thus, it becomes natural to base the specification of cost functions allowing for variation in hospital cost structure in terms of their specialities.

The ideal preference would be to take care of each of the 50 odd specialities separately. However, drawbacks exist. Certain specialities are only available in few hospitals and explicitly including them requires severe demands in data and analytical time. Also there could be interpretation problems from such extensive undertakings. That was why almost all similar studies in the past made attempts to combine individual specialities which were thought to exhibit resemblance in resource utilization and cost characteristics, to form speciality groups. This study made use of speciality grouping developed by the Scottish Common Service Agency. This is given in Appendix 1. The speciality groups are thought mutually exclusive and contain some form of homogeneity in the specialities contained in them, for instance, similarity in their resource use.

The effect of case-mix differences between hospitals has been widely accredited as having influence on their cost structure, mainly on inpatient costs. Our cost function being outlined does not directly include any of the previously developed case-mix measures presented in several cost studies. It is possible to present several reasons for doing so. The case-mix measures developed are neither uniform nor universally accepted. Their formulation was based on some complex statistical techniques, such as Information Theory, principal components analysis and the like, making interpretation of the empirical results difficult. Findings on the effect of case-mix are also conflicting. The result depends on the types of hospitals studied. Studies mostly based on highly variable hospitals, say in size, and patient care service mixes found case-mix (effect) to be one of the main factors explaining cost structure variations between hospitals. However, as will be made clear in Chapter 5, the sample of hospitals to be analysed by us are selected:

(i) having some similarity in the type of patient care services they provide;
(ii) constrained to include hospitals with similar scale of activity (in number of beds)
(iii) restricted in respect of some speciality mixes; they have, for example, hospitals with large long-stay speciality beds were excluded.

This we think minimizes the effect of case mix variation existing between them. In addition, Stein (1980) had also found that case-mix measures of 45 Scottish hospitals do not contribute to explain their unit cost variation. It is true that our sample includes more numbers of teaching hospitals, compared with Stein's sample of hospitals, but they have common ground, being both from Scottish hospitals.

That was not the main reason to exclude specific case-mix measuring variables from the cost function. We think the use of speciality grouping helps to solve those problems with respect to case-mix factor. According to Bailey and Ashford (1984, p.24): " case-mix variations within speciality do not have an appreciable effect. For this reason patients were disaggregated by speciality group, ... ". By the same token case-mix variations within speciality group composed of specialities with similar resource use may not be significant. In Bailey and Ashford's study different case-mix measures were studied by aggregating patients with respect to age, sex, diagnostic case-mix and specialities etc. Of these groupings that according to specialities led them to conclude the above quoted. In view of the explanatory power of their cost model variables with estimated multiple correlation coefficient (R^2) of about 98%, the influence of excluding case-mix measures may not have been severe.

The aggregation of specialities according to groups applies only to inpatient care services. That is the variables denoted BED, IPC and OCD in equation (4.1). There are 7 speciality groups formed. But Mental Handicap (**MH**) speciality group has been excluded as will be explained later in Chapter 5, while discussing the data. Therefore, the remaining 6 are to be used. They are denoted by **DGH**, **LS**, **SA**, **OBS**, **MI**, and **SC** speciality groups (see Appendix 1). This grouping, however, does not apply to the non-inpatient services, measured by the number of non-inpatient attendances (NIP). Instead, five forms in which the different non-inpatient services provided are implemented, namely, Consultant (**CNSL**), Ancillary (**ANCL**), Accident and Emergency (**ACDN**), Day-patients (**DPAT**) and Day Cases (**DYCS**) out-patient services. That means, in these classes of outpatient services the various specialities given at each of them were put into a single group - one for each.

Thus, the total running costs function presented in Equation (4.1) can be reformulated in the following form:

$$TC_i = f\,(\underline{BED}_{ij}, \underline{IPC}_{ij}, \underline{OCD}_{ij}, \underline{NIP}_{ik}, \underline{TEACH}_{im}, \underline{Pr}) \;\ldots\ldots\; (4.2)$$

The $\underline{BED}_{ij}$, ..., $\underline{TEACH}_{im}$ and $\underline{Pr}$ are now vectors representing raw elements of set of variables. The full definition of these variables will be presented in Section 4.8 at the end of this chapter.

4.4 Effect of Multicollinearity between Variables

Consider the exogeneous variables listed in the right hand side of Equation (4.2) above. Of these variables, collinearity among BED_j, IPC_j and OCD_j is strong. This is because of the fact that more inpatient cases are comparably treated in large hospitals and these patients do occupy more beds. This interrelationship raises problems of multicollinearity, indicating that if the cost model is to be estimated with the notion that all regression assumptions are being satisfied and ordinary least squares are applied, then inference about the estimated coefficients will be violated. The consequence of the problem statistically is that standard errors of the coefficients of the model will be overstated and thus the effect of each variable will not be grasped independently of others.

Like Bailey and Ashford (1984, pp.250-251), we take two routes to counter such problems of multicollinearity. One, to: "model each of the several components of costs separately in preference to treating total costs as single entity". The cost components are medical staff, nursing staff, catering and pharmacy supply, etc. costs of hospitals making its total running costs. This will be covered under the analysis of cost components of total running costs of hopspitals in Chapters 7 and 8. The second attempt was to reformulate the inpatient care, bed use measuring variables, IPC_j and OCD_j, in such a way that they can be expressed in terms of 'excess' patients discharged and 'excess' occupied bed days, above a certain average value. This was thought to reduce multicollinearity existing between them and the BED_j variables too. We incorporate this approach here.

For a given hospital i with speciality group j , expected IPC_{ij} and OCD_{ij} were calculated using the Scottish national average bed-use, measured by occupancy ratio ($\overline{OCR}_j$) and case flow rates ($\overline{CFR}_j$), respectively. $\overline{OCR}_j$ and $\overline{CFR}_j$ are presented in table 4.1 for each speciality group. There are about 303 Scottish hospitals in 1985-86 fiscal year which formed the target population of the analysis as will be described in the next chapter. Both values of the national average bed-uses are calculated based on all the hospitals in the following way:

$$\overline{\mathbf{OCR}}_j = \sum_{i=1}^{303} \mathbf{OCD}_{ij} \Big/ \left(\sum_{i=1}^{303} \mathbf{BED}_{ij} \times 365\right) \text{, and}$$

$$\overline{\mathbf{CFR}}_j = \sum_{i=1}^{303} \mathbf{IPC}_{ij} \Big/ \left(\sum_{i=1}^{303} \mathbf{BED}_{ij} \times 365\right),$$

for j = 1, ... 6, representing speciality groups.

Then, the expected occupied bed days ($\mathbf{EOCD}_{ij}$) and expected inpatient cases treated ($\mathbf{EIPC}_{ij}$) for speciality group j of hospital i were computed from:

$$\mathbf{EOCD}_{ij} = \mathbf{BED}_{ij} \times \overline{\mathbf{OCR}}_j \times 365 \text{, and,}$$

$$\mathbf{EIPC}_{ij} = \mathbf{BED}_{ij} \times \overline{\mathbf{CFR}}_j \times 365, \qquad \text{for} \quad j = 1, \ldots, 6, \text{ respectively}$$

These figures imply that a given hospital i with speciality j would be expected to have $EOCP_{ij}$ inpatient occupied bed days and $EIPC_{ij}$ inpatient cases discharged if its bed occupancy ratio and case flow rates coincide with that experienced nationally, on the average.

The 'excess' occupied bed days and 'excess' inpatient cases, denoted by $\mathbf{EXP}_{ij}$ and $\mathbf{EXC}_{ij}$, respectively, for speciality group j of hospital i was then calculated as differences between relevant actual and expected values. Mathematically they can be expressed as:

$\mathbf{EXD}_{ij} = \mathbf{OCD}_{ij} - \mathbf{EOCD}_{ij}$, for excess occupied bed days, and

$\mathbf{EXC}_{ij} = \mathbf{IPC}_{ij} - \mathbf{EIPC}_{ij}$, for excess inpatient cases.

EXD_{ij} and EXC_{ij} are sorts of residuals from average values and have either negative or positive values. Positive EXD_{ij} and EXC_{ij} is an indication that the hospital operates above the national bed-use experience and vice-versa. In such cases the hospital would have relatively smaller length of patient stays than the national average and possibly higher cost per inpatient weeks too.

Therefore, reformulating the total running cost of hospital functions presented in equation (4.2), we have a relation given by:

$$\mathbf{TC}_i = \mathbf{f}\ (\underline{\mathbf{BED}}_{ij}, \underline{\mathbf{EXC}}_{ij}, \underline{\mathbf{EXD}}_{ij}, \underline{\mathbf{NIP}}_{ik}, \underline{\mathbf{TEACH}}_{im}, \underline{\mathbf{Pr}}) \quad \ldots\ldots\ldots \quad \mathbf{(4.3)}$$

From this the basic form of the structure of total running costs of hospitals can be approximated as:

$$\mathbf{TC}_i = \alpha_0 + \sum_{j}^{6} \alpha_j\, \mathbf{BED}_{ij} + \sum_{j}^{6} \beta_j\, \mathbf{EXC}_j + \sum_{j}^{6} \theta_j\, \mathbf{EXD}_{ij} + \sum_{k}^{5} \gamma_k\, \mathbf{NIP}_{ik}$$

$$+ \sum_{m}^{4} \tau_m\, \mathbf{TEACH}_{im} + \mathbf{u}_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(4.4)}$$

where, assumed $\mathbf{u}_i \sim N(0, \sigma^2)$ - (but see section 4.6)

i, stands for hospital i, i=1, ..., n

j, stands for speciality group j, j = 1, ..., 6. ,in such a way that, j = 1, denotes

DGH, ..., j = 5 denotes MI, and j = 6 denotes SC speciality group.
k stands for non-inpatient classes, so that, k=1 denotes, CNSL, ..., upto k = 5, denoting DPAT;
m stands for the different measures of teaching activity of hospitals, such that, m = 1 denotes STDN, m = 2 denotes NURS, m = 3 denotes major teaching status (MAJOR), m = 4 denotes minor teaching status (MINOR).

Therefore, BED_1, EXC_1, EXD_1, NIP_1 and $TEACH_1$ are abbreviated as BEDDGH, EXCDGH, EXDDGH, NIPCNSL and TEACHSTDN, respectively. The others follow the same nomenclature.

α_0, α_j, β_j, θ_j, γ_k, and τ_m are parameter coefficients for estimation.

Formally they may be interpreted - with the exception of α_0, τ_3, τ_4 - as the marginal costs of providing an additional unit of the respective resources or services they intend to represent, corresponding to patient care or medical teaching. Since marginal costs should have positive magnitude, thus, their expected values should be greater than zero. But note that, due to definitions of EXC_j and EXD_j [see above] marginal costs of BED_j and that of EXC_j and EXD_j are interrelated. Because by definition:

$$\mathbf{MC(BED_j)} = \partial \mathbf{TC} / \partial \mathbf{BED_j} = \alpha_j + \partial(\beta_j \mathbf{EXC_j} + \theta_j \mathbf{EXD_j}) / \partial \mathbf{BED_j} \quad \ldots\ldots \quad \mathbf{(4.5)}$$

Where, ∂ is the partial derivative function. $\mathbf{MC(BED_j)}$ denotes the marginal cost of providing one additional bed to jth speciality group inpatient services, keeping the effect of other factors constant. . We will describe this in some detail in Chapter 6, table 6.4.2 . The coefficients, α_0, τ_3 and τ_4 may be interpreted as average overhead costs. This means, α_0 measures average overhead costs, common to all hospitals being analysed. Whereas, τ_3 and τ_4 measure the average overhead costs of major and minor teaching hospitals in excess of overhead costs of non-teaching hospitals.

' These overhead costs can be interpreted as measures of expenses incurred to hospitals providing neither patient care nor teaching services. Their expected values are assumed unknown.

4.5 Economies of Scale and Scope

Equation (4.4) above represents the basic set-up of the total running costs function. There are needs to reformulate this cost function in order to investigate the existence of economies of scale and scope influence in the operation of NHS Scottish hospitals. The concept of economies of scale, to put it simply, implies the proportional relationship between the increment in the scale of activity of hospitals to provide a given service and the subsequent change in its costs. As an example, if there is evidence showing that hospital costs on the average proportionally seem to decrease with an increase in its operational capacity, measured usually in terms of allocated staffed beds, then the costs are said to exhibit internal economies of scale. Hence, the hospital can have a benefit from enlarging its level of output via providing more facilities. On the contrary, the reverse of this relationship between change in hospital size and the costs incurred manifests diseconomies of scale.

The methodologies proposed to investigate the effect of economies of scale in similar cost studies usually involve the use of variables measuring hospital beds and patients discharged in their cost models. In our case as will be shown in Chapter 6, several specifications of equation (4.4) will be tried by adding quadratic and cubic order terms of BED_j and NIP_k variables.

The other aspect of cost analysis focuses on what is called economies of scope. The main implication of economies of scope is that, hospitals which combine activities cost less to run than hospitals providing them separately. According to Cowing et al. (1983, p.267): " Given economies of scope, the resource costs of producing the services jointly - that is, together by a single hospital - will be less than the sum of the individual costs of producing each service separately - that is by hospitals each specialising in a single (or subset of) service(s)...." . Thus, diseconomies of scope signifies cost ineffectiveness due to joint production. We might expect, naturally, the cost of patient care and teaching to be minimized within a hospital producing both of them together, rather than in two different hospitals, one specializing in patient-care services and the other on teaching of medical students. Hence, economies of scope may prevail.

The notion of economies of scope can be illustrated mathematically as saying, for example, that $TC(Y_1, Y_2) < TC(Y_1, 0) + TC(0, Y_2)$, if there is economies of scope in the total running costs of a certain hospital, producing two types of services, Y_1 and Y_2. Where, $TC(Y_1, Y_2)$ means total running costs of the hospital while jointly producing Y_1 and Y_2, and $TC(Y_1, 0)$ and $TC(0,$ $Y_2)$, respectively, mean total running costs incurred in separate production of Y_1 and Y_2 in two different hospitals.

Advising on how to make inference about economies of scope in the hospital sector they continued:"A more appropriate econometric framework would be the multi-output cost function that allows the marginal cost of any individual services to depend upon a variety of variables including the levels of other services being provided...." (Ibid, p. 267).

There is limited application in the literature about studies of economies of scope and how the mathematical expression of the cost functions should be formulated appropriately. Our analysis incorporates interaction variables between the different sets of variables listed in equation (4.4). The assumption was that if there seems to be influence of economies of scope due to the presence of various services (in the hospital) represented by the set of variables in the model, then there should exist a possibility of their interacting.

Economies of scope due to presence of different specialities in inpatient activity will be tested through the inclusion of $\mathbf{BED_j \times BED_l}$, type variables within BED_j variables. Similarly that existing between inpatient and non-inpatient care activities will be tested using $\mathbf{BED_j \times NIP_k}$ variables.

Economies of scope expected due to teaching activity undertaken with other hospital activities will be studied employing $\mathbf{BED_j \times TEACH_m}$ and $\mathbf{NIP_k \times TEACH_m}$ interaction variables.

Finally, collecting those variables outlined from Section (4.3) up to the present, together, the full specification of the total running costs model was assumed to be expressable in the following equation:

$$TC_i = \alpha_0 + \sum_j^6 \alpha_j BED_{ij} + \sum_j^6 \beta_j EXC_{ij} + \sum_j^6 \theta_j EXD_{ij} + \sum_k^5 \gamma_k NIP_{ik}$$

$$+ \sum_m^4 \tau_m TEACH_{im} + \sum_j^6 o_{j1} BED^2_{ij} + \sum_j^6 P_{j1} BED^3_{ij}$$

$$+ \sum_k^5 q_{k2} NIP^2_{ik} + \sum_k^5 P_{k2} NIP^3_{ik} + \sum_{j}^6 \sum_{l}^6 {}_{j \neq l} q_{jl} (BED_{ij} \times BED_{il})$$

$$+ \sum_j^6 \sum_k^5 r_{jk} (BED_{ij} \times NIP_{ik}) + \sum_j^6 \sum_m^4 s_{jm} (BED_{ij} \times TEACH_{im})$$

$$+ \sum_k^5 \sum_m^4 t_{km} (NIP_{ik} \times TEACH_{im}) + u_i \qquad \text{..........} \quad (4.6)$$

Where, assumed $u_i \sim N(0, \sigma^2)$

$\alpha_0, \alpha_j, \beta_j, \ldots, s_{jm}$ and t_{km} are model parameters to be estimated.[All j,k,l,and,m start from 1 in the equation].

From this equation we are able to see that the derivation of marginal costs of a given hospital service provision depends on the level of the other services. In such multi-product nature of hospital operation difficulties arise on how to distinguish the influence on costs by altering the level of one type of service, without allowing for the effects that might be induced as a result of the level of provision of the other services. This point has been discussed by Cowing et al. (1983), but seems far from furnishing concrete solutions. The approach taken by us in this respect will be made clear in the coming chapters, while presenting empirical results obtained from the above model fitted to the available Scottish hospitals data.

But to state it simply here, we took an ad hoc action which seems to us practicable in view of these difficulties and data limitation. Because the sample of hospitals at our disposal (or that we have chosen) are only 81, the possibility of incorporating all the variables specified in equation (4.6) and estimate their coefficients seem technically unjustified. Therefore, a process of model building approach was adopted to select the 'best' subset of variables that can adequately approximate the variability in the total running costs of the hospitals being studied. From this outcome we also look at whether the variables thus selected related to economics of scale and scope concepts and hence affect the cost structure of the hospitals.

In selecting the above scale and scope variables we have based our conclusion (criterion) by testing for the significance of appropriate coefficients of variables in the above model given in equation (4.6). In the absence of no apriori uniformly accepted knowledge the best possible alternative we thought thus relies on statistical grounds.

4.6 Problem of Hetroscedasticity

Simpler versions of the above cost function had been implemented in several hospital inpatient cost studies, Bailey and Ashford (1984), Popplewell (1982) and Ho (1983) to name a few. All of them in their study of cost structures of different sets of NHS hospitals rejected the Homoscedasticity (constant variance) assumption made about variance of total costs of hospitals. Therefore, estimation of the cost-models parameters through ordinary least squares (**OLS**) method was found inappropriate. Weights were proposed to apply the weighted least squares(**WLS**) or to transform the model variables and use OLS technique to estimate their coefficients.

Bailey and Ashford (1984, p.254), indicated that $\mathbf{Var(C_{ki}) \propto B_i}$, where C_{ki} is the cost component of the total inpatient cost of hospital i and $\mathbf{B_i}$ is total available bed-days of the same hospital. ($\propto$ stands for 'proportional to'). However, the above remaining listed researchers, Popplewell (1981, Table 2) and Ho (1983, p. 45), opted to accept that, $\mathbf{Var(C_i) \propto (TB_i)^{1.7}}$, where C_i is total inpatient costs of hospital i in their study and TB_i is its total allocated staffed beds .

These suggestions were based on the analysis of the estimated values of the error variable, or estimated residuals and some plots of these. The truth of the non-constant variance of total running costs in our case can be seen from figure 4.1, Scatter plot of TC_i with the total allocated staffed beds (TB_i) for a sample of 81 Scottish hospitals to be studied. Clearly, $Var(TC_i)$ increases with the size of the hospital, measured in TB_i. [The data used for the plot is 1985-86 fiscal year].

Prior to embarking into the present work, we have performed an extensive analysis about the influence of hetroscedasticity of variance in fitting a model of total inpatient cost of Scottish hospitals based on data for 1979 fiscal year. However, due to time constraint the analysis was not repeated for the year 1985-86 which is the basis of this work. The technique of analysis applied was that described in Johnston (1984, pp.298-302) ('Statistical Tests of Hetroscedasticity'). The aims were to prove whether there is indeed such non-constant variance influence and try to approximate the form of weights required to apply appropriate least squares estimation method.

The finding confirms what is seen from figure 4.1. Out of different alternatives tried, the statistical evidence suggests that the variance of total inpatient costs might depend on the total allocated staffed beds of hospitals. Although, it was not possible to confirm exactly that a specified mathematical relationship exists between $Var(C_i)$ and TB_i like the ones reported by the above analysts , there was an indication from our analysis that some form of association prevails between them. The evidence seems to be stronger if assumed $Var(C_i) \propto TB_i$; since there was no conclusive evidence to assume otherwise, the estimation process to be discussed shortly accepts also that:

$Var(TC_i) \propto (TB_i)$, implying, **$Var(TC_i) = \sigma^2 TB_i^{1.7}$** ; $\sigma^2 > 0$, unknown constant. Where, TC_i is total running costs and TB_i is total staffed beds allocated by hospital i. $i = 1, \ldots, n$. Also this usage helps for comparative purposes.

Either by multiplying the right and left hand side of the equations presented in the last section by $TB^{-0.85}$ the cost models will be transformed ready for applying ordinary least squares estimation. Or as we did in Chapters 6 - 8, these weights can be used to fit models implementing weighted least squares techniques, with $TB^{-0.85}$ used as weights. The assumption made about U_i, the random error variable becomes: **$U_i \sim N(0, \sigma^2(TB_i)^{1.7})$**, $i = 1, \ldots, n$, in equations (4.4) and (4.6).

4.7 Simultaneous equations problem

The total running cost functions presented in section 4.5, equation (4.6), assumes that the dependent variable total running costs of hospitals is determined by the set of independent variables, namely BED_j, EXC_j, EXD_j, NIP_k, $TEACH_m$, and the remaining others. The relationship is one-sided. That is to say, the level of funding of hospitals is dependent on the amount of beds and the level of bed-use already attained to provide its patient care and/or teaching services with no extra conditions attached to the latter factors (beds and bed-use). If this assumption holds, then the estimation of the cost function can readily be undertaken through ordinary or generalised least squares techniques as need be.

However, complications arise if there are grounds for believing that the exogenous variables might depend upon the resources at the hospital's disposal, such as medical or professional and technical staff available to it.

which in turn influences the level of its expenditure. For instance, the number of patients admitted and discharged might depend on the decision of the physician. The problem magnifies in the event of analyses of cost components of total running cost of hospitals which are composed of staff and supply cost components. Since there is believed to be such simultaneous relationship in the hospital sector, then some of the variables of the cost function, especially the EXC_j, EXD_j and NIP_k would not be strictly exogenous predetermined variables (such views have been expressed by Feldstein (1967) and Sloan et al. (1983). [Also see Chapter 7 for details].

This calls for the simultaneous equation problem approach in econometric analysis. The above variables and u_i (error variable) in the cost function specified are no longer independent as required and leads to inconsistent and biased coefficient estimates if the OLS or GLS methods of model estimation are applied. Two approaches were taken towards tackling this problem. They are:

a) To assume no such simultaneous relationship between costs and the variables determining it, and/or if it does, its effect is negligible. Hence, the regression assumptions are believed to be satisfied in this respect. The assumptions seem justified at the level of the total running costs, but not guaranteed at the cost component level.

Based on this approach, the cost functions were estimated both for total running costs and its cost components to be discussed in Chapters 6 and 7, respectively. The total running cost model to be adopted for explanation and other purposes of the study was investigated and chosen, using this approach.

b) To accept that there may exist such a simultaneous relationship between the model variables. Thus, EXC_j, EXD_j and NIP_k become endogenous variables. This approach requires the adoption of simultaneous equation estimation procedure. Structural equations will be specified for the above variable assumed endogenous and the two stage least square estimation technique will be applied. Full discussion and empirical results for this approach are outlined in Chapter 8 for total running costs and its components.

Clearly approaches (a) and (b) can produce different empirical results and interpretations. The intention for doing so will be dealt with in Chapter 8 in conjunction with the empirical results from the analysis.

4.8 Full Definition of Variables

Consider the total running costs (TC) models developed on the above sections. Before departing to introduce the data used in the estimation aspect of this model we present here definitions for the linear variables in equation (4.6).

1. Dependent Variable

1.1 Total Running Costs (**TC**): This is the total expenditure incurred to the hospital net off capital costs, such as depreciation and building costs, and local authority taxes or rates. Costs refer to the full operating costs of the hospitals throughout a 12 months period fiscal year ending 31st March. [Also date reference for all the following variables, except where stated, is the same).

2. Independent Variables

2.1 Allocated staffed bed (**BED_j**): This is the average number of beds the hospital provides in a given speciality group throughout a 12 month period, while maintaining an acceptable level of staff provision. The data for this variable was computed from the total number of staff bed days allocated to the jth speciality group of the hospital, within the year under consideration, divided by 365 days. BED_j may differ from the maximum number of available beds - which includes borrowed, loaned and temporarily assigned beds within different speciality groups or other hospitals - mainly as a result of shortage of staff.

2.2. Excess inpatient cases (**EXC_j**): This gives the difference between the actual and expected number of inpatients discharged and/or deaths from the jth speciality group of the hospital, throughout a 12 month period. The expected number of inpatient cases is the product of allocated staffed beds (BED_j) and the Scottish national average case flow rate per year of each speciality group j.

2.3. Excess occupied bed days (**EXD_j**): This gives the difference between the actual and expected occupied bed days of the inpatient service of the hospital in the jth speciality group throughout a 12 months period. The expected occupied bed days of jth speciality group is the product of allocated staff bed days (BED_j x 365) and Scottish national average bed occupancy ratio. Occupied bed days refer to the available bed days of the hospital and hence can be larger than its allocated staffed bed days .

2.4. Non-inpatient attendances (**NIP_k**): The following variables represent the five measures corresponding to the non-inpatient care services provision of Scottish hospitals.

2.4.1. Consultant outpatient attendance (**NIPCNSL**). This is the total number of outpatient cases treated throughout a period of 12 months.

2.4.2. Ancillary outpatient attendances (**NIPANCL**). This gives the total number of outpatient cases treated at the Ancillary department or session of the hospital throughout a 12 months period. Physiotherapy and other auxilliary services are examples of ancillary treatments.

2.4.3. Accident and Emergency Outpatient attendances. (**NIPACDN**). This is the total number of outpatient cases treated in the Accident and Emergency department of the hospital throughout a period of 12 months.

2.4.4. Daypatient Attendances **(NIPDPAT)**. This is the total number of outpatient cases treated in the day and night patient departments or session of the hospital throughout a period of 12 months. The difference between day-care and day patient departments is that the latter provides particularly services for mental illness and mental handicapped type patients.

2.4.5 Daycase attendances (**NIPDYCS**). This represents the total number of outpatient cases treated in the Daycase inpatient facilities and day-stay bed unit department or sessions of the hospital through a 12 months period.

2.5 Teaching activity measures ($\mathbf{TEACH_m}$)

2.5.1 Undergraduate Medical Students (**STDN**): This is the weighted number of undergraduate medical students that were in training for one academic year in the given hospital. (Full description will be presented in Chapter 5). The data excludes dental medical undergraduate students, also complying with the exclusion of dental hospitals among the hospital to be analysed.

2.5.2 Nurses in Training (**NURS**): This the weighted equivalent number of nurses that were in training within a 12 month period in the hospital . The data refers to 60% of the nurse time allocated to the hospital's cost. The actual number would be two-thirds larger. Thus,total running costs of the hospital includes 60% of their expenses actually spent on them. The remaining 40% of the nurse-time is assumed to refer to their salary and other employer's costs which are directly charged to the Health Board concerned.

2.5.3 Teaching Status (**TS**): This consisted of dummy variables indicating the level of teaching activity in the hospital. It is a designation given to the hospital by its Health Board possibly based on the amount of facility available for training the medical students. They are basically qualitative variables. There can be three such variables:

MAJOR designates a major teaching hospital, i.e. a hospital where a considerable amount of teaching activities being undertaken [They are hospitals under functional classes 01, 07, 22 and 34 - seeAppendix 2]. The variable has value 1 for such hospitals, and 0, otherwise.

MINOR designates a hospital with some (minor') teaching units but not necessarily wholly teaching. [Hospitals under functional class 2 - Appendix 2]. The variable has a value 1 for such hospitals and 0 otherwise , and ,

CONTROL designates the non-teaching hospitals, hospitals with no or very little teaching activity . It has a value of 1 to represent such hospitals and 0 otherwise.

The teaching activity presumably includes the four teaching hospital responsibility discussed in Chapter 2, section 2.2.

TABLE 4.1. BED USE. NATIONAL RATES * BY SPECIALITY GROUP

Speciality Group	(j)	Case flow rate per year ($\overline{CFR}j$)	Occupancy ratio ($\overline{OCR}j$)	Length of stay (days) ($\overline{LST}j$)
DGH	1	0.087	0.74	8.5
LS	2	0.007	0.97	131.1
SA	3	0.070	0.73	10.4
OBS	4	0.115	0.59	5.1
MI	5	0.005	0.86	184.6
MH	-	-	-	-
SC	6	0.082	0.48	5.9

Note

- omitted speciality group

* see definitions inside, in chapter 4 — 1985/86 Fiscal year data used.

Length of stay = Occupancy Ratio/case flow rate per day

$(\overline{LST}j) = \overline{OCR}j/\overline{CFR}j$

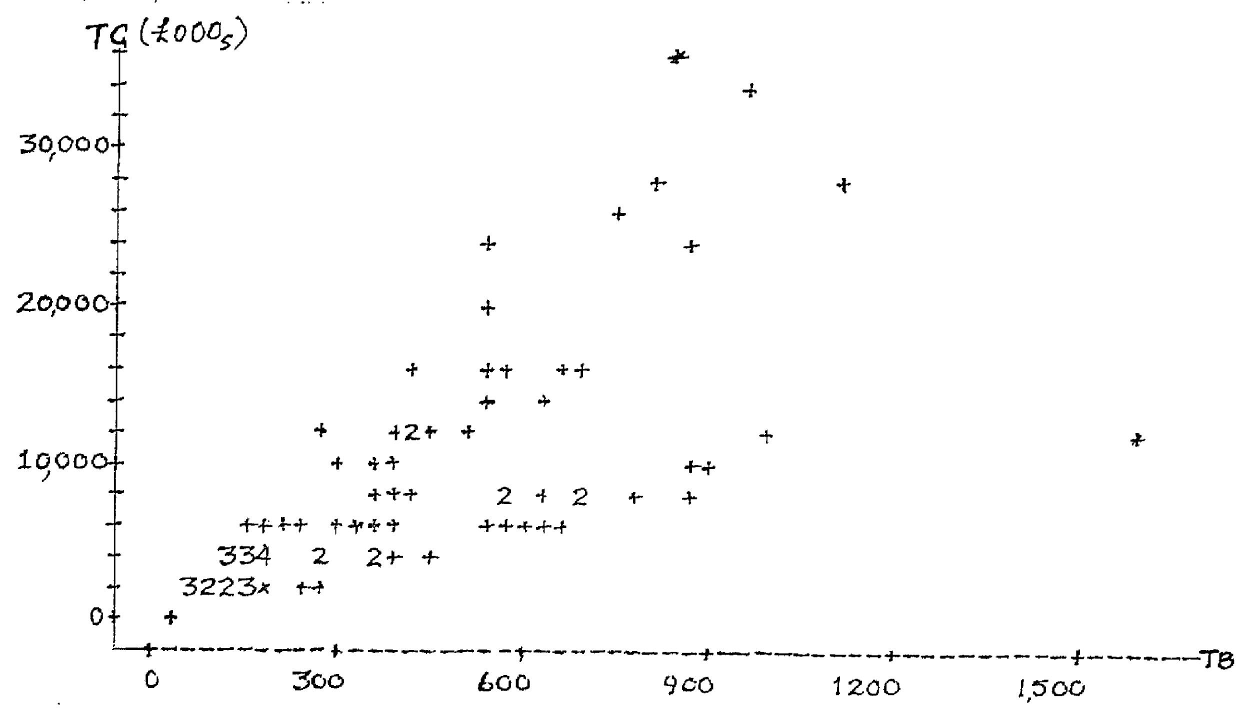


Figure 4.1. Plot of Total Running Costs(TC) vs Total Allocated Staffed Beds(TB) of Hospitals.

(1985/86 fiscal year data used)

CHAPTER 5

THE DATA USED

5.1 Introduction

The data used in this study was gathered from different sources of published and unpublished information specific to Scottish NHS hospitals. The target of the analysis is therefore, directed towards all Scottish hospitals. The data are collected in accordance with the requirements of the model variables specified for total running costs of hospitals in chapter 4. However, information on all Scottish hospitals was not that used in estimating this and other cost models to be discussed in later chapters of our work. Some adjustments were made to get a consistent form of input.

The chapter will describe what was done in organising the available data. The first section focusses on explaining the sources and type of data chosen from them, and how some discrepancies observed between different sources are adjusted to reconcile. The second section tells us about selecting hospitals among the lot to construct a meaningful sample of hospitals data. The last section presents some descriptive statistics calculated from this prepared sample data, for the model variables and compares them between teaching and non-teaching hospitals.

5.2 Sources and Reorganisation of Data

5.2.1 Sources of data

The bulk of data used in this project comes from two main sources. They are from ISD(S)1 and Scottish Health Service Costs, Form 5.

From the ISD(S)1 form hospital type, its unit codes and treatment speciality [see Appendix 1] can be identified. For our study the following data are extracted for each speciality of a hospital:

- Type of hospital and its Unit Codes;
- Treatment Speciality Codes (see Appendix 1);
- Average Allocated Staffed Beds;
- Total Occupied Inpatient (Bed) Days;
- Total Inpatient Cases Treated;
- Consultant Out-patient Attendances;
- Ancillary Out-patient Attendances;
- Accident and Emergency Out-patient Attendances;
- Day-patient attendances;
- Daycase Out-patient Attendances;

Accident and Emergency (speciality code 49) was part of Consultant out-patient attendances. Day-patient attendance includes Night patient attendances from Daycase inpatient facilities and day stay bed unit. The data is collected from the 12 month period beginning from April 1985 to March 31st, 1986.

The second part of the data was drawn upon Form 5 of Scottish Health Service Costs. These constitute:

- Hospital Name and functional Classification (See Appendix 2);
- Hospitals Teaching Status (Major/Minor/non-teaching);
- Total Inpatient and Total Running Costs;
- Departmental Staff and Supply Costs;
- Inpatient and Out-patient Unit Costs (cost per case and cost per patient week); and
- Whole time Equivalent (WTE) Number of Nurses in Training.

The period covered for the data is the same as above, 1985-86 fiscal year. Each type of data coincides with the model variables, defined in chapter 4, section 4.8, and are self-explanatory. Therefore, we refrained from elaborating further on them.

The last, but important, section of data was drawn from Information directly supplied by the Scottish Common Health Service Agency on Medical and Dental undergraduate students training for 1982-83 Academic Year. There was difficulty in acquiring the actual number of students training at each hospital and Health Board as well as for the same period as the other data we have (ie. 1985-86 fisal year). These made it necessary to undergo some computational reformulation of the data supplied to produce estimates of actual figures. Through manipulation of the different data supplied on students the weighted equivalent number of medical undergraduate students was derived for the 1982-83 Academic Year (AY) as explained in Appendix 3. This data is a necessary factor for the objective of this study, and hence, it must be made consistent with the other data outlined above. Therefore, some assumptions were made in using the data; for example assuming that the distribution of the number of students directly depends on the amount of student hours spent at each hospital, and that there may not be dramatic change in the number of students trained in the AYs from 1982-83 up to 1985-86. With these assumptions in mind, a derived weighted student number was used as an estimate for 1985-86. Also assumed was that the number of students trained within any AY (October to September) would be similar to a comparable number that might be proposed for any financial year (April to March).

The data breakdown for Medical students excludes Dental students due to the unavailability of adequate information by hospitals for some Health Boards. Additionally it is expected that the clinical activity implemented in training Dental studens may be lower than for Medical students, which implies a separate estimate would have to be made for them. Since most of the education for these students are given at the Dental hospitals, none of them are included in the sample of hospitals to be studied as to be seen below.

5.2.2 <u>Reorganisation:Excluded and Combined Hospitals</u>

The two main sources of data, IDS(S)1 and Form 5, should have supplied information essentally on the same set of hospitals. That is the same coding and total number of hospitals. However, discrepancies were observed.

Generally four adjustments were made to create consistency between the two sources in respect of the following problems cited:

(i). Different codes were used for some hospitals.
They are;

- St. Brendan Hospital,
- Royal Edinburgh Hospital, and
- Glenrothes Hospital.

In Form 5, W105H, S223H and F713H were reported to be the codes of these hospitals, while in ISD(S)1, they were coded W106H, S299H, and F716, respectively. This later set of codes is adopted throughout.

(ii). Some hospitals appear twice in Form 5 and once in ISD(S)1. These are Ayrshire Hospital (A103H), and Victoria Infirmary (G306H). Both are separated into two hospitals, on the basis of their speciality treatments given on ISD(S)1. Thus, Ayrshire became Ayrshire Central (A103H), a geriatric Hospital, and Ayrshire Maternity Hospital (A103H). Victoria Infirmary, became Victoria Infirmary (G306H), a Maternity hospital and Victoria Geriatric Unit (G307H).

(iii). Some hospitals appear twice in Form 5 and once in ISD(S)1: This is similar to (ii) but rather than deviding them in to two they were combined to form one hospital. These hospitals are:

- Inverclyde Royal (C313H) was combined with Lanarkfield Children's Unit Day hospital (C313E),
- Coathill hospital (L103H) was combined with Coathill day hospital (L103E),
- Bilbonhill hospital (N491H) was combined with Bilhonhill day centre (N491E),

The codes for the first hospital mentioned in each case are adopted.

(iv) Some hospitals (units of other main hospitals) appear twice or more in ISD(S)1, but only once in Form 5. The following combinations were formed:

- G503H & G512H to give G503H
- F712H & F715H to give F712H
- S114H & S1154 to give S114H
- N141H & N184H to give N141H
- N182H & N183H to give N182H
- N194H & N198H to give N198H
- S216H, S217H, S218H, S219H, S222H, S223H, S224H, S229H, S231H, S232H, S242H & S299H to give S299H
- S214H, S230H, S240H & S241H to give S214H

The respective data of each combination of hospitals were reorganised accordingly. This reconstruction produced 352 hospitals with complete data in Form 5. But some of these hospitals, listed especially under functional classes 44 to 49, were reported to be "individually comparable with any other unit and where costs would not be expected to run parallel with any other hospitals in the full list." SHHD (1986, p28). Furthermore, no data was given for some of these hospitals in ISD(S)1. Hence all hospitals in functional classes 45 to 49, three others from class 44 and all Dental hospitals were excluded from further consideration in the analysis, leaving 303 hospitals, common to both forms as required. Those hospitals became the target population of Scottish hospitals from which a sample of 81 specific hospitals were selected for the analysis of this study. A full explanation will be given in the following section.

5.3 Non-Teaching Hospitals Selected as Control Groups

5.3.1 Why selective use of hospitals?

Under the management of 15 regional Health Boards, the above 300 or more Scottish hospitals are distributed. Of these hospitals only 33 participate in Clinical training. They are mainly distributd between four Health Boards.

Furthermore, there are about 49 functional categories into which all hospitals are classifiable on the basis of the types of health services provided at each hospital. [see Appendix 2]. According to 1986 Scottish health service costs published information, the teaching hospitals are only functional classes 1, 2, 7, 22 and 34; while the remaining goes to the non-teaching hospitals. Teaching hospitals are designated also, either as major (classes 1, 7, 22 and 34) and as minor (class 2) teaching type depending on the extent of training undertaken at the centre.

Teaching and non-teaching hospitals do not only differ in the extent of services but in the size of services or facilities provided. Teaching hospitals are mainly larger in size, measured in average number of allocated staffed beds, and have generally either Supra-Area or Special-Category Specialities, with the exception of major teaching, psychiatry hospitals. In contrast non-teaching hospitals are comparatively small-sized and most lack facilities for the two mentioned specialities, (only 40 out of more than 270 have at least one of them). In addition it is evident that some of the non-teaching hospitals are practically incomparable with the teaching ones; for instance like the GP (General Practitioner) and Cottage non-teaching hospitals, due to their limited operational activities.

It was from these points that we tried to form an alternative sample of hospitals, to be used as a basis of the analysis. This made it necessary to select a group of non-teaching hospitals, to be used as a control group, based on some preconditions being satisfied.

This form of selective use of sample of hospitals was not a new practice. WPRA in their study of hospitals in Scotland (SHHD, 1977) and RAWP, for similar purpose in England and Wales (DHHS, 1976) and others had applied it practically. The well known '45-sample' hospitals of RAWP was the sources to provide the 'base line' costs of English teaching hospitals in the development of SIFT. Also, WRPA had chosen a group of non-teaching hospitals that was classified, at the time under functional categories 11, 12, 25, 35 and 42 to compute the equivalent costs of teaching hospitals. WRPA's preference for these hospitals stems from the fact that hospitals in classes 11, 12, and 42 provide DGH and pediatrics;

classes 25 provided Obstetrics and classes 35 psychiatry type services, which correspondingly identify with similar types of services given in the teaching hospitals; DGH and pediatrics in class 1, 2, 7 and 41, Obstetrics in class 22, and psychiatry in class 34. As pointed out in chapter 2, section 2.3, comparisons of actual teaching hospital costs and their equivalent costs estimated from the said set of hospitals produced the excess cost of teaching.

The main requirement of this exercise is to minimise the incomparability and disimilarity between the two groups of hospitals that may exist, outwith the main factors differentiating them, and if not accounted for may lead to obtain misleading results and interpretations.

5.3.2 Criterion of Selecting hospitals

A similar idea was adopted in selecting the non-teaching hospitals to be used as controls, to WPRA's, which was discussed earlier. However, additional refinements were made to the selecting conditions. The similarity lies in the fact that the primary concern was to select those non-teaching hospitals that have correspondingly identical types of service categories as the teaching ones. In general, 48 Scottish non-teaching hospitals out of about 270, were chosen on the basis of the criterion stated below. These hospitals are listed in table 5.1.

(i) Each hospital selected should have either Supra-Area (SA) or Special Category (SC) speciality services, where, the SC speciality group should include an intensive baby care unit and/or accident and emergency, other than a communicable desease unit. Exceptions apply for psychiatry hospitals, since both types of hospital have some of the above specialities.

This condition has two implications. First, it may enable us to establish the excess cost of teaching hospitals accountable solely to the influence of hospitals level of teaching and related activity, but not due to differences manifested by the extent of these specialities patient care services. Secondly, it reduces the apparent difference in hospital case-mix that may exist between the two types of hospitals.

(ii) More weight was given to non-teaching hospitals that did provide DGH, Obstetrics, pediatrics and psychiatry services, corresponding to the teaching hospitals. However, seven hospitals were also included outside these categories, 2 from class 6, 1 from class 13, 1 from class 14 and 3 from class 44. Their inclusion is compatible with all the other three conditions (i), (iii) and (iv) provided.

(iii) All teaching hospitals have more than 100 allocated staff beds, which was not true in most non-teaching hospitals. The restriction made here imposes all hospitals in the sample to be formed to have at least 100 allocated staffed beds. But due to the small size of most of the non-teaching obstetric hospitals, only the other conditions were imposed on them.

(iv) There were hospitals satisfying the above three criterion but with a large proportion of their total allocated beds, more than a third (1/3) of the total, assigned to long-stay (LS) speciality services. It was known that hospitals with large longstay services are inclined to incur less unit costs(cost per week) compared with the other speciality services. Thus, conditions were set up to exclude hospitals from the sample if more than a third (1/3) of the total allocated staffed beds were assigned to long-stay speciality group and half of those beds were not allocated for geriatric assessment long-stay speciality services. [see Appendix 1]

The above criterion was also imposed on the teaching hospitals. There are three hospitals that do not fulfil condition (i). They are coded F704, G504 and S110, all minor teaching hospitals. [see table 5.1]. But none of them are excluded from the analysis on the assumption that their effect may be minimal. The comments received from the Scottish Common Services Agency on these criterion implemented and the hospitals finally chosen are in agreement with what was done here.

5.3.3 <u>The Selected sample and Its Implications</u>

Table 5.1 is a list of the 81 teaching and non-teaching sample of hospitals selected from a total of over 300 Scottish hospitals. The 48 non-teaching hospitals, known from now as CONTROL, were compared with WRPA's sample of about 55 hospitals used in their 1977 study of Scottish hospitals resource allocation. This produced about 41 hospitals common to both. The remaining seven in the new sample are two from class 06, one from class 13, one from class 14 and three from class 44.

(i) Comparison of Unit Costs and related data

Table 5.2 presents data for the sample on some measures of health care characteristics distributed according to teaching status; major and minor teaching and non-teaching (control) hospitals. These are cost per case, cost per week, average bed occupying ratio, length of stay and case flow rates. Cost per inpatient case and cost per inpatient weeks are measures of hospital unit costs frequently used in similar studies to show the different cost structures between the two types of hospitals as presented, for example, in Drummond (1978) and Culyer et al.(1978).

The table indicates that average cost per inpatient case for teaching hospitals was about a third (1/3) of the controls, non-teaching hospitals. In contrast, cost per inpatient week was higher in the teaching hospitals by about 29 percent. We may note however that the inpatient cost per case and per inpatient week presented, for instance, in Drummond (1978), p144) for English Hospitals, seems to suggest that both unit costs are higher for the teaching hospitals than their non-teaching counterparts. Surprisingly the data we got for Scottish hospitals wouldn't conform to the above pattern. Because if unit costs in terms of inpatient care for teaching was compared with the non-teaching hospitals the latter group seems to have higher average unit costs (per case). But the comparison made between a major and minor teaching hospitals shows that for both units costs those hospitals involved in major teaching activity have on average larger unit costs.

Considering the other portion of information given on the same table, the control hospitals have larger length of stay (double that of the teaching hospitals) and bed occupancy ratio (about 5% more than the teaching hospitals), which may explain why they have got comparably smaller cost per inpatient week. This is because a hospitals average unit costs per week is believed to be reduced "by lengthening the patients stay, since the days of care provided towards the end of a patient's stay are generally less resource-intensive." (Drummond (1978, p144))

On the other hand, the teaching hospitals showed: (a) larger case flow rate, which is about double that of the controls, non-teaching hospitals, (b) bigger volume of inpatient cases treated (almost three times the controls) and (c) smaller length of stay (half of the controls), that might explain for their smaller cost per inpatient case of the teaching hospitals. The evidence, thus obtained from the data of unit costs of hospitals, as can be seen, is inconclusive to show the higher cost of teaching hospitals as was anticipated and advocated in some research papers. This implies a need for a more sophisticated approach that could allow for other factors influencing hospital costs, like, their size, scale and intensity of speciality cases treated and their speciality mix, the level of teaching activity and others, to get adequate measures standardised for these differences.

The data presented in the same table, for the controls and all non-teaching hospitals in Scotland show the expected similarity between them. Nevertheless, suppse all the non-teaching hospitals were to be implemented in the analysis instead of the controls, then the data implies that other than the previously discussed problems on the incomparability of some the non-teaching with the teaching hospitals the conclusions would have been based on non-teaching hospitals, who in the average have about one-tenth (1/10) of the cases treated and one-third (1/3) of the inpatient weeks of the teaching hospitals. We think this difference probably influences the results more than the real factors. So the selection of the controls might guard against such undesired heterogeneity effects.

Table 5.2 also presents data on major and minor teaching hospital costs and scale of activity. It seems that hospitals with major teaching activities may incur higher cost per case and per patient week compared with that of hospitals participating in small scale medical teaching activity. The data indicates that on the average, in the minor teaching hospitals, more patients are treated, they have higher case flow rate and bed occupancy ratio. This could be an implication that differences may exist between the two sets of teaching hospitals in the scale and intensity of patient care as well as medical training. For instance, more hospital time and resources might have been spent on training in the major compared with the minor teaching hospitals as their nomenclature intended to represent.

(ii) Comparison of hospitals by speciality group and teaching status

The nature and extent of hospital's activity are directly related to the amount of resources available towards providing its different speciality services. Keeping other factors constant, this could be seen in terms of the size of staffed beds allocated to each speciality group services provided in the hospitals. Thus, the aim of this section is to present the result of some preliminary analysis made on the distribution of number of hospitals and their allocated staff beds between speciality groups by teaching status.

The proportional distribution of allocated beds in a given speciality group between sets of hospitals, classified by their teaching status depends on the number of hospitals from a certain set, who have that speciality. So the first result of analysis made concentrates on comparison of this distribution of hospitals according to the type of speciality group they have and teaching status, presented in table 5.3. The table is based on the sample of 81 hospitals, which from here on holds up to the end of the project. Looking at the table, what seems significant first of all is the small number of hospitals - say less than five - in some of the speciality groups. For example, long-stay (LS) speciality treatments are available in only three major teaching hospitals, and Mental Handicap (MH) speciality services in three hospitals from the whole sample. Two points need a mention. One, Mental Handicap Speciality Group was dropped from further analysis and two, the small number of hospitals with some of the speciality groups may restrict the future cost analysis of hospitals by teaching status. [see chapter 6]

For each speciality group a chi-square (X^2) test (Appendix 4) was performed to check whether the proportional distribution of number of hospitals, having each speciality is the same between teaching status. The result showed that in the case of hospitals with DGH, LS and SA speciality groups the hypotheses of equality of proportions was rejected, that means different number of hospitals exist with these speciality groups and teaching status, it might be possible, however, there could be the same proportion of hospitals with OBS, MI and SC speciality groups between the three types of hospitals.

A pair-wise comparison of the proportion of number of hospitals between any two types of teaching status of hospitals, using Bonferoni multiple comparisons (Appendix 4) shows that there may be significant differences in proportion of number of hospitals:

(i) with DGH speciality group between major and minor, and between minor and control,
(ii) with long stay (LS) speciality group between major and minor and, between major and control, and
(iii) with supra-area (SA) speciality group between major and control and between minor and control teaching hospitals.

The remaining 12 such pair-wise comparisons implied equal proportion of hospitals.

The distribution of proportion of allocated staff beds (BEDS)by speciality group and teaching status of hospitals was presented in table 5.4. Note that the definition of the proportions given are as follows, for example:

Proportion of beds for DGH Speciality Service in Major teaching hospitals	=	Total DGH speciality beds in main teaching hospitals	÷	Total beds in major teaching hospitals who have DGH speciality group service.

By inserting other types of teaching status instead of major as well as the other speciality groups instead of DGH, gives the required proportions for the remaining speciality groups. Consider the proportion quoted for DGH speciality groups under major teaching hospitals. This information tells us that, from the total number of staffed beds allocated to the 11 major teaching hospitals that provide DGH speciality care treatment 76.1 per cent of it goes to serve DGH type patients. The remaining 23.9 per cent of the beds goes to the service of other speciality groups given in these hospitals. Also from three major teaching hospitals providing long-stay speciality service, only 5.1 per cent of the beds are allocated to accommodate such type of patients.

It can be inferred from the table that the distribution of BEDS are not identical between the three types of hospitals for the different speciality groups. The X^2 test made based on the proportions of beds also confirmed this point. A pair-wise multiple comparison of the proportion of beds between teaching status of hospitals within a given speciality group was performed using the same method as above. The following results can be extracted from such analysis: the percentage of beds between major and minor teaching hospitals might be similar for SA and SC speciality groups, while the same is true between minor and the control type hospitals for DGH and LS speciality groups. However, no pairs of proportion of speciality group beds are the same between major and control type hospitals. In addition, the proportion of speciality group beds seem higher in control,non-teaching rather than the major teaching hospitals, for all specialities, save DGH.

The proportion of beds calculated for a given speciality to some extent depends on the number of hospitals who provide it. Inspite of this fact, they probably explain the differences in the average size of provision of resources available to teaching and non-teaching hospitals, as measured by allocated staffed beds, the basic factor determining their cost. Since table 5.3 also shows that except for some pair-wise proportional differences observed (statistically) between the three types of hospitals, in most cases the proportions of number of hospitals were shown to be the same. Therefore, the different proportion of beds observed between the teaching and non-teaching hospitals, as well as major and minor teaching hospitals may imply actual differences in their size of resources and hence costs among them.

5.4 Descriptive Data of Cost model variables

Before the empirical results of the models fitted are outlined some explanations in terms of descriptive statistics of each variable for the 81 Scottish hospitals being studied will be given. The descriptive data are arranged according to teaching status of hospitals to show the average differences existing between the three types of hospitals, major, minor and non-teaching (control). First of all, however, to have a clear view of the information presented in the following tables, it would be helpful to look back at the distribution of numbers of each type of hospital with a given speciality group and teaching status from table 5.3.

(i) In terms of total running costs (TC)

Data in tables 5.5 to 5.7 indicate the average values of all variables, and their coefficients of variation - which shows the variability in the data of the given variable as a percentage of its average value - distributed according to teaching status of hospitals. Table 5.5 presents data on total running costs (TC) and allocated staff beds (BED_j) variables. The impression to be gained from the table is that on the average teaching hospitals in Scotland spend almost twice the non-teaching (control) hospitals included in the sample. There appear to be little difference in variability of costs within the two sets of hospitals. The coefficient of variation for the 33 teaching hospitals running costs is also 69 per cent of their average value. The range of the running cost of the combined sample of hospitals goes from the smallest spending just about half a million pounds to the largest spending almost £36 million annually in the Fiscal Year 1985/86. This figure varies between teaching and non-teaching hospitals as depicted in table 5.8, which presents data in some selected measures. The median value of TC, in teaching hospitals is about £11 million and that for non-teaching is almost £5 million. That means half of the hospitals in each group spent above or below the figure shown. There are only 7 out of 48 hospitals among the controls which have total running costs above the median value of the teaching hospitals and 5 teaching hospitals below the median value of the controls. Thus implying that the teaching hospitals tend strongly to have higher total running costs than controls.

Giving attention to table 5.8 again the picture seen for total running costs also holds with respect to the (total allocated staff beds, TBED), level of bed-use in inpatient services (total occupied bed days (OCD) and total inpatient cases (TIPC)), level of activity in non-inpatient services (total non-inpatient attendances, (TNIP)) and teaching responsibilities (measured in number of students and nurses). The data for these measures indicate that the teaching hospitals generally have higher values of the above measures listed. Although the teaching hospitals constitute larger expenditure, size and inpatient and non-inpatient cases treated, their cost per inpatient case is smaller than the control non-teaching ones.

(ii) <u>In terms of Allocated Staffed beds (BED_j) variables</u>

BED_j variables represent the hospital's allocated staffed beds in j^{th} speciality group. The average values listed in table 5.5 are calculated from the group of hospitals under a given teaching status. Clearly evident is that the teaching hospitals on average have more beds staffed and allocated than the controls (non-teaching) in all speciality groups defined except the mental illness (MI). This speciality group is mainly related to the control hospitals, who have about 20 mental illness hospitals. We note that there is high variation in the BED_j variables compared with TC because of the fact that some observations in BED_j are zeros, i.e., no beds. This is true for EXD_j and EXD_j variables also. For instance, there are only 11 hospitals in the major teaching category with DGH speciality beds, (Table 5.3) giving an average among these of 385 beds. Since all minor teaching hospitals have DGH speciality beds the corresponding average is the same as in table 5.5, i.e. 334 beds, and for control, non-teaching there are only 18 hospitals putting their average to 234 beds.

The comparatively larger average number of beds in the teaching hospitals than the non-teaching may mean they have more operational capability to provide patient care and other teaching and related services, thus requiring more resources and incurring proportionally higher costs.

(iii) <u>In terms of Bed-use Measures: EXC_j and EXD_j</u>

The data in table 5.6 gives the average values of Extra inpatient cases and patient days of the 81 hospitals in the sample by speciality groups and teaching status. These are measures of the use made of the allocated staffed beds of the hospitals for each speciality group in comparison with the nationally expected bed-use attained over all Scottish hospitals. Hence, positive values of EXC_j and EXD_j are indicative of hospitals operating with greater intensity than the average experience of all Scottish hospitals, including themselves. We see from the table that the teaching hospitals have on average more extra inpatient cases and occupied bed days than the national expectations, while the controls-non-teaching hospitals do not have such clear cut appearance; for the DGH, supra-area (SA) and mental illness (MI) speciality groups the controls have less inpatient cases treated than the national averages. The same holds for DGH, MI and Special category (SC) speciality groups with respect to extra occupied patient days.

Differentiating teaching hospitals as major and minor reveals that the latter set of hospitals have less occupied bed days than the national average for long-stay (LS) and SA specialities, while for the former similar condition exists for MI speciality group.

The data for EXC_j and EXD_j depends on the hospitals case flow rates (CFR) and bed occupancy ratios (OCR) presented in table 5.9, by speciality group and teaching status. Note that, our calculation of these measures are weighted averages with similar definition given in section 4.4, chapter 4. Comparison of this table's data with that shown in table 4.1, averages for all Scottish hospitals may reveal why there should be negative and positive values of EXC_j and EXD_j.

Because, by definition $EXC_j = IPC_{ij} - ((\overline{CFR}_j) \times BED_{ij})$ [see section 4.4]. Or, $EXC_j = (CFR_{ij} - \overline{CFR}_j) \times BED_{ij}$. where, CFR_{ij} is case flow rate for hospital i in speciality group j, and $\overline{CFR}_j$ is national case flow rate for all Scottish hospitals in speciality group j. [see Table 4.1]. Grouping CFR_{ij} for a set of hospitals with a given teaching status gives table 5.9. The same for EXD_j, which uses bed occupancy ratio of hospitals.

Concerning the sample of hospitals under analysis their average CFR and OCR appear to increase with their teaching status; that means, major has higher CFR and OCR than the minor and control type hospitals, in all the speciality groups. For example, for DGH speciality group, CFR increased from 0.083 cases per bed-day (= 31.9 per year) for the control to 0.094 cases per bed-day (= 34.3 per year) for the minor to 0.108 cases per bed-day (= 39.4 cases per year) for major type hospitals. The exception is for Mental Illness speciality group which has more CFR and OCR in the minor teaching hospitals than the major ones.

However, looking at their average length of stay (occupied bed days per cases), this measure tended to decrease with the level of teaching of the hospitals, unlike the above two measures of bed-use. For instance, in the same DGH speciality group patients stayed on the average for 8.7 days in the controls, 8.1 days for the minors and 7.3 days in the major teaching hospitals, which takes the opposite pattern of that shown above. In general, it can be seen from the table that this distinction doesn't hold between the minor and control (non - teaching) hospitals for some speciality groups.

Thus, the data of EXC_j and EXD_j exhibits potentially systematic differences between the three types of hospitals and between them and the national Scottish experience. Thus, to finalise this section's illustration table 5.10 gives the distribution of number of hospitals with positive values of EXC_j and EXD_j between teaching and non-teaching (control) sets of hospitals. Clearly for both EXC_j and EXD_j, the teaching hospitals group have more hospitals lying above the zero mark, than below it, in all speciality groups, except for long-stay (LS) and special category (SC) speciality groups. The case for the control (non-teaching) groups is not conclusive as such, since for EXC_j they seem to generally lie below zero, but for EXD_j this is not always the case for all speciality groups.

The summary from the above tables of bed-use measures data could be that the teaching hospitals especially those with considerable (major) teaching activity seem to make extensive uses of the beds available to them.

(iv) In terms of Non-inpatient activity Variables (NIP_k)

The data in table 5.7 presents average and coefficient of variation statistics for hospitals' non-inpatient care and teaching activity variables. Non-inpatient care services are more commonly available in the 81 Scottish hospitals, unlike the speciality group inpatient care services. Consultancy, Ancillary, Accident and Emergency, Daypatient and Daycase outpatient facilities were provided in 79, 73, 32, 45 and 54 hospitals, respectively in 1985/86.

Considering the non-inpatient care data by the level of teaching status, the number of attendances increases with the level of teaching activity. Major teaching hospitals had more visits on the average than the minor teaching and the controls (non-teaching). Also, the minor teaching had more outpatient visits than the control (non-teaching) hospitals. To take an example, there were about 70,000, 66,000 and 18,000 outpatient attendances on the average to the consultancy departments of major, minor and non-teaching hospitals, respectively in 1985/86 fiscal year. This could be an indication to the different level of resources available in the three types of hospitals to provide these services and/or the efficient use of what was limitedly available to undertake them.

(v) In terms of teaching activity variables (STDN, NURS)

The data for teaching variables was given in table 5.7. Generally all teaching and some non-teaching hospitals in the sample undertake both training medical students (STDN) and nurses (NURS). There are 58 and 78 hospitals with medical students and nurses, respectively out of the 81. The teaching hospitals had on the average about 46 medical students, much more than the non-teaching, which had an average of 3, in the 1982/83 academic year. Among the teaching hospitals, the major ones had trained on average about 52, while the minor have 38 undergraduate students per hospital in 1982/83 academic year. The pattern is similar for training nurses distributed between teaching and non-teaching hospitals with 82 and 31 nurses in training per hospital in 1985-86, respectively. But there seems to be slightly more nurse trainees in minor teaching, about 97 per hospital, compared to 73 per major teaching hospitals.

As can be seen from table 5.8 all non-teaching hospitals had trained less than 24 medical students, which for the teaching hospitals represent the median student number. With respect to nurse in training there was only 6 non-teaching hospitals with their number of training nurses exceeding 68, the median nurse number for the teaching group of hospitals. Only 5 teaching hospitals trained less than 25 nurses.

(vi) Summary

To summarise the presentation of the descriptive data of total running costs model variables, from the above results we may note the following:

(a) teaching hospitals seem to have more allocated staffed beds and make more use of them,

(b) teaching hospitals provide more non-inpatient care services, serving larger number of outpatient attendances, and

(c) teaching hospitals provide more training services to medical students and trainee nurses, in comparison to the control, non-teaching hospitals.

Therefore, these points could give some explanation as to why the teaching hospitals spent on the average twice that of the non-teaching (controls). But to confirm whether this level of expenditure is significantly affected by teaching responsibilities of the hospital needs the outcome of the results in the next chapters.

TABLE 5.1. LIST OF HOSPITALS STUDIED, WITH TEACHING STATUS

Code	Hospital Name	Teaching Status	Functional Class
A103	Ayrshire Central Maternity	Con	25
A111	Cross House Hospital	Con	12
A201	Ailsa, Ayr	Con	35
A203	Heathfield, Ayr	Con	06
B117	Dingleton, Melrose	Con	35
C101	Argyll and Bute, Lochgilphead	Con	35
C206	Vale of Leven, Alexandria	Con	11
C309	Rankin Memorial	Con	25
C310	Ravenscraig, Greenock	Con	35
C313	Inverclyde Royal	Min	02
C403	Dykebar, Paisley	Con	35
C408	Paisley Maternity	Con	25
C411	Royal Alexandra Infirmary	Min	02
F704	Victoria, Kirkcaldy	Min	02
F705	Forth Park Maternity	Con	25
F712	Strathedon, Cupar	Con	35
F804	Dunfermline Maternity	Con	25
G101	Belvedere	Con	13
G105	Gartloch, Gartcosh	Con	35
G107	Glasgow Royal Infirmary	Maj	01
G108	Royal Maternity, Glasgow	Maj	22
G207	Stobhill, Glasgow	Min	02
G208	Stoneyetts, Chryston	Con	35
G210	Woodilee, Lenzie	Con	35
G302	Leverndale, Glasgow	Con	35
G304	Phillipshill by Busby	Con	14
G306	Victoria Infirmary, Glasgow	Min	02
G308	Rutherglen Maternity	Con	25
G405	Southern General, Glasgow	Min	02
G504	Gartnavel General, Glasgow	Min	02
G505	Gartnavel Royal, Glasgow	Maj	34
G513	RHSC, Yorkhill	Maj	07
G515	Queenm Mothers, Yorkhill	Maj	22
G516	Western Infirmary, Glasgow	Maj	01
H202	Raigmore, Inverness	Min	02
H205	Craig Duncan, Inverness	Con	35
L102	Bellshill Maternity	Con	25
L106	Monklands District General	Con	12
L204	Hartwood, Shotts	Con	35
L208	Law Hospital, Carluke	Con	12

TABLE 5.1. LIST OF HOSPITALS STUDIED, WITH TEACHING STATUS (continued)

L210	Motherwell Maternity	Con	25
L214	William Smellie, Lanark	Con	25
L302	Hairmyres, East Kilbride	Con	12
N101	Aberdeen Royal Infirmary	Maj	01
N102	Woodend General, Aberdeen	Min	02
N121	Royal Aberdeen Childrens'	Maj	07
N161	Aberdeen Maternity	Maj	22
N193	House of Daviot, Pitcaple	Con	35
N194	Kingseat, Newmachor	Maj	34
N198	Royal Cornhill, Aberdeen	Maj	34
N491	Bilbohall, Elgin	Con	35
S105	Eastern General, Edinburgh	Min	02
S107	Edenhall, Musselburgh	Con	44
S109	Hardmanflat inc. Vert Memorial	Con	35
S110	Leith	Min	02
S112	Northern General, Edinburgh	Con	44
S116	Western General, Edinburgh	Maj	01
S201	Astley Ainslie, Edinburgh	Con	44
S204	Edinburgh City Hospital	Min	02
S207	Rosslynlee, Roslin	Con	25
S214	Elsie Inglis	Con	35
S225	RHSC, Edinburgh	Maj	07
S226	Edinburgh Royal Infirmary	Maj	01
S227	Simpson Memorial, Edinburgh	Maj	22
S299	Royal Edinburgh Hospital	Maj	34
S301	Bangour General, Broxburn	Min	02
S302	Bangour Village, Broxburn	Con	35
T101	Ninewells, Dundee	Maj	01
T102	Dundee Royal Infirmary	Maj	01
T114	Royal Dundee, Liff	Maj	34
T201	Bridge of Earn	Con	06
T202	Perth Royal Infirmary	Con	11
T215	Murray Royal, Perth	Con	35
T311	Sunnyside Royal, Montrose	Con	35
T312	Stracathro	Con	12
V102	Falkirk Royal Infirmary	Con	11
V106	Bellsdyke, Larbert	Con	35
V201	Stirling Royal Informary	Con	11
Y102	Cresswell Maternith	Con	25
Y103	Crichton Royal Dumfries	Maj	34
Y104	Dumfries and Galloway	Con	12

TABLE 5.1. LIST OF HOSPITALS STUDIED, WITH TEACHING STATUS (continued)

Notes:

1. Letters with the hospital code indicate their Health Board.

They are:
A - Ayrshire and Arran,
B - Borders,
C- Clyde,
F- Fife,
G - Greater Glasgow,
H - Highland,
L - Lanarkshire,
N - Grampian,
S - Lothian
T - Tayside,
V - Forth Valley,
Y - Dumfries.

2. Teaching Status:

Maj - Major Teaching Hospital
Min - Minor Teaching Hospital
Con - Control, Non-Teaching Hospital

3. Description of functional class - see Appendix 3.

TABLE 5.2. COMPARISON OF HOSPITAL UNIT COSTS AND SCALE OF ACTIVITY: MEAN VALUES GIVEN. 1985/86 SCOTTISH HOSPITALS DATA

(i) Unit Costs

Type of Hospitals / Variables	All Scottish Hospitals (n - 303)	Non-Teaching Hospitals All (n - 270)	Non-Teaching Hospitals Controls (n - 48)	Teaching Hospitals All (n -33)	Teaching Hospitals Major only (n -20)	Teaching Hospitals Minor only (n-13)	The sample Hospitals (Combined) (n-81)
Inpatient Cost* per Inpatient case (£)	7226	7894	4899	1763	2426	742	3599
Inpatient Cost* per Inpatient week (£)	407	386	461	593	627	540	514
(ii) Scale of Activity							
Inpatient cases	2636	1370	4463	12999	11992	14549	7940
Inpatient Weeks	7868	6296	16110	20729	20972	20356	17992
Length of stay **	20.9	32.2	25.3	11.2	12.2	9.8	15.9
Case flow rate ** (per year)	14.6	9.5	11.7	25.2	23.0	29.6	18.3
Occupancy ratio ** (x 100)	83.6	83.8	81.1	77.4	76.8	79.8	79.6

Notes:
* Source: Scottish Health Service Costs (SHHD, 1986)
** Length of stay - Occupied bed days per inpatient cases
Case flow rate per year - Inpatient cases per Allocated Staffed Beds.
Occupancy Ratio (in %) - Ratio of occupied and allocated staffed bed days.

TABLE 5.3. DISTRIBUTION OF HOSPITALS WITH BEDS, BY SPECIALITY GROUP AND TEACHING STATUS

Speciality Group	Major (from n_1=20)	Minor (from n_2=13)	Control (from n_3=48)	Combined Sample(from n = 81)
DGH	11	13	18	42
LS	3	10	19	32
SA	10	5	14	29
OBS	6	5	15	26
MI	10	5	23	38
MH	1	0	2	3
SC	13	9	15	37

n_i = sample size in hospital type i. i = 1, major, i = 2, minor, i = 3, control.
$n = n_1 + n_2 + n_3$

TABLE 5.4. DISTRIBUTION OF ALLOCATED STAFF BEDS BY SPECIALITY GROUP AND TEACHING STATUS (%)*

Speciality Group	Major (n_1 = 20)	Minor (n_2 = 13)	Control (n_3 = 48)
DGH	76.1	66.1	64.4
LS	5.1	16.6	16.2
SA	9.6	9.5	12.3
OBS	34.2	9.5	41.2
MI	74.8	12.3	86.9
MH	NA	NA	NA
SC	5.7	5.7	7.1

NA = Dropped from Analysis

* see definition given in section 5.2.3, page 64.

TABLE 5.5. DESCRIPTIVE DATA: TOTAL RUNNING COST (TC) AND SPECIALITY GROUP BEDS (BED_j)

Teaching Status Variables	Major (n_1 = 20) Average	C.O.V	Minor (n_2 = 13) Average	C.O.V	Controls (n_3 = 48) Average	C.O.V.	Combine Sample (n = 81) Average	C.O.V	Min.	Max
TC(£000s)	13467	77	12888	54	5906	69	8893	85	476	35959
BED DGH	211.1	128	334.2	35	87.1	164	157.5	129	0	832
BED LS	6.5	254	69.0	109	24.4	150	27.1	171	0	235
BED SA	30.5	139	22.0	193	5.2	258	14.1	220	0	168
BED OBS	32.7	162	25.1	139	22.8	165	25.6	163	0	143
BED MI	201.6	154	33.5	149	230.5	151	191.3	165	0	1600
BED SC	16.6	93	21.7	106	8.7	141	12.7	127	0	73

TABLE 5.6. DESCRIPTIVE DATA: EXC_j and EXD_j

Variables	Major (n_1=20) Average	C.O.V.	Minor (n_2=13) Average	C.O.V.	Controls (n_3=48) Average	C.O.V.	Combined Sample (n = 81) Average	C.O.V.	Min.	Max
EXC DGH	1642.0	134	859.0	226	-137.0	774	462.0	378	-2884	6297
EXC LS	37.0	275	174.1	136	59.6	328	72.4	263	-229	902
EXC SA	45.5	720	62.2	379	- 42.5	354	-3.9	5795	-682	710
EXC OBS	197.1	226	65.6	502	29.7	1459	76.8	558	-946	2434
EXC MI	48.0	472	140.2	153	- 60.3	384	- 1.4	17171	-1069	870
EXC SC	233.0	310	68.8	437	4.7	3796	71.3	639	-646	2471
EXD DGH	3436.0	292	2145.0	368	-743.0	440	752.0	889	-14466	30327
EXD LS	275.0	473	- 990.0	266	649.0	454	294.0	901	-9220	14949
EXD SA	576.0	191	- 293.0	304	11.0	5233	101.6	828	-3019	3150
EXD OBS	908.0	267	381.0	439	401.0	503	523.0	399	-5838	9806
EXD MI	- 480.0	1570	1167.0	283	- 496.0	2529	- 225.0	4746	-61711	28121
EXD SC	693.0	151	732.0	308	- 194.7	291	173.0	701	-1698	7305

TABLE 5.7. DESCRIPTIVE DATA: NIP_k, STDN and NURS

Variables	Major (n_1=20)		Minor (n_2=13)		Controls (n_3=48)		Combined Sample (n=81)			
	Average	C.O.V	Average	C.O.V	Average	C.O.V	Average	C.O.V	Min.	Max
NIP CNSL	70293	111	66405	69	17912	139	38628	138	0	253344
NIP ANCL	60160	114	61767	63	20083	141	36668	130	0	255922
NIP ACDN	22702	113	24655	84	5474	228	12806	168	0	89667
NIP DPAT	7074	145	5104	130	3656	144	4732	152	0	37819
NIP DYSS	2580	105	2600	76	828	147	1545	131	0	7189
STDN	51.5	117	38.0	68	3.0	155	20.6	187	0	214
NURS	725	80	96.7	52	31.2	87	51.9	94	0	218

Notes for tables 5.5 - 5.7

C.O.V.	= Coefficient of Variation = (Standard Deviation/Average) x 100
Average	= Arithmetic mean of the data for that group of hospitals
Min	= Minimum value
Max	= Maximum value
TC	= Total Running Costs net off rates and capital costs.
BEDj	= Allocated Staffed beds in speciality group j.
EXCj	= Extra inpatient cases in speciality group j.
EXDj	= Extra occupied bed days in speciality group j.
NIPk	= Non inpatient attendances in classification k.
STDN	= Weighted equivalent (WTE) number of undergraduate medical students.
NURS	= WTE number of Nurses in training

TABLE 5.8. DESCRIPTIVE DATA: COMPARISON OF DATA BETWEEN TEACHING AND NON-TEACHING (CONTROLS) HOSPITALS

Variables	Teaching Hospital Median	Teaching Hospital with greater than Median of Controls (b)	Non-Teaching Hospital Median	Non-Teaching Hospital with greater than Median of Teaching Hosp. (c)
Total Running Cost (£000s)	10767	28	4779	7
Inpatient cost (a) per inpatient Case	797	6	1332	29
TBED	540	23	342	12
TOCD	413	23	244	12
TIPC	11,344	29	1855	7
TNIP	131,824	30	21726	6
STDN	24	33	1.5	0
NURS	68	28	25	6

Notes (a) Source: Scottish Health Service Costs (SHHD, 1986)

TBED - Total number of allocated staffed beds
TOCD - Total number of occupied beds
TIPC - Total number of inpatient cases
TNIP - Total number of non-inpatient attendances
STDN - Weighted equivalent (WTE) Number of Medical Undergraduate Students (1982/83)
NURS - WTE number of training nurses

(b) the remaining number of hospitals out of the total 33 gives the less than values.

(c) the remaining number of hospitals out of the total 48 gives the less than values.

TABLE 5.9. DESCRIPTIVE DATES: BED USE BY SPECIALITY GROUP AND TEACHING STATUS (AVERAGE FOR TEACHING CLASS)

Speciality Group	Maj. (n_1=20)	Min. (n_2=13)	Cont. (n_3=48)
(i) CASE FLOW RATES: (In-patient cases per allocated bed day).			
DGH	0.108	0.094	0.083
LS	0.012	0.014	0.014
SA	0.074	0.078	0.048
OBS	0.132	0.122	0.112
MI	0.005	0.016	0.004
SC	0.120	0.090	0.083
(ii) LENGTH OF STAY (occupied bed days per in-patient case).			
DGH	7.3	8.1	8.7
LS	47.0	66.5	74.0
SA	10.5	8.8	15.2
OBS	5.1	5.2	5.7
MI	170.0	59.4	212.5
SC	5.0	6.4	5.1
(iii) OCCUPANCY RATIO: (occupied bed days per allocated bed days)			
DGH	0.79	0.76	0.72
LS	1.08	0.93	1.04
SA	0.78	0.69	0.73
OBS	0.67	0.63	0.64
MI	0.85	0.95	0.85
SC	0.60	0.58	0.42

Note: The same definition presented in chapter 4, section 4.4 to compute national average case flow rates, length of stay and occupancy ratio for Scottish hospitals are,respectively applied to calculate this table's statistics.

TABLE 5.10. DESCRIPTIVE DATA: NUMBER OF HOSPITALS WITH ECXj and EXDj GREATER THAN ZERO (>0)

Speciality groups (j)	Teaching Hospital			Non-Teaching (controls)		
	n_j	EXCj >0	EXDj >0	n_j	EXCj >0	EXDj >0
DGH	24	19	15	20	10	10
LS	13	12	6	19	11	9
SA	16	10	10	8	3	6
OBS	11	9	8	15	7	10
MI	16	12	10	24	7	16
SC	22	11	16	22	9	8

Note n_j = Number of hospitals with non-zero EXCj and EXDj observations in the j^{th} speciality group.

APPENDIX 1. Grouping of Hospital Specialities (WP method)

Speciality Group	Specialities (and Code)	
District General Hospital (DGH)	Acute Mixed Specialities (76) Convalescent ...DGH (27) Ent. (03) General Medicine (16) GP Acute (73) Haematology (62) Homoepathic (36)* Metabolic Disease (18) Opthalmology (04) Orthopaedic Surgery (02) Paediatric Medicine (39) Poisons (22) Respiratory Medicine (28) Staff Wards (75) TB Respiratory (29) Unclassified (11,13,66,76,97)*	Cardiology (17) Dermatology (23) Gastroenterology (21) General Surgery (01) Gynaecology (42) Medical Oncology (37) Nephrology (24) Oral Surgery/Medicine(12) Other (98) Paediatric Surgery Rehabilitation (26) Rheumatology (25) STD(Genito-urinary-medicine) (32) Urology (05)
Long stay (LS)	Geriatric Assessment (50) GP Longstay (74)	Geriatric Longstay (51) Young chronic sick (52)
Supra-Area (SA)	Cardia-Thoracic Surgery (07) Neurosurgery (06) Radiotherapy (34)	Neurology (19) Plastic Surgery(8)Burns(9) (and Maxillo-Facial Cases) Spinal paralysis (38)
Obstetrics (OBS)	GP Beds (45)	Specialist (43/44)
Mental Illness (MI)	Adolescent psychiatry (57) Mental Illness (53)	Child psychiatry (56) Psycho-Geriatric (54)
Mental Handicap (MH)	Mental Deficiency (59)	
Special Category (SC)	Accident & Emergency (49) Intensive treatment unit (48)	Special/Intensive Baby Care Unit (46) Communicable Diseases(31)

Source: copied from HO (1983)

*Added by the author

APPENDIX 2. Function Classification of Hospitals

Functional Class	
01	Large general major teaching hospitals covering a full range of services (other than maternity in some cases).
02	General Hospitals with some teaching units but not necessarily wholly teaching
04	Small general hospitals with some specialist staff including a surgical unit. No maternity.
05	Small general hospital with some specialist staff including a surgical unit but with maternity.
06	General non-teaching hospitals but not covering the full range of medicine and surgery.
07	Large teaching hospitals for children covering the full range of medicine and surgery.
08	General practitioner cottage hospital with no maternity unit and with limited surgery done either by general practitioner or visiting consultants. Centres for consulting clinics.
09	General practitioner cottage hospitals with maternity units and with 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 no surgery of any kind.
11	Mixed specialist hospitals with maternity. No special unit. Consultant type surgery undertaken.
12.	Mixed specialist hospitals without maternity units. No special units. Consultant type surgery undertaken.
13.	Hospitals with medical and/or surgery units but with a large chjronic 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 geriatritian. May be with or without young chronic sick but no major assessment unit.

APPENDIX 2. **Function Classification of Hospitals (continued)**

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 unit.
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.
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 but having at least some other variable non-surgical acute activity.
28.	ID hospitals with other special acute activities including a surgical one.
29.	Hospitals still dealing essentially with medical tuberculosis and other chest cases. No thoracic surgery.
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 full range of treatment.
35.	Non-teaching mental hospitals giving full range of treatment.
38.	Mental deficiency Units. Children only.
39.	Mental deficiency Units providing full range of service. Adults only.
40.	Mental deficiency Units providing full range of services. Mixed adults and children.
42.	Small non-teaching specialist hospitals.

APPENDIX 2. **Function Classification of Hospitals (continued)**

43. Dental hospitals.

44. Miscellaneous hospitals which by function are not individually comparable with any other Unit and where costs would not bne 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.

Source: Copied from Scottish Health Service Costs (SHHD, 1986).

APPENDIX 3. Derivation of Under-graduate Medical Students Data

There are four Health Boards in Scotland among a total of 15, mainly involved in teaching undergraduate medical students. They are, Glasgow, Grampian, Lothian and Tayside Health Boards. Corresponding to them, four Scottish Universities, namely, Glasgow, Dundee, Edinburgh and Aberdeen, provide medical education for undergraduate medical students. The students are distributed among hospitals, administered by each Health Board, for clinical training. The available information on the number of students depends on the two following sources:

(a) Yearly total number of graduating medical/dental students from 1982-83 to 1984-85, Academic Year (AY) was supplied for each University. Added to this, the actual enrolment figures of students for 1982-83 AY at the University of Glasgow , School of Medicine was known. Comparing these total number of graduates with those on enrolment showed about 4 per cent drop-out rate for Glasgow. This became the basis for uplifting the yearly number of graduates for the remaining three Universities to get an approximate number of enrolment for each AY, with the assumption that some form of uniformity exists between universities' working conditions in Scotland.

(b) Corresponding to each of the teaching Health Boards one of the four universities and several hospitals exists involved in teaching. For such set of hospitals, under specific Health Board and the university, data on either the distribution of student hours, days or sessions was provided. The information available was as follows:

For Hospital under Glasgow Health Board: total number of student hours spent by each hospital.

For Hospital under Lothian Health Board: total number of student days spent by each hospital.

For Hospital under Tayside Health Board: percentages of clinical sessions spent by each hospital, taken from the total clinical sessions in all hospitals in this Health Board.

APPENDIX 3. Derivation of Under-Graduate Medical Students Data (continued)

and,

for Hospitals under Grampian Health Board: total number of clinical sessions spent at each hospital for training the number of medical students assigned to them.

The combination of these two data sets from (a) and (b) was used to derive the weighted equivalent number of medical students. The data on dental medical students was excluded both from (a) and (b). [see Chapter 5].

The manipulation of these data was straightforward. Graduates data for three successive academic years were uplifted by 4 per cent to provide approximate enrolment figures as said above. Weights were calculated for each hospital within a specific health board using the distribution of student hours, days or sessions data in (b). These weights multiplied by the approximated number of students enrolled for each academic year gave the weighted equivalent number of medical students. These figures were summed over the three years period producing the final approximation of the number of medical students trained in the academic year 1982-83 for each hospital.

APPENDIX 4. SOME STATISTICAL CONCEPTS

A. Chi-Square(χ^2) test

Suppose X_i are a sample of n in dependent categorical observations from a multinominal distribution, classified into p distinct categories with a likelihood function:

$$Lik(\underline{\theta},\underline{X}) = \frac{n!}{\prod_{i=1}^{p} X_i!}\prod_{i=1}^{p}\theta_i^{X_i},$$

subject to, $\sum_{i=1}^{p}\theta_i = 1$ and $\sum_{i=1}^{p} X_i = n$

Assume that hypothesis tests about the θ_i's of the following form are required:

$H_0 : \theta_i = f_i(\underline{\phi})$

$H_1 : \theta_i$ not specified

Where $f_i(\cdot)$ is a given function, and $\underline{\phi}$ parameter of interest. This test was shown to be undertaken through the log-likelihood ratio test using the statistic given as:

$$2\log_e\lambda = 2\log_e\frac{\underset{H_1}{Max}\ Lik(\underline{\theta},\underline{X})}{\underset{H_0}{Max}\ Lik(\underline{\theta},\underline{X})}$$

$$= 2\sum_{i=1}^{p} x_i \log_e(x_i/\hat{m}_i)$$

Where $\hat{m}_i = n\, f_i(\hat{\underline{\phi}})$ are the estimated expected number of observations in category i under H_0.

APPENDIX 4 SOME STATISTICAL CONCEPTS (continued)

$\underset{H_1}{Max}$ and $\underset{H_0}{Max}$ signify maximum likelihood es mators of $\underline{\theta}$ under hypothesis H_1 and H_0, respectively.

The log-likelihood ratio test is usually approximated with Pearson's (Chi-square) test statistic given by the function:

$$X^2 = \sum_{i=1}^{P} [(X_i - \hat{m}_i)^2 / \hat{m}_i]$$

Under H_0 : $2 \log_e \Lambda$ or X^2 has approximate χ^2 distribution with degrees of freedom = dim. $\underline{\theta}$ - dim. $\underline{\phi}$. This test is applied to investigate mainly equality of proportions in cross-classified or categorical data.

B. Bonferoni Multiple Comparisons.

Given P parameters of interest, $\theta_1, \ldots, \theta_p$ from a Multivariate normal or asymptically normal distribution, Bonferoni Multiple comparison technique is one of several ways available to investigate relationships between sets of θ_j simultaneously, $j = 1, \ldots\ldots, P$. θ_j can be proportions, means, regression parameters, etc.

Suppose tests of the type ,

$$H_0 : d_t = \theta_i - \theta_j \qquad \text{------ (1)}$$

$H_1 : d_t = 0$, for $i \neq j$ are desired.

APPENDIX 4 SOME STATISTICAL CONCEPTS (continued)

One of such tests could be undertaken by constructing an interval estimate with confidence probability $1-\alpha$ expressed as:

$$I_t(d_t) = \hat{d}_t \pm t\,(h, 1-\alpha/2) * s.e\,(\hat{d}_t) \quad \ldots\ldots\ldots\ldots \quad (2)$$

where $t(h, 1-\alpha/2)$ is a $(1-\alpha/2)$ probability value of the t-distribution with h degrees of freedom, and,

S.e $(\hat{d}_t)$ is standard error of $\hat{d}_t$.

In case of θ_i not from normal distributions, N (0,1) is used instead of t(h).

The application of Bonferoni's type techniques of multiple comparison arises when various comparisons among the p parameters θ_j are required, simultaneously. Suppose all tests of the above (1) form are of interest. Thus, $\binom{p}{2} = k$ comparisons are required.

Then k possible confidence intervals given in (2) can be constructed, for t=1, ..., k.

Here $P_r(I_t(d_t) \text{ contains } d_t) = 1-\alpha$

$= 1 - P_r(I_t(d_t) \text{ does not contain } d_t)$.

However, P_r (at least one of the $I_t(d_t)$'s does not contain d_t) $\leq k\alpha$.

APPENDIX 4 SOME STATISTICAL CONCEPTS(continued)

The Bonferroni multiple comparison uses confidence intervals that account for such discrepancy. They are expressed as:

$$I_t(d_t) = \hat{d}_t \pm t\,(h,\ 1 - \alpha/2k)\ \text{s.e}\ (\hat{d}_t), \qquad \text{for } t = 1, -, k.$$

such that,

P_r (at least one of the $I_t(d_t)$'s does not contain d_t) $\leq \alpha$, as required.

Where P_r (:) means 'probability of'.

C. Miscellaneous

(i) R^2 - Multiple Correlation Coefficient

Given a model $\underline{Y} = \underline{X\beta} + \underline{U}$ and, the estimated model $\hat{\underline{Y}} = X\tilde{\underline{\beta}}$, and residual sum of squares (RSS), the multiple correlation (R^2) defines the proportion of variation in the dependent variable ($\underline{Y}$) explained by the (p+1) independent variables in (X). This is calculated from:

$R^2 = 1 - \frac{RSS}{TSS}$ where TSS = Total Sum of squares of variarion in $\underline{Y}$. $= \sum_{i=1}^{n}(Y_i - \bar{Y})^2$

The figure is usually expressed as percentages.

(ii) $\bar{R}^2$ - Adjusted Multiple Correlation

Given R^2 as defined in (i) above, its value, adjusted for the number of independent variables included in the regression equation and the number of cases (sample size) is defined by:

$$\bar{R}^2 = 1 - [(1 - R^2)(n-1/n-p-1)]$$

where p = number of independent variables

n = sample size

(iii) F-ratio

Suppose: a goodness of fit test of the following form is desired:

$H_0 = E(Y) = X_1\beta_1$ - with q independent variables included, and

$H_1 = E(Y) = X_1\beta_1 + X_2\beta_2$, with P independent variables included; $p > q$.

Assume both models under H_0 and H_1 satisfy the classical regression assumptions given in Chapter 3. Then the test is usually undertaken by the log-likelihood ratio test given by:

$$F = \frac{(RSS_0 - RSS_1) / (p-q)}{RSS_1 / (n-p-1)}$$

where, RSS_0 and RSS_1 are the estimated residuals sum of squares from fitted models specified under H_0 and H_1, respectively, and n-sample size.

If this observed value of F, compared with the standard F distribution with (p-q, n-p-1) degrees of freedom, for a prespecified confidence level have got larger magnitude, then the model under H_1 is considered 'best' fit to the data than that on H_0.

(v) - (Simple) Correlation Coefficient (r)

This statistic determines the degree of linear relationship existing between two variables, Say X and Y. The correlation coefficient, given n observations on both variables is calculated from the equation

$$r = \left[\sum_i^n\sum_j^n (X_i - \bar{X})(Y_j - \bar{Y})\right] / \left[\left(\sum_i^n (X_i - \bar{X})^2 \sum_j^n (Y_j - \bar{Y})^2\right)^{1/2}\right]$$

(a) r nearer to (-1) or (+1) shows strong linear relationship between X and Y

(b) $1/2(\log(1+r/1-r))$ has asymptotic $N(0,1/n-3)$ distribution, which can be used to perform hypothesis tests about significance of r.

CHAPTER 6

EMPIRICAL RESULTS FROM MODELLING

TOTAL RUNNING COSTS

6.1 Introduction

In the preceding chapters the theoretical background followed towards devising the solutions for the problems at our disposal were discussed. The main problem could be summarized to ask: how can we decide on the extent to which teaching activity incurs extra costs to the hospitals providing it? The decision criterion devised was that similarly implemented in previous studies. We suggest also to explain the cost structure of hospitals within a certain mathematical expression, which in this case is a multi – product model of total running costs, relating cost with different variables, measuring the hospitals various resources and services, including teaching.

Based on this model and the available data we try to determine whether the variables measuring the level of teaching activity of hospitals such as number of medical undergraduate students, nurses in training and the teaching status designating them, indicates a significant relationship with their total running costs after standardizing for the effects of other factors. The way forward for this is to look at the empirical results of the estimated total running costs model when fitted to a selected sample of 81 Scottish hospitals data for the fiscal year 1985/86.

The present chapter reports results of the total running cost model estimated by means of weighted least squares technique - to reduce the problem of hetroscedasticity, considering that the model and its variables satisfy or can be seen to adhere to the other classical multiple regression model assumptions required for accurate and efficient estimation of its parameters. In the process of estimation there are four areas of interest that the total cost model would be tested about and on which emperical results presented from an analysis of the data of the 81 selected Scottish hospitals. That means, we try to decide which of the following aspects of hospital operational system contributes most to the variation of their total running costs structure. Namely:

- the effects of patient care related activities,
- the effects of scale of hospital activity,
- the effects of scope of hospital activity, and,
- the effects of teaching related activities.

Each of these areas constitute several variables in the cost model specified and the total number of variables to be considered from all of them is large. The model estimation will incorporate about 100 variables, comprised of linear, quadratic, cubic and interaction terms of variables, each in accordance with the area of interest it was designed to represent. However, it seems impractical to include all these variables at once into the model and to try to estimate the parameters associated to all of them, independent of others, due to several reasons. The role of Section 6.2 will be to state the problems likely to arise from such practice, the options available and the model estimation procedure proposed to overcome them. Each step of the estimation procedure outlined will be applied starting from Section 6.3.

6.2 Proposed Method of Model Building Process

Through estimation of the total running cost model generalized in equation (4.6), section 4.5, Chapter 4, we are interested, as said earlier, in assessing the importance of each variable in the model using available data. But the small sample of hospitals in relation to the number of variables creates difficulty. A compromise was needed between this small sample size of hospitals selected to fit the cost model specified and the number of variables included, i.e. more than 81, including the quadratic, cubic and interaction terms of variables. There were four optional actions to take. Either :

(i) To ignore the influence of some of these variables from the start and respecify the cost model;

(ii) to redefine the model variables, so that a set of them would be represented by a single or few variables, for instance, instead of specifying some variables corresponding to say hospital beds, cases and occupied days by the six speciality groups, either to use three variables to denote total beds, cases, occupied bed days respectively, or some similar reorganization of these variables;

(iii) increase the sample size, say, to use all Scottish hospital data, or

(iv) to apply appropriate statistical model variables selection procedure and choose those that are shown to have significant effect in explaining the variability in hospital costs,most.

Options (i) and (ii) somewhat coincide. But what was meant in (1) was, say, to ignore the effect of interactions quadratic and cubic variables from the models to be fitted. These at best require some justification, economical or statistical as (iv). The review of literature made indicated that no concensus exists in what the form of the cost function of hospitals should look like. Some include quadratic, cubic and interaction variables in their cost models and interpreted the important effect they have. [Sloan et al. (1983) and other recent studies]. Almost all have used quadratic and sometimes cubic variables in their cost function to investigate the influences of economies of scale in the hospital sector. To prefer the second option (ii) means, for example, the same as assuming that unit costs of bed provision, or treatment care, or residential care, or some similar measure (say marginal costs) are uniform between different speciality groups of hospitals. But studies made on speciality costs of hospitals forced us to assume otherwise. [Bailey and Ashford (1984), Popplewell (1981) and many others]. There could be an argument also that this variability between speciality services of hospitals could be covered by variables measuring speciality case-mix of hospitals. Why this was not implemented had been discussed in Chapter 4. Its limitation for the present purpose might not be serious. Nevertheless, it was thought that using meaningful variables representing the characteristics of speciality services of hospitals may lead to a more direct interpretation of the results than using some complex measure of case-mix of hospitals as variables in the cost model specified.

The option under (iii) was not preferred from the beginning. Some hospitals, among the non-teaching hospitals, may not be compared with the teaching hospitals in most respects. Comparing costs of small general practitioner hospitals (such as those in functional class 18 and 19 - see Appendix 2), with the teaching hospitals would give misleading results, even if standardized for some basic factors differentiating their costs. Hence, option (iv) was followed as the appropriate course in fitting the total running cost model to data of the 81 hospitals. A four-step model fitting itera-tion procedure was followed as will be described as follows, to select the 'best' subset of variables that could explain most of the variability between total running cost of hospitals.

(i) The starting point of the model estimation uses only linear terms of all variables corresponding to inpatient and non-inpatient care services. The set-up of the model assumes that the main determinants of running costs are due to the resources consumed for patient care services. We termed this part of the cost function, 'Basic' total running cost model (BCM) given by :

$$TC_i = \alpha_0 + \sum_{j=1}^{6} \alpha_j BED_{ij} + \sum_{j=1}^{6} \beta_j EXC_{ij} + \sum_{j=1}^{6} \theta_j EXD_{ij} + \sum_{j=1}^{5} \gamma_k NIP_{ik} + U_i$$

where, $U_i \sim N\ (0, \sigma^2 (TB_i)^{1.7})$.

Different statistical techniques, like step-wise regression, described in Chapter 3, section 3.6, were applied to check the necessity of these variables in the model to explain the variations in TC_i. The same is done for all other steps discussed next. If some of them were shown to be redundant variables, they will be omitted from further inclusion in any stage of the modelling. This produces what we call 'Basic Economic' Model (BEM1), economical in such a way that it omits variables which within the framework of the model do not add a significant explanation compared to the variables already included. The results of this stage is given in Section 6.3.

(ii) BEM1 becomes, from now on, the basis for testing the contribution of the remaining variables in the full model of the running costs. At this step (ii), quadratic and cubic terms of some of the variables from BED_j and NIP_k included in BEM1 are added to investigate the influence of economies of scale. Effective variables among these are added to BEM1. The model thus chosen is called BEM2 and is discussed in section 6.4, on how to achieve it.

(iii) Interaction variables listed in the full model will be added to BEM1 and the same thing done as in step (ii). This means, first, those involving BED_j x BED_1 are considered. The model to emerge is called an economies of scope Model 'A' and denoted by BEM3A. Secondly, variables involving BED_j x NIP_k are considered. The results termed as Economies of Scope 'B' and becomes BEM3B. Finally, interactions between teaching variables and BED_j and between teaching and NIP_k are considered producing a model which was called an economies of scope model 'C', abbreviated BEM3C. The interaction variables were to be added at each economies of scope levels 'A' or 'B' or 'C' models, if there are variables remaining in BEM1 corresponding to the individual variables forming the interaction terms. For example, if there was no more BEDDGH, (denoted by BED_1) or NIPCNSL (denoted by NIP_1) in BEM1, then interactions formed using these variables will not be included. The result is given in section 6.5.

(iv) Finally, all variables selected from step (i) to (iii) and including the teaching variables are collected to form the alternative general total running cost model (GCM). Using this cost model the effect of teaching variables will be investigated and presented in Section 6.6.

Figure 6.1 presents the diagrammatical outline of this proposed estimation process. The discussion of empirical results will follow the respective steps (i) to (iv).

We like to note, however, that although the above ad hoc estimation procedure was implemented in practice, we also tried to observe and justify as far as necessary, whether the omitted variables at a certain stage (say (i)) would not be required for the next stage (say (ii)) using some simple statistical diagnostic model checking methods. For example, plots of residuals obtained from the fitted models with the omitted variables are considered good indicators of inadequate decision for excluding these variables.

iv) Some Final comments: Suppose the procedure leads us to accept that p variables suffice for the finally adopted total running costs model for explanation and prediction purposes of total running costs of hospitals. The intention in our analysis of the cost components of total running costs makes use of these p variables of this model rather than undergoing another modelling procedure for each cost component. This was the method applied in such studies as Feldstein (1967) and Culyer et al. (1978), with respect to analysis of cost components. We also adhere to it, that is, using the same specification for each cost component.

Additionally, an analysis of the effect of simultaneous relationships between model variables to be described in Chapter 8 considers only the variables included in the above model.

6.3 Basic Cost Model: Results Using Linear Term Variables

The total running cost model to be described in the present section, as was said earlier, makes use of the linear terms of BED_j, EXC_j, EXD_j and NIP_k variables among all those specified in the full cost model.

There are 23 such independent variables involved in the model building process for which the empirical results are to be discussed. By fitting the total running cost model including only those linear independent variables, it was assumed that the main sources of hospital total running expenditure is that directly spent for inpatient and non-inpatient care sectors of the hospital activity, i.e. for patient care services. Thus, the change in costs due to the presence of economies of scale and scope in the operation of hospitals, as well as the additional expenses incurred for teaching activities may be derived after allowing for the variation with respect to the extent of patient care activities and the resources used to achieve the level of provision of patient care services already attained. This presumption was thought to hold in both teaching and non-teaching hospitals.

Weighted least square is used to estimate their corresponding coefficients of the model variables, as defined previously. The results of the models fitted are presented in table 6.3.1. Four different specifications were considered to illustrate the model building process. They are denoted on the table by models (I) to (IV). In Model (I) only the six BED_j variables were included, whereas in Model (II) all variables corresponding to inpatient care services, BED_j, EXC_j and EXD_j were used. Even though these models omit other necessary variables that determine total running costs, both have large explanatory power. Model (I) and (II) respectively explain about 95% [$=R^2$ - see Appendix 4] and 97.5% of the total variation of the total running costs of hospitals. The addition of 12 bed use variables (of EXC_j and EXD_j) compared with Model(I) only increased R^2 (multiple correlation) by 3% showing their limited importance nevertheless the increment in R^2 is statistically significant at 5% confidence level. [See Appendix 4 about F-test].

The estimated coefficients of BED_j variables are somewhat unchanged, except for BEDLS and BEDSC. The coefficient of BEDLS now becomes positive, though still insignificant, while that of BEDSC reduces by almost a third. Table 5.9 reveals that LS and SC constitute speciality groups with one of the smallest and largest case flow rates, respectively, with the reverse in bed occupancy ratio. However, the effect of collinearity of the corresponding variables of BED_j, EXC_j and EXD_j were seen to be insignificant from sample coefficient of correlation (r) analysis [see Appendix 4]. Hence, the observed change may not have been caused by a collinearity effect but may be due to the model's better fit to the data. Since the hospitals being studied have at least two of the three hospital activities, inpatient and non-patient care and teaching, the two models reported above do not satisfactorily portray the actual structure of hospital costs. Our intention of elaborating on them is to explain the results of the next models fitted.

Models (III) and (IV) are those mainly of interest to us. Model (III) includes all variables that were intended for analysis in the present section. Thus, variables measuring hospital resources (BED_j) and its uses (EXC_j and EXD_j) and the scale of non-inpatient care activity (NIP_k) taken altogether determine about 98.4% of the total variability in the hospitals' total running costs. Some of the unexplained variability is hence accounted for by the remaining variables of the full model specification, such as economies of scale and scope and teaching measures.

In Model (III), five additional NIP_k variables were considered in relation to Model (II.) It is observed that the coefficients of both BED_j and NIP_k sets of variables were substantially reduced compared with that obtained in Models (I) and (II). Probably the latter models may have inflated the true values of the coefficients of each set of variables. But the coefficient of BED_j variables have shown stability for BEDDGH, BEDSA, BEDOBS, and BEDMI compared between Models (I) and (II) and the inclusion of NIP_k variables altered them. Two possibilities exist for such alteration. Either the effect of both sets of variables have been readjusted and standardized to the new situation or collinearity between BED_j and NIP_k has something to do with it.

Indeed, we observed significant pairwise correlations between BED_j and NIP_k variables. But no alternative option was possible to reduce it. One method of reducing it would have been to replace, say, NIP_k by other set of variables uncorrelated with BED_j and each other. Even if there were such proxy variables, correlation with the size of hospitals should always be expected. We left the original variables as they are because the collinearity was not very serious, so that the inversion of the design matrix [i.e. (X^TX) where X is matrix of independent variables] was still possible and the coefficients can be estimated with reasonable accuracy.

One can generalize from the results of Model (III) that some of the 23 variables seem to be redundant in determining total running costs. Furthermore, some of these coefficients representing marginal coststurns to be negative which is an unexpected relationship. Therefore, we applied step-wise regression analysis to select a subset of variables that actually might satisfy both statistical and economical expectations.

The Selection Method applied was All-subset step-wise regression technique using BMDP9R Computer programme. Among the numerous subsets produced through this technique and investigated in turn, the one reported in Model (IV) was chosen. The selection criterion made use of Mallow's Cp defined in Chapter 5. The Mallow's Cp statistics calculated for all possible different subsets reach the minimum when the selected subsets have 16 variables.[see Figure 6.2 for plots of selected sub-sets of variables and their Mallow's Cp].

The plot seems to indicate that when the subset includes 12 or 13 variables (i.e. P) their Mallow's Cp calculated approximately equals P. [see the diagonal line in the plot]. But a number of possible subsets, with 12 or 13 variables observed seem to be unsatisfactory for further interpretation, because generally, the variables shown in the subsets with those variables , include all of BED_j, some from EXC_j and NIP_k and sometimes none from EXD_j variables. One representative sample out of the several subsets with 12 variables have all six BED_j, EXCDGH, EXCOBS and EXCSC from inpatients,and NIPCNSL, NIPDPAT,and NIPDYCS from non-inpatient related variables with R^2 = 98.0%. According to this subset it implies that hospitals may not have expenditure for inpatients residential care, however long the patients stayed in the hospital, which is improbable. Therefore, having this in mind, what matters in model building process is the interpretability of the results achieved but not necessarily the actual number of variables that must be included, we looked for subsets that have more than 12 variables and finally settled for Model (IV), as shown in the table.

The sub-set has some statistical appeal in that an omission or addition of variables to this subset thus reduces the explanatory power of the model.[see the Mallow's Cp in figure 6.2]. It was not only the statistical part that is satisfied but the apriori economical expectation of the coefficients of the model, which gave the marginal costs that are positive in magnitude. [see table 6.3.2 for example]. These 16 variables, Model (IV) is thus the basic economic cost model (BEMI) and became a benchmark to test the other additional remaining variables from the full model specification. BEMI explains 98.25% of total running costs variability between hospitals and is highly significant (F - ratios = 224.3). Compared with Model (III) the omission of the five bed-use (EXCLS, OXCOBS, EXCMI, EXDMI and EXDSC) as well as the two non-inpatient (NIPANCL and NIPACDN) variables are not statistically significant (F = ratio = 0.60, $p > 0.25$), i.e. no supporting evidence for including them. [P denotes the conditional probability of observing this value of F-ratio larger than itself, given the null hypothesis is true, which at present is accepting a model with the 7 variables included rather than otherwise.]

There was no apparent change in the magnitudes of the estimated coefficients of the variables by omitting the above seven variables from the full linear model, Model(III). They are stable. There is only one coefficient non-significant at 10% but five at the conventional 5% confidence level. Table 6.3.2 reports estimated marginal costs of beds obtained from Models (III) and (IV). This table shows that the point estimates obtained from the full linear model (23 variables) and economical model (16 vaiables) are almost similar, except possibly for special category (SC) speciality group beds. Therefore, the loss in information by using Model (III) instead of Model (IV) is minimal economically and statistically.

The estimated coefficients of variables represent the marginal cost of providing each type of hospital resources or services. The model finally selected (BEM1) implied that keeping other factors constant, an additional DGH speciality bed costs on average about £21,200 per annum for a given volume of EXC and EXD. [see table 6.3.2]. From table 4.1 all Scottish hospitals on the average gave service to 31.9 DGH speciality inpatient cases per bed per year in 1985-86. Thus, the cost of an additional DGH bed on the average may be £665 (= £21,200/31.9) per bed per case. The same can be said about other speciality group bed marginal costs. With respect to bed-use variables for a fixed bed provision an additional extra inpatient case - above that nationally expected in the DGH speciality group, costs for treatment about £271 per year for given number of occupied bed days. Similarly the residential cost of an extra DGH speciality patient day amounts to about £47 for given number of patient cases. Also the marginal costs of an additional consultancy outpatient was estimated at about £34 per attendance per year in 1985-86 fiscal year.

Finally these results show that in the absence of other factors unaccounted for in the model, but capable of determining structure of total running costs, such as scale and scope of economies and teaching activities, it may be expensive for Scottish hospitals to provide more resources for DGH, supra-area and special category speciality group inpatient care services. Furthermore, daycase outpatient visits seem to cost higher than the other types of non-inpatient care services.

6.4 Results Using Quadratic and Cubic Terms of Variables

The section precedng this identified the basic total running cost model. It has already explained about 98.25% of the cost variation between the hospitals studied. The model denoted BEM1 can be expressed as follows:

$$\begin{aligned} TC_i = \alpha_0 + \sum_{j=1}^{6}\alpha_j BED_{ij} + \beta_1 EXCDGH_i + \beta_2 EXCSA_i + \beta_3 EXCSC_i \\ + \theta_1 EXPDGH_i + \theta_2 EXDLS_i + \theta_3 EXDSA_i + \theta_4 EXDOBS_i \\ + \gamma_1 NIPCNSL_i + \gamma_2 NIPDPAT_i + \gamma_3 NIPDYCS_i + u_i \quad \ldots\ldots(6.4.1) \end{aligned}$$

where, $u_i \sim N(0, \sigma^2 (TB_i)^{1.7})$, for $i = 1,2, \ \ldots \ , 81$. $\sigma^2 > 0$.

and, BED_j still represents all the six BED_j variables for each speciality group j, DGH...to., SC.

The modelling results to be described next adds quadratic (e.g. $BED^2{}_j$) and cubic (e.g. $BED^3{}_j$) orders of variables corresponding to BED_j and NIP_k variables that are in equation (6.4.1). The two variables of NIP_k (i.e. NIPANCL and NIPACDN) that were present in the full specification of the basic linear cost model were omitted. The decision for omitting the quadratic and cubic order effects of these variables relied on analysis of scatter plots of estimated standardized residuals (r_i), [defined in Chapter 3], versus each of these two variables. The residuals were obtained from the fitted values of equation (6.4.1) to the data. If these variables are required for inclusion in the cost model the plots should indicate a sort of curvilinear relationship between the residuals and the omitted variables. These plots are given in Figure 6.3 and 6.4. The plots for NIPANCL, as can be seen, do not show any pronounced curvature. They are almost randomly scattered around the zero horizontal line of the residuals. But a slight upward parabolic shape seems to be seen from the plot corresponding to NIPACDN. In any case, a regression of the residuals on either of NIPACDN, $NIPACDN^2$ or $NIPACDN^3$ or all of them fitted did not warrant any significant relationship. Thus, this diagnostic check was taken as guarantee for their omission.

The same preliminary check of the scattered plots of residuals against the variables to be analysed in this section was made before fitting the models. The outcome was not optimistic. That means, curvilinear relationships may not be necessary in the running cost model.[the figures are not reproduced]. We observed that except probably for BEDSC, the other remaining variables showed no sign of a quadratic or cubic type relationship.

Having this in mind, what followed was to fit models to the data employing the additional variables and to judge the resulting outcome. The criterion adopted was the increment in, say R^2, due to the addition of the 18 quadratic and cubic variables in the presence of the 16 linear ones. From that it would be possible to judge whether the scale of hospital activity had any cirvilinear relation with the total running costs.

Table 6.4.1 lists two cost models fitted to the data to test the importance of such variables. Model (I) includes all quadratic terms and Model (II) all the quadratic and cubic terms of BED_j and NIP_k variables. Model (I) has an explanatory power of (R^2 = 98.60%) with almost all quadratic variables seeming to be superfluous, meaning that none of their estimated coefficients are statistically significant. The model was not better than BEMI (16 Variables model) confirmed from an F-test.[$F = 1.01$, $p > 0.10$]. Model (II), the full cost model for this section analysis explains 98.60% of the cost variability. We observed here the problem of multicollinearity which is usually associated with fitting polynomial regression models. Hence, it is thought that the significant variables indicated corresponding to quadratic and cubic terms of BEDSL and NIPDPAT, may well be the outcome of collinearity influence.

Two methods of counteracting the problem of multicollinearity in the case of fitting polynomial regression model could be observed : (a) to make use of what is called orthoganial polynomials technique of model fitting, or (b) the simplest case proposed to make the usual F-tests in what is called a backwards elimination manner until a significant model is arrived at.[see Seber (1977, p. 217)]. We opted for the latter. The maximum degree of the polynomial was already fixed to the cubic degree. Then F-tests were performed between Model (II) vs (I),[with F-ratio = 1.02] and Model (I) vs BEM1, [with F-ratio = 2.07]. In both tests we have no convincing evidence to prefer the other two models specified in preference to the basic linear cost model (BEM1).[$p > 0.10$ and $p > 0.05$, respectively].

The above statistical tests are general and could have overshadowed the usefulness of individual variables being considered, so the technique of stepwise regression was applied to choose some variables that could improve the fit of the model. Forward step-wise regression was proposed in the present section rather than All-sub_set selection method used earlier. The reason was the large number of variables under investigation - 34 in all - not suitable for the All-subset selection.[Note BMDP handles only 27 variables]. The 16 linear variables already chosen in earlier sections were <u>forced</u> to be included in any subset to be finally adopted. Thus,additional quadratic or cubic term variables were expected to be selected as far as they can significantly improve the model fit above that already achieved. This 'forcing' restriction was essential due to the fact that it guards against rejecting variables inappropriately imposing different selection principles or guarantees the inclusion of those considered important. After such consideration, several specifications of the two models in table 6.4.1 were investigated. We set F-to-enter at 4. But no additional variables were indicated to be beneficial in the presence of the 16- linear variables of BEM1.

Therefore, we were led to conclude that the variables specified in the full cost model to represent the effect of economies of scale of hospital operation do not have much influence in determining the cost structures of hospitals being studied.[see Appendix 5(A) for the result without forcing restriction to some variables of the model].

The conclusion leaves the basic economic model (BEM1) as a model selected at this second step of the modelling procedure.

Taking the results provided under Model (II) in table 6.4.1, the estimated coefficients were supposed to define marginal costs of resources (BED_j) and services (EXC_j and others), assuming the effect of other factors are kept constant. Under such model specification the marginal costs vary depending on the levels of the different hospital resources and services, and their computations will become very complicated. Therefore, we resort to considering the signs of the estimated variable coefficients.

BED_j variables, with respect to DGH, supra-area, mental illness and special category seem to have similar outlines (i.e. positive for linearBED_j and BED_j-quadratic and negative for BED_j-cubic, except for BEDSC which has also negative value for its linear term). This pattern implies probably a bell-shaped marginal costs of bed curve (function) for these specialities. The remaining two specialities (longstay and obstetrics) BED_j variables coefficients signs confirm with a U-shaped marginal cost of bed curve (function).

With respect to NIP_k variables, consultant and daypat imply U-shaped curve for marginal cost of attendance curve, while that for daycase is a bell-shaped marginal cost curve. In any case, since the model has been shown to be unsatisfactory fit to the data, the above implications may not explain the true structure of total running costs of the hospitals studied.

6.5 Economies of Scope: Results Using Interaction Variables

6.5.1 Interaction Within Speciality Groups

Interaction variables in the total running cost model were implemented to examine the interdependence of levels of different hospital activities. We are looking in the analysis for such independence in three directions. The first presented in this subsection concentrates on the likely association within the hospital inpatient speciality group services. We like to know for instance whether the cost of bed provision in the DGH speciality group in a certain hospital can be affected by the presence of other speciality groups. In practice such dependence should prevail due to joint use of resources, so that it may not actually be possible to separate costs exactly for each speciality group individually. What interests us here is to see whether the association is effective in determining the structure of hospital costs.

As explained earlier, variables of the form BED_j X BED_l will be investigated to see the association within speciality groups. Data in tables 6.5.1 and 6.5.2 were designed to show some characteristics of these variables. Table 6.5.1 gives distribution of hospitals according to number of speciality groups they have. Let us consider the combined sample of 81 hospitals. About 75% of them have at least two speciality groups. The remaining are single speciality group hospitals, which are mainly specialising in mental illness services. Distinguishing hospitals by teaching status reveals that 67%, 80% and 92% of the hospitals,respectively in the controls, major and minor set have two or more speciality groups.

Table 6.5.2 on the other hand shows the cross-classification of hospitals with non-zero observations in the BED_j X BED_l variables. For example, 43 hospitals in the sample have DGH , out of which 27, 23, 11, 13 and 31 of them, respectively, have also either of LS, SA, OBS, MI and SC speciality groups. The distribution seems to have a pattern. Most hospitals appear to have other speciality group services if they already have any of DGH or SC. This may, of course, be the reflection of the conditions imposed to select the hospitals into the sample. But still there are limited mix up of specialities unrelated to the selection criterion. Hospitals with MI speciality groups do not frequently appear with another. Also those with OBS only appear most in relation with SC speciality group.

The likely deduction from the pattern might be that there could be an understood practice in the hospital sector in combining speciality groups as a result of a gain in reduced costs and/or improved operational efficiency. It could be shown too the need of the community where the hospitals are situated, as well as the demand by other non-inpatient services provided by them.

The table also indicates the problem we could face in fitting the model anticipated due to the limited number of observations in some interaction variables. Because, out of 15 interaction variables formed, 10 of them have only at-most 15 non-zero observations, while the remaining, at-least 66 observations are all zeros. First, accurate estimated coefficients may not be obtained from such limited data. Second, some preliminary diagnostic checks (such as residual plots studied previously) could not be considered effectively.

Hence, for the model building process, we concentrated on the outcome of the step-wise regression results, having in mind these a priori expectations to guard against, if unlikely results showed up. That is to say it would be impractical to accept a significant interaction from the use of 3 non-zero observations of BEDMI x BEDOBS or others with similar limitations.

The stepwise regression applied was the usual forward stepping with similar forcing restrictions imposed about the previous 16 linear term variables as in Section 6.4. We are looking for significant variables among the new set, hence F-To-Enter was set to 4.

The attempt to search for extra variables that significantly improve the model fit to the data among 15 BED_j XBED_l interaction variables, in the presence of the 16 linear variables come to the conclusion that no more variables could have due benefit. Therefore, the model with 16 variables remains the model selected for this step. [comments about the results from step-wise regression without imposing restriction on the linear variables are given in Appendix 5(B)].

To finalise this section, the model results including all the 15 BED_j X BED_l variables are reported in table 6.5.4. Since the model was shown to be unsatisfactory in terms of fit to the data, the implication of the estimated coefficient of these interaction variables may not be important indicators of the existence of economies or diseconomies of scope due to use of resources by speciality group services. For information, there are only 5 negative valued coefficients out of the 15 possible variables considered. They are for DGH X OBS, DGH X MI, LS X SA, LS X SC, as well as SA X OBS variables. Noting from table 6.5.2 we see that except for LS X SC variable, the other four variables have only less than 13 non-zero observations which may not guarantee their accuracy. If the model had been accepted in preference to BEM1 (16 variables) the implication would have been existence of economies of scope due to the above speciality groups listed. However, that is not the case and there is no conclusive evidence to accept it.

6.5.2 Interaction between inpatient and non-inpatient care services

This constitutes the second form of interaction effects sought. It looks at the capacity of the interdependence of levels of inpatient care of speciality groups and different forms of non-inpatient care activities to influence the cost structure of hospitals. For example, it might be of interest to know whether the presence of DGH or other speciality group in the hospital might reduce the cost of providing any type of non-inpatient care services. The variables defined to look at such association are denoted BED_j X NIP_k. There are 18 of them (=6 from BED_j X 3 from NIP_k).

Before the modelling results are outlined, let us detail some characteristics of the new interaction variables data. Table 6.5.3 presents the number of hospitals with non-zero observations of each variable. By non-zero observation of, say, BEDDGH X NIPCNSL, we mean both types of inpatient and non-inpatients are available in the hospital considered. The table signifies that hospitals which have consultancy outpatients (NIPCNSL) also have one of the speciality group inpatient services. On the contrary, a relatively small number of hospitals have both day-patient outpatient (NIPDPAT) and other inpatient speciality services, with the exception of mental illness. The connection between daypatient and mental illness services is not surprising since both deal with similar types of patient care. Daycase outpatient (NIPDYCS), however, occurs infrequently in conjunction with the mental illness inpatient service, otherwise the number of hospitals giving both this and inpatient specialities are fairly large compared with daypatient outpatient services.

In order to attend to the contribution of these new interaction variables in the cost model building process, the 18 interaction variables were combined with the 16 linear variables from the last subsection's analyses. The model fitted using these 34 variables is listed under table 6.5.5. Clearly without going into further investigation, the limited importance of the new variables could be seen. The estimated coefficients of the interaction variables were all non-significantat at 5% confidence level. The only variable that seemed to simulate any effect is NIPDYCS X BEDSC, but both individual NIPDYCS and BEDSC have become redundant.

The change in R^2 due to the addition of 18 variables is not encouraging; from 98.25% under BEM1 (16 variables) it only increased to 98.70%. Adjusted for degrees of freedom ($\bar{R}^2$ - see Appeneix 4), this increment of course turns to nearly a loss in explanatory power. Proceeding with the usual step-wise regression produced similar conclusions to those reported in previous sections. That means, as far as the 16-linear variables in the linear model are being concerned, none of the interaction variables may be necessary. The alternative modelling result, using all variables and applying forward stepwise regression was listed in Appendix 5(C). We are not convinced with the subset of variables indicated there due to its limitations in explaining the structure of hospital costs.

Considering the estimated coefficients of the model variables including the 18 BED_j X NIP_k variables reported in table 6.5.5, with particular reference to the interaction variables, we see that some of them have negative estimated coefficients. If the model were accepted, the result would seem to imply that the presence of consultancy non-inpatient services with LS, MI and SC inpatient speciality services would perhaps benefit the hospitals concerned or vice-versa. In the same manner, day-patient non-inpatient services provided with LS, SA and SC speciality inpatient services as well as day-case non-inpatient services provided with DGH, SA, OBS and MI inpatient speciality services might produce similar effects to the total running costs of hospitals. However, there is no concrete evidence to recognise the importance of these results.

6.5.3 Interaction between Patient care and Teaching activity

Within the last four divisions of Chapter 6, which considers the model building aspect of total running costs of hospitals, we have come to accept - in the absence of the effect of teaching variables in the cost model that the costs could have a possible linear relationship with the hospital resources and activity measuring variables. In the following subsection,s the teaching variables, number of students (STDN), training nurses (NURS) and teaching status (MAJOR, MINOR, CONTROL) of hospitals would be implemented and the same procedure applied to assess their usefulness in the cost model being developed.

To facilitate the flow of the continuing discussion, first we present the results from the analysis of interaction of teaching and patient care variables.

The patient-care variables chosen for the purpose are BED_j and NIP_k variables. But with respect to teaching, there are two possibilities from which the interaction variables could be created. One is the Health Board designation, teaching status (TS) of hospitals, and the alternative being the remaining two variables (STDN and NURS). The objective of the analysis is to see whether the structure of cost of hospitals can be effected by the interdependence between their levels of teaching and non-teaching activities. So which one of the alternative teaching variables chosen to create the interaction variables depends on determining the suitable proxy for level of teaching activity.

The teaching status of hospitals is a classification decided by the health boards, possibly based not only on the extent of teaching responsibility but also on other conditions, for example, scale and quality of facilities available in the hospital for patient care. But we lack detailed information in how this was done. Teaching status may be related with other factors such as quality of care, research capacity differing case mix of specialities. Therefore, the interaction effects observed, using teaching status, could be confounded with these influences. Concerning training nurses (NURS) data, it only covers 60% of the nurse time that is allocated to the costs of hospitals. This variables data, given in table 5.7, shows no indication of numbers of nurses trained increasing with the level of teaching of hospitals. In fact it is larger in the minor teaching hospitals, unlike the data of other variables of interest here, BED_j and NIP_k. Therefore, the use of NURS variable to form interactions did not seem feasable. Hence, the variable depicting number of medical students (STDN) was implemented. The variable is thought to be important in reflecting effect of teaching in hospital costs and may signify the true nature and association between teaching and patient care services of hospitals.

New variables of the form BED_j X STDN and NIP_k X STDN, a total of nine were included in the cost models, with the 16 linear variables from the last sections. The data in tables 6.5.2 and 6.5.3 gives the distribution of the number of hospitals with non-zero observations in the nine interaction variables being considered. With respect to BED_j X STDN , a comparatively large number of hospitals facilitate training undergraduate medical students and provide either DGH or special category speciality inpatient services. Generally, a quarter of the sample of hospitals train students and give either of the six speciality inpatient care services. With respect to the NIP_k X STDN variables, almost all hospitals providing facilities for undergraduate students training also have the three types of the non-inpatient services (consultant, daypatient and daycase).

The two cost models fitted to the data are listed in table 6.5.6. Model (I) includes the six BED_j X STDN, while (II) uses the three NIP_k X STDN variables. Both also include STDN and NURS variables. In any case, models fitted with or without these latter two variables does not affect the significance pattern of the estimated coefficients of the other interaction variables in the model. Their presence is only for convenience. The outline of the coefficients with respect to statistical significance is similar to what has been seen in the last three subsections. There is a clear demarcation between the linear and the interaction variables. None of the latter variables are statistically significant either at 10% and/or 5% confidence levels.

A step-wise regression technique applied to both models, selected only the STDN variable in the presence of the 16 linear variables (BEM1). Thus, though the STDN variable seems to have no influence, in the presence of the interactions, considered individually is statistically significant. Therefore the cost model selected also remains the same 16 variables at this stage.

For information let us see the results of both full models reported in table 6.5.6, in spite of the fact that no use will be made of them further. From Model (I), coefficients of BEDSA X STDN, BEDMI X STDN and BEDSC X STDN are estimated to be negative. If they were significant and selected their implications is an existence of economies of scope due to the presence of either or all these, three specialities and teaching activities in one hospital. As the level of teaching activity increases, their costs could decrease, or vice versa. On the other hand, DGH, long-stay and obstetrics speciality inpatient services provided, coupled with teaching in the same hospital, have a tendency to increase costs, i.e. a possibility of diseconomies of scope.

From Model (II), only NIPCNSL X STDN have negative estimated coefficients. The remaining two have positive values. The reduction in magnitude of the estimated coefficient of STDN variable compared with that in Model (I) could be the effect of collinearity. The next section produces the consequence of using the individual teaching variables, namely, STDN, NURS and TS, with the 16 linear variables still shown to be important.

6.6 Results from the Use of Teaching Variables

The present section leads us to the final part of the model building process. There are essentially four additional variables to be considered here, all showing the way teaching activity in a certain hospital are measured. We have the two variables for status of teaching hospital (MAJOR and MINOR), the weighted equivalent number of medical students (STDN) and training nurses (NURS). The objective of the current analysis is to implement these variables and come up with a final total running cost model for Scottish hospitals being analysed.

6.6.1 Structural differences between models for teaching and non-teaching hospital costs

In Section 6.4 we have noted that the teaching hospitals may be differentiated from the controls (non-teaching) not only by their level of teaching activity, but also with respect to the level of bed (resource) provision and the extent of the use made of it. Thus,there is a possibility that they can be differentiated from the controls in terms of the set of factors in the previous sections - BED_j, EXC_j, EXD_j and NIP_k producing possible varying estimated coefficients, if separate models were fitted to each group of hospitals data. We have extended the analysis to see whether such distinguishing factors can be reflected between the teaching and non-teaching hospital cost structures. We used variables in BEM1, in addition to the teaching variables.

The use of the dummy variables formed depicting the teaching status of hospitals, named, MAJOR, MINOR and CONTROL was the first that was considered for this purpose. The result, using the six BED_j variables, and these dummy variables were reported in table 6.6.1. Included are STDN and NURS variables. The problems of using these dummy variables were mentioned on several occasions, in particular in the limited number of hospitals in some speciality groups. In view of this, of particular interest from the table was the negative estimated coefficient of MAJOR X BEDLS and MINOR X BEDLS, which indicate that keeping other factors constant, one additional long-stay bed provision in the major teaching hospital incurs a reduction in the marginal costs of approximately £120,000 per annum, which may be hard to believe!. There are only three major teaching hospitals with long-stay speciality. They are hospitals with the maximum total running costs among hospitals in the sample, namely, Aberdeen Royal Infirmary (N106), Edinburgh Royal Infirmary (S226) and Ninewells hospital (T101). [see table 6.6.4].

From table 6.6.1 it appears that there could be significant pairwise differences among the coefficients of BED_j variables corresponding to the three types of hospitals. For example, between MAJOR and MINOR for BED DGH or the others. However, restricting the long-stay speciality bed marginal cost to be the same (constant) between the three types of hospitals, [i.e. fixing coefficients of MAJORBEDLS = MINORBEDLS = CONTROLBEDLS = C], this was checked. We found no conclusive evidence to assume such differences exist between the estimated coefficients for $MAJORBED_j$, $MINORBED_j$ and $CONTROLBED_j$ for the 81 hospitals studied, at 5% conventional confidence level, for all j, i.e. between the six speciality groups. Thus, we came to realise that the differences could be the side-effect of the above inaccurate coefficient estimated for MAJOR X BEDLS based on the three hospitals. These results were discussed to show why information on teaching status of hospitals cannot be helpful to differentiate between hospitals in respect of variables like the above. The main problem is of course the limited sample size.

As another attempt, separate cost model was fitted each to the teaching and non-teaching hospitals' sample data using the 16 linear (BEM1) and 2 teaching variables. The objective was to check the structural differences between the estimated coefficients obtained from the two types of hospital data. The test statistics was an F-test as described on Johnston (1985, pp. 207-225). We made two hypothesis tests:

(a) teaching and non-teaching hospitals may have different overhead costs (i.e. constant terms of the models), and,

(b) teaching and non-teaching hospitals data produce significantly different estimated coefficients corresponding to the 18 variables.

The model fitted to data of teaching hospitals sample explained 98.36% of the total variation, while for the non-teaching hospitals data the model fitted explained 99.25% of the variability of their total running costs. [see table 6.6.2].

From the coefficients estimated it can be observed that the teaching and non-teaching hospitals data seem to produce differing values. Obviously some variables have coefficients larger in magnitude for the teaching hospital samples than the control samples, and the reverse is true also for the controls for some variables. It can be seen in addition that the non-teaching hospitals sample produced coefficients, statistically significant and have superior explanatory power (R^2). There are two explanations: one, these hospitals are more homogeneous than the non-teaching, in view of their selection and, two, they have larger sample size compared with the teaching hospitals.

The hypothesis test described earlier was performed. In both instances, (i) and (ii), we were led to believe that there was no conclusive evidence to suggest that both hypothesized differences prevailed between teaching and non-teaching hospital costs under conventional confidence levels.

But further analysis, in terms of overhead cost estimates between MAJOR, MINOR and CONTROL types of hospitals on the other hand revealed that:

(a) overhead costs of MAJOR could be significantly larger than the MINOR teaching hospitals;

(b) overhead costs of CONTROL, non-teaching could be significant larger than the MINOR teaching hospitals,

(c) but no definite evidence to assume that differences might exist between overhead costs of MAJOR and CONTROL (non-teaching) hospitals.

We next consider the implication of the final cost model chosen with due regard to the above discussed results.

6.6.2 The Adopted Total Running Costs Model and Its Implications

The total running costs model finally selected is reported in table 6.6.3. Included in the equation are the 16 variables corresponding to the non-teaching activities of hospitals and 4 others regarding the part of the teaching activities. The variables explained 98.6% of the variability in the total running costs of hospitals studied and this is a significant improvement compared with the 16 variables of Model BEM1. (F-ratio = 3.82, $p < 0.05$). It implies that the teaching activities of hospitals could be one of the factors determining their costs as anticipated.

The interpretation given to the coefficients of the variables in the final cost model is similar to the previous cases. They can be used to define marginal costs of providing the respective resources and services that the variables intended to represent. Concerning the coefficients of the teaching variables, the positive values for both STDN and NURS estimated imply training medical students and nurses count as additional costs to the hospitals' concerned. Hence, according to 1985/86 Scottish hospital data, an additional medical undergraduate student is estimated to cost around £14,600 per year to the hospitals involved in this activity. A 95% confidence limit for cost per medical student would suggest that this cost could be as high as £31,000.

Similarly the data showed that training one additional nurse in the Scottish hospital costs about £10,630 per annum in 1986/86, keeping other factors constant. This cost of nurse training includes the 60% of the financial costs to the hospital for employing the nurses. [The remaining 40% of the expenditure which is directly paid by the Health Boards concerned for the salary of the nurse and other related employers' costs (insurance, for example accounts for about £2,300 per trainee nurse computed from 1985/86 data of the 81 Scottish hospitals]. We can say that with 95% confidence level, the true marginal cost of training one additional nurse to the hospitals concerned may come up to about £23,000 per year in 1985/86.

Concerning the other teaching variables in the model, it is evident that the extra teaching costs of the teaching hospitals, particularly for MAJOR, comes from their overhead costs represented by the coefficients of MAJOR variables, regardless of the scale of resources or service provision the hospitals undertake in comparison to the non-teaching hospitals. Therefore, the model suggests an extra cost of nearly half a million pounds (£440,500) per major teaching hospitals might have been spent in 1985/86, because of the considerable teaching activity undertaken compared with the non-teaching control types of hospitals. By the same token, being a minor teaching hospital seems to have no extra costs, unlike the major teaching hospitals, but might have in fact a lower overhead cost of about £688,500 per hospital compared with the non-teaching hospitals.

Using the estimated coefficients of the final model we estimated the expected total running costs of each type of hospitals at the average values of the variables, using the data outlined in tables 5.5 to 5.7. The results are listed in table 6.6.4. From this table we observed the following points:

(i) Assuming a certain hospital was designated as major and might have trained about 52 undergraduate medical students per year in 1985/86, this would have cost it on the average about £1.2 million, nearly 10% of the actual average annual total running costs of major teaching hospitals. Furthermore, assuming the same hospital also might have trained about 72 nurses per year, its annual additional cost of teaching would rise almost to £2 million pounds, which accounts for 15% of the actual average total running costs of such type of hospitals. [The student and nurse costs account for 76% of this total teaching costs]. The remaining 85% of the actual costs seem to be that accounted for the non-teaching services of the hospital.

(ii) With respect to the minor teaching hospitals, taking same sort of assumptions as in (i). 'minor' teaching hospitals who have on average trained 38 undergraduate medical students and 97 nurses would have spent about £1.6 million in 1985/86, which accounts for 12% of the average actual total running costs of such types of hospitals. We see from the table that the minor teaching hospitals seem to spend slightly more on non-teaching activities on the average compared with major teaching hospitals. Their expenditure for non-teaching services might be estimated at about 88% of their actual average total running costs.

(iii) With respect to the non-teaching (control) hospitals, the decomposition of the estimated total running costs at the mean levels of their data of all variables puts about 6% of their actual total costs for teaching activities provided. The remaining 94% of their costs was estimated to be that spent on non-teaching services, considerably larger than the two types of teaching hospitals share for this purpose. Since the control hospitals have only 3 medical students per hospital, the additional teaching costs (£376,000 per year per hospital) estimated was practically due to training nurses.

The adopted model, being compared with the results reported for the basic economic cost model (BEM1) in table 6.3.1, shows that including the teaching variables in the model seen to reduce the estimated coefficients of the 16-variables common to both of them. In particular the variables affected correspond to those named after supra-area (SA) and special category (SC) speciality groups, either , for BED_j, or EXC_j or EXD_i in the models. We might note that these two speciality groups are those most commonly provided inpatient services in the teaching hospitals [see Chapter 4]. Nevertheless, the conclusions to be made about the cost of providing different inpatient and non-inpatient services appear unchanged. Because, still it can be deduced that the provision of beds for SA and SC might be expensive compared with the other speciality groups and so is their treatment costs. Also, residential cost of supra area speciality group might be higher in comparison to other specialities. These conclusions are as anticipated. Supra-Area and special category services are believed to require more resources in skilled medical staff and sophisticated equipment. We can say also that treatment of Daycase outpatient services might be more expensive in comparison with the other forms of outpatient visits.

The model has also been used for prediction purposes. The total running costs predicted for 1985/86 within the framework of the selected model variables was given in Table 6.6.5. Also listed are confidence and prediction intervals with 95% confidence.

6.6.3 Diagnostic Check of the Model: Analysis of Residuals

In the previous sections, several statistical tests and comments were made as though the models estimated have satisfied the statistical assumptions required to undertake them. The objective of the present section is to check the justifiability of these assumptions within the context of the model specification chosen.

The adopted cost model was implemented to estimate the expected total running costs of hospitals, which was reported in table 6.6.5. The residuals are then computed as the difference between the actual and those estimated total running costs. The use made of these residuals are numerous, the primary role being to check the feasibility of the regression assumptions.

(a) Verifying statistical assumptions:
The simplest technique for this purpose is to investigate different plots of residuals with other variables. Figure 6.5. illustrates the scatter plots of he standardized residuals with the estimated total running costs. This plot indicates whether non-constant variance, non-linearity, outlier and influential observations and other related regression model discrepancies exist. It is possible to see from the plot that the observations are fairly randomly scattered around the horizontal zero line. Hence, some of the above discrepancies might not affect the model. However the plot seems to show some problems. There are seven hospitals with more than two standard error of residuals and some hospitals with estimated costs at least £21 million to have

residuals forming scattered clusters far from the bulk of the hospitals with less than the specified total costs.

The large residuals case, probably means an outlier hospital could exist in the sample. But statistical outlier tests [see Weisberg 1985 , Chapter 5] performed on those estimated residuals showed none of the hospitals (observations) in the sample behave differently from the others. The cluster of hospitals case, was thought to imply the tendency of influential hospitals , say, the teaching, to determine the magnitudes of the estimated coefficients of the model variables more than others. Analysis of influential cases (observations) in regression modelling is somewhat complicated and not easy to overcome. There are statistical techniques to examine them. [see the reference above].

Using these techniques of examining influential observations we found possible existence of some influential hospitals in the sample. But it was found that they do not belong, neither to a particular group with a given teaching status, nor with larger total running costs as was presumed. Influential observations can be eliminated and the model re-estimated, but with the small sample size and objective of the study such as ours, the attempt may not be a proper cource to follow. The problem would have been serious if a single observation imposes a great deal of influence. For example, we found that possibly 16 observations (hospitals) influencing the coefficients of the teaching variables in particular, 6 from controls, 5 from major teaching and 5 from minor teaching hospitals, with costs ranging from the minimum of £497,000 to the maximum of about £36 million.

Figure 6.6 presents the normal probability plot of the estimated residuals. The role of the plot, as its name implies, is to verify the normality assumption. Clearly the assumption that the sample observations could have come from a population of hospitals having normal distribution is justified. Hence, the statistical tests and confidence interval constructed so far could have the required supportive probability assumptions.

(b) Other Systematic Differences Between Hospitals

The use of residual analysis can also show systematic patterns unobserved through employing some other additional variables. We have only investigated differences in the structure of hospital costs in terms of factors related to patient-care and teaching activities. But hospital costs might vary due to other underlying factors. What we want to examine here is the influences of regional location and management and accounting policies of the various Health Boards administering the hospitals. For example, hospitals under Greater Glasgow Health Boards could have both influences. It is a teaching Health Board and its hospitals are situated around a city that may have some different factor prices than the other regions in Scotland.

To observe these points, we relied on similar forms of plots of residuals estimated. The plot under consideration is given in Figure 6.7. The standardised residuals of each hospital was plotted against their serial identification. For instance, the letter A in the plot represents hospitals under Ayrshire and Arran Health Board, ... to G denoting Greater Glasgow Health Board, ... up to finally Y, denoting those under Dumfries Health Board. These alphabets coincide with the coding of hospitals listed in table 5.1 in Chapter 5.

Our criterion of investigation is to look for hospitals with above and below the zero residual horizontal line. Then explore for possible patterns. Hospitals above this line (or positive residual costs) are those with actual total running costs more than estimated expected total running costs. So they seem to be expensive to run given the level of resources and services they experienced. Those below the line (or negative residual costs) on the contrary, seem to spend less than their level of resources and activity might justify. Our interest was particularly to see this pattern within hospitals under the teaching Health Boards situated at Glasgow (G), Grampian (N), Lothian (S), and Tayside (T) compared with those under the non-teaching Health Boards.

Concerning the Teaching Health Boards (HBs), the plot shows more hospitals in Glasgow and Tayside to have positive residuals. There are 17 and 8 hospitals in the sample, respectively, administered under Glasgow and Tayside HBs, of these, 11 and 7 hospitals, respectively, have positive residuals estimated. More hospitals under the other two teaching HBs (Grampian and Lothian), in contrast, have negative residuals. There are 8 and 16 hospitals, respectively, under Grampian and Lothian HBs, of which 6 and 9 respectively show negative residuals. Note that the non-teaching HBs have small numbers of hospitals and do not show such considerable distinction.

When the teaching and non-teaching dichotomy of the hospitals were taken into consideration we observed no profound patterns. Both sets of hospitals have almost half of them with positive and the remaining half with negative estimated residual costs.

The analysis, therefore, suggests that modelling total running costs of hospitals should take into consideration the influence of their hospitals' regional location and possible differences in management structures of the Health Boards administering them. We like to note that this notion was not described while formulating the total running cost function (Chapter 4) because it did not seem likely to us that differences in location and management structure of hospital might have significant effect on Scottish hospital costs. In the light of the present circumstances, it could be beneficial to consider them in some detail.

As can be observed from the sample of hospitals we have, it would not be feasible to incorporate the location of all Health Boards as additional variables into the model building process. Because the sample is formed of hospitals gathered from 12 Health Boards, most of which except the four teaching Health Boards, have only at most 7 hospitals. Dummy variables created with such limited observation, to represent the location of Health Boards, would not be considered able to produce reliable results.

As a matter of interest, however, we formed five dummy variables, called GLASGOW, GRAMPIAN, LOTHIAN, TAYSIDE and REMAINED, to represent, respectively the 4 teaching and the last one, the non-teaching type Health

Boards. The objective was therefore to look at possible differences between the cost structures of hospitals under teaching and non-teaching Health Boards with due regard to their location. We used these dummy variables including the previous MAJOR, MINOR and CONTROL classification of teaching status to fit the intended models. The result is reported in table 6.6.6. The model results corresponding to MAJOR variable for example compares the major teaching hospital's overhead costs with the non-teaching hospitals, that are in fact not under the administration of teaching Health Boards. It is clear then, major teaching hospitals may have additional (extra) teaching costs of £619,700 per year per hospital, compared with the non-teaching hospitals. This is about 30% larger than the corresponding comparison under the model which does not fit location, (see model 6.6.3). The minor teaching hospitals have still lower overhead costs than the non-teaching hospitals. Of particular interest that can be observed are differences between hospitals under Tayside HB compared with hospitals under other non-teaching HBs in the sample. The results indicate that the latter type of hospitals might have incurred additional extra cost of about £773,200 per hospital per year in 1985/86 in comparison to the said non-teaching hospitals. However, this difference would not be considered significant with the conventional 5% confidence level, since T-ratio equals 1.85 with 56 degrees of freedom.

The model explains 98.72% of the variability of total running costs of hospitals studied, not very different from that of the finally adopted model given in table 6.6.3 (R^2 = 98.6%). Therefore, location and teaching status of HBs may not have much influence in differentiating the cost structure of hospitals. The designation of teaching hospitals as major and minor could play equal role for such purpose.

6.7 Summary

The general empirical results presented in this chapter can be summarized briefly.

Data of 33 teaching and 48 non-teaching Scottish hospitals were used to find a suitable functional relationship between their total running costs and measures of different inputs and outputs. The constraint of this small sample size has forced us to adopt an ad hoc model building process which selected 20 of the variables out of the various possibilities considered. These variables selected signified that above all others, variables related to teaching activity of hospitals are one of the determinants of total running costs. The cost function specification implied through the selected variables also showed costs are linearly related to the scale of hospital resources and activities. In so doing it was found that within the data of the hospitals studied, Scottish hospitals might not have any form of financial gain through an increase in their operational capacity as well as combination (mix) of the various services they provided. In other words their total running costs are influenced neither through the impact of economies of scale nor scope of activities.

Emphasising on the influence of teaching activities of hospitals on their costs, it was found that training medical students and nurses involves creating additional costs to the hospitals undertaking them. Also, the teaching status designation of hospitals by their Health Boards have a contribution in indicating the presence of additional costs of operation incurred by the major teaching hospitals. Hence, a major teaching hospital on average could probably have spent about 15% of its total running costs for facilitating teaching and related services. This share of teaching costs is about 12% for the minor teaching hospitals. The analysis also showed the control, non-teaching hospitals to have some additional teaching costs due to their training of nurses.

Even though the data had suggested the teaching hospitals to have comparably larger total costs, resources and services provision, no evidence was available to assume that marginal costs of the various hospital resources and services to be different among the teaching and non-teaching hospitals. However, there is implication that, on average the teaching hospitals, particularly those participating in major teaching activity, might have spent less on patient care services to compensate for their comparatively larger expenditure on teaching activities.

Finally, we might not have possible differences in the cost structure of hospitals, due to either the administrative policy of the Health Boards and/or the regional location of the hospitals.

TABLE 6.3.1. BASIC LINEAR COST MODELS FOR TOTAL RUNNING COSTS.

Independent Variables	(I)	(II)	Basic Linear Cost Model (BCM) (III)	Basic Economic Cost Model (BEM1) (IV)
BED DGH	33.23 (23.47)	27.413 (17.92)	19.70 (8.87)	20.18 (9.96)
BED LS	- 4.35 (-0.090)	8.023 (1.89)	9.27 (2.17)	7.59 (1.89)
BED SA	43.35 (5.32)	51.357 (7.52)	39.13 (6.18)	38.49 (6.50)
BED OBS	23.53 (5.19)	24.297 (6.84)	17.83 (4.84)	17.18 (5.16)
BED MI	12.64 (14.00)	11.000 (14.01)	9.82 (11.37)	9.43 (12.33)
BED SC	72.17 (5.26)	26.210 (2.06)	28.98 (2.56)	33.29 (3.29)
EXC DGH	-	0.6066 (5.50)	0.309 (2.66)	0.271 (2.53)
EXC LS	-	0.1370 (0.14)	- 0.014 (-0.02)	-
EXC SA	-	0.8580 (1.48)	0.763 (1.47)	0.898 (1.83)
EXC OBS	-	0.2833 (1.32)	0.339 (1.69)	-
EXC MI	-	1.2446 (1.26)	0.688 (0.77)	-
EXC SC	-	0.9231 (2.27)	0.661 (1.70)	0.736 (2.29)
EXß DGH	-	0.0846 (3.28)	0.050 (2.04)	0.047 (1.99)
EXD LS	-	0.1038 (2.49)	0.057 (1.54)	0.059 (1.68)
EXD SA	-	0.0754 (0.45)	0.212 (1.42)	0.204 (1.44)
EXD OBS	-	0.0270 (0.70)	0.028 (0.78)	0.066 (2.75)
EXD MI	-	0.0173 (0.80)	0.007 (0.38)	-
EXD SC	-	0.0578 (0.66)	-0.050 (-0.60)	-
NIP CNSL	-	-	0.029 (2.71)	0.034 (4.44)
NIP ANCL	-	-	0.006 (0.63)	-
NIP ACDN	-	-	0.007 (0.47)	-
NIP DPAT	-	-	0.052 (1.59)	0.068 (2.40)
NIP DYCS	-	-	0.219 (1.77)	0.298 (2.89)
CONSTANT	-794.3 (-4.08)	55.1 (0.24)	-59.1 (-.0.28)	-85.1 (-0.51)
R^2	94.66	97.53	98.36	98.25
MSE	104.0	57.6	41.5	39.6

Note Figures inside parenthesis are T - ratios of Coefficients = Coefficient / s.e. (Coefficient)

where, s.e. means standard error of. Figures are in £000s, except for R^2 and T-ratios- same also in next tables.

TABLE 6.3.2 ESTIMATED MARGINAL COSTS (3) of SPECIALITY GROUP BEDS PROVISION OF HOSPITALS

Speciality Group (j)	ESTIMATED FROM Full Linear Model (Model III)(1)	Basic Economic Model (BEM1) (Model IV)(2)
BED DGH	20.8	21.2
BED LS	9.9	8.3
BED SA	40.1	39.4
BED ODS	19.5	18.7
BED MI	9.8	9.4
BED SC	31.9	37.4

Notes: Costs are in £000s.

(1) and (2) See Table 6.3.1.

(3) Let the total running cost model be given by Model (III):

$$\tilde{TC} = \tilde{\alpha}_0 + \sum_{j=1}^{6}\tilde{\alpha}_j BED_j + \sum_{j=1}^{6}\tilde{\beta}_j EXC_j + \sum_{j=1}^{6}\tilde{\theta}_j EXD_j + \sum_{k=1}^{5}\tilde{\gamma}_k NIP_k$$

The marginal cost of an additional speciality bed, say BEDj,

denoted, $MC(BED_j) = \frac{\partial \tilde{TC}}{\partial BED_j} = \tilde{\alpha}_j + \tilde{\beta}_j \frac{\partial EXC_j}{\partial BED_j} + \tilde{\theta}_j \frac{\partial EXD_j}{\partial BED_j}$

($\sim$ indicates estimated figures).

From definition of EXC_j and EXD_j of Chapter 4,

$EXC_j = IPC_j - \overline{CFR}_j x BED_j x 365$ and $EXD_j = OCD_j - \overline{OCR}_j \times BED_j \times 365$

where, $\overline{CFR}_j$ and $\overline{OCR}_j$ are National average Scottish hospitals case flow rates and bed occupancy ratio, respectively. IPC_j and OCD_j are inpatient cases and occupied bed days ,respectively.

It is also possible that:$IPC_j = BED_j \times CFR_j \times 365$ and $OCD_j = BED_j \times OCR_j \times 365$

where, CFR_j and OCR_j are, respectively average sample case flow rates and occupancy ratios, at the mean levels of IPC_j and OCD_j of the 81 Scottish hospitals.

Therefore, $MC(BED_j) = \tilde{\alpha}_j + 365\,[\tilde{\beta}_j x(CFR_j - \overline{CFR}_j) + \tilde{\theta}_j x(OCR_j - \overline{OCR}_j)]$,

assuming that no change in bed-use (CFR_j and OCR_j) due to an additional speciality group j bed.

This definition of $MC(BED_j)$ was used in the table for results of Model (III) and (IV) as indicated.

TABLE 6.4.1 MODELS FITTED TO TOTAL RUNNING COSTS: ADDING QUADRATIC AND CUBIC ORDER VARIABLES

Independent Variables	Model(I)	Model(II)
BED DGH	23.05 (5.75)	16.75 (2.32)
BED LS	- 1.26 (-0.17)	14.88 (1.07)
BED SA	44.86 (3.94)	27.77 (0.91)
BED OBS	4.41 (0.36)	27.59 (0.99)
BED MI	10.37 (5.43)	5.47 (1.34)
BED SC	84.94 (2.20)	- 23.72 (-0.46)
BED SQR DGH	-0.0039 (-0.53)	0.0196 (0.61)
BED SQR LS	0.0750 (1.44)	-0.1857 (-0.82)
BEDSQR SA	-0.0584 (-0.64)	0.4403 (0.54)
BEDSQR OBS	0.0842 (1.15)	-0.4400 (-1.05)
BEDSQR MI	-0.0010 (-0.50)	0.0078 (1.04)
BEDSQR SC	-0.7791(-1.34)	4.2000 (2.43)
BEDCBD DGH	-	-2.6E-5 (-0.66)
BEDCBD LS	-	1.0E-3 (1.24)
BEDCBD SA	-	-2.2E-3 (-0.58)
BEDCBD OBS	-	2.4E-3 (1.34)
BEDCBD MI	-	-4.3E-6 (-1.19)
BEDCBD SC	-	-5.3E-2 (-2.88)
EXC DGH	0.264 (2.19)	0.381 (2.45)
EXC SA	1.028 (1.85)	0.596 (0.99)
EXC SC	0.362 (0.96)	0.525 (1.24)
EXD DGH	0.043 (1.55)	0.042 (1.45)
EXD LS	0.076 (1.94)	0.055 (1.29)
EXD SA	0.141 (0.95)	0.215 (1.39)
EXD OBS	0.047 (1.66)	0.060 (1.63)
NP CNSL	0.018 (1.47)	0.040 (1.85)
NIP DPAT	0.090 (1.51)	0.249 (2.63)
NIP DYCS	0.020 (0.10)	0.068 (0.21)
NIPSQR CNSL	8.0E - 8 (1.12)	-2.8E-7 (-0.85)
NIPSQR DPAT	-1.6E-6 (-0.69)	-1.6E-5 (-2.04)
NIPSQR DYCS	4.8E-5 (1.18)	6.6E-5 (0.35)
NIPCBD CNSL	-	1.3E-12 (1.00)
NIPCBD DPAT	-	3.0E-10 (1.77)
NIPCBD DYCS	-	-8.1E-9 (-0.37)
CONSTANT	-105.5 (-0.40)	232.0 (0.50)
R^2	98.5	98.9
MSE	39.5	34.7

Note: BEDSQR = $(BED)^2$

BEDCBD = $(BED)^3$

NIPSQR = $(NIP)^2$

NIPCBD = $(NIP)^3$

Figures are in £000s.

TABLE 6.5.1 DISTRIBUTION OF HOSPITALS BY NUMBER OF SPECIALITY GROUP AND TEACHING STATUS

Number of Speciality Groups[a]	Number of Hospitals[b] Combined Sample (n = 81)	Non-Teaching (Control) (n = 48)	Major Teaching (n = 20)	Minor Teaching (n = 13)
1	21*	16	4	1
2	21**	14	5	2
3	21	11	6	4
4	12	6	4	2
5	4	1	0	3
6	2	0	1	1

Notes a. Number of Speciality Groups in the hospitals. 1 for Example, indicates hospitals with Single Speciality Group .

b. Number of hospitals with the given number of Speciality Groups.

* All Single Speciality Mental illness (MI) hospitals.

** 15 of the hospitals have Obstetrics (OBS) and Special Category (SC) Special Groups.

TABLE 6.5.2 DISTRIBUTION OF NUMBER OF HOSPITALS WITH NON-ZERO OBSERVATIONS OF INTERACTION VARIABLES OF THE FORM: BED_j x BED_l and BED_j x STDN

BEDj / BEDl	DGH (j=1)	LS (j=2)	SA (j=3)	OBS (j=4)	MI (j=5)	SC (j=6)
DGH (l=1)	43[1]					
LS (l=2)	27	31				
SA (l=3)	23	15	24			
OBS(l=4)	11	11	6	26		
MI (l=5)	13	11	6	3	38	
SC (l=6)	31	20	15	26	8	44
STDN	38	27	20	23	23	40

Note 1. Figures listed in the diagonal line are number of hospitals with non-zero observations of BEDj. The data given below this diagonal is the same as that above it (and not reported).

TABLE 6.5.3 DISTRIBUTION OF NUMBER OF HOSPITALS WITH NON-ZERO OBSERVATIONS OF INTERACTION VARIABLES OF THE FORM BED_j x NIP_k and NIP_k x STDN

STDN, BED_j / NIP_k	STDN (58)	DGH	LS	SA	OBS	MI	SC
CNSL (k = 1) (79)[1]	58	43	30	24	26	36	44
DPAT (k=2) (45)	34	23	19	14	5	31	16
DYCS (k=3) (54)	46	41	27	24	19	13	32

Note Figures inside parentheses are number of hospitals with non-zero observations of NIP_k and STDN variables.

TABLE 6.5.4 TOTAL RUNNING COSTS MODELS: ADDING INTERACTION VARIABLES - USE OF BED_i XBED_l VARIABLES.

Independent Variables	Estimated Coefficients and (T-Ratios)
BED DGH	20.81 (8.44)
BED LS	5.98 (0.55)
BED SA	48.18 (3.41)
BED OBS	8.45 (1.31)
BED MI	8.89 (10.31)
BED SC	19.01 (0.94)
BED DGH X LS	0.0170 (0.61)
BED DGH X SA	0.0033 (0.06)
BED DGH X OBS	-0.0075 (-0.21)
BED DGH X MI	-0.0310 (-0.93)
BED DGH X SC	0.0263 (0.32)
BED LS X SA	-0.2680 (-1.35)
BED LS X OBS	0.1620 (0.94)
BED LS X MI	0.0011 (0.02)
BED LS X SC	-0.3528 (-1.18)
BED SA X OBS	-0.4545 (-1.72)
BED SA X MI	0.0104 (0.10)
BED SA X SC	0.8900 (1.33)
BED OBS X MI	0.2294 (0.38)
BED OBS X SC	0.4189 (2.05)
BED MI X SC	1.0211 (1.53)
EXC DGH	0.3511 (2..86)
EXC SA	0.7976 (1.50)
EXC SC	0.2530 (0.67)
EXD DGH	0.0661 (2.41)
EXD LS	0.0859 (2.18)
EXD SA	0.0743 (0.42)
EXD OBS	0.0579 (1.91)
NIP CNSL	0.0242 (2.77)
NIP DPAT	0.0658 (2.14)
NIP DYCS	0.2082 (1.85)
CONSTANT	235.2 (0.88)
R^2	98.73
MSE	37.4

Figures in £000s.

TABLE 6..5.5 TOTAL RUNNING COSTS MODELS: ADDING INTERACTION VARIABLES - USE OF BED_jXNIP_k VARIABLES.

Independent Variables	Estimated Coefficients and (T-Ratios)
BED DGH	22.43 (5.88)
BED LS	4.78 (0.71)
BED SA	45.13 (3.55)
BED OBS	22.52 (3.48)
BED MI	9.08 (8.53)
BED SC	16.32 (0.81)
EXC DGH	0.3803 (2.54)
EXC SA	0.7455 (1.24)
EXC SC	0.3750 (0.88)
EXD DGH	0.0472 (1.52)
EXD LS	0.0735 (1.70)
EXD SA	0.0526 (0.26)
EXD OBS	0.0981 (3.25)
NIP CNSL	0.0179 (1.28)
NIP DPAT	0.1036 (1.37)
NIP DYCS	0.2427 (0.80)
*CNSL X DGH	4.1 E-5 (1.21)
* CNSL X LS	-1.0 E-4 (-0.52)
* CNSL X SA	2.4 E-4 (0.78)
* CNSL X OBS	9.9 E-5 (0.72)
*CNSL X MI	-6.7 E-5 (-0.44)
*CNSL X SC	-4.9 E-4 (-1.35)
*DPAT X DGH	8.9 E-5 (0.19)
*DPAT X LS	-7.0 E-4 (-0.84)
*DPAT X SA	-9.9 E-4 (-0.61)
*DPAT X OBS	2.2 E-3 (0.89)
*DPAT X MI	1.4 E-5 (0.09)
*DPAT X SC	-6.4 E-5 (-0.14)
*DYCS X DGH	-1.3 E-3 (-0.99)
*DYCS X LS	3.7 E-3 (0.87)
*DYCS X SA	-3.2 E-3 (-0.72)
*DYCS X OBS	-5.2 E-3 (-1.62)
*DYCS X MI	-1.1 E-4 (-0.12)
*DYCS X SC	2.3 E-2 (1.96)
CONSTANT	13.0 (0.05)
R^2	98.69
MSE	41.70

* denote BED X NIP

TABLE 6.5.6 TOTAL RUNNING COSTS MODELS: ADDING INTERACTION VARIABLES – USING BED_j X STDN AND NIP_k X STDN VARIABLES

Independent Variables	MODEL (I) (BED_j X STDN)		MODEL (II) (NIP_k X STDN)	
BED DGH	17.9	(7.25)	18.20	(7.74)
BED LS	6.67	(1.31)	7.45	(1.81)
BED SA	39.01	(3.75)	31.88	(4.91)
BED OBS	15.17	(3.22)	15.39	(4.56)
BED MI	9.04	(10.06)	9.14	(10.96)
BED SC	33.08	(1.86)	33.63	(2.99)
BED DGH X STDN	0.0016	(0.05)	–	-
BED LS X STDN	0.0691	(0.52)	–	-
BED SA X STDN	-0.1495	(-0.72)	–	-
BED OBS X STDN	0.0537	(0.39)	–	-
BED MI X STDN	-0.0115	(-0.12	–	-
BED SC X STDN	-0.1449	(-0.28)	–	-
EXC DGH	0.2233	(1.89)	0.1675	(1.39)
EXC SA	0.5851	(1.00)	0.6051	(1.14)
EXC SC	1.0595	(2.90)	0.8368	(2.40)
EXD DGH	0.0402	(1.41)	0.0257	(0.98)
EXD LS	0.0638	(1.62)	0.0567	(1.54)
EXD SA	0.1848	(1.22)	0.1279	(0.87)
EXD OBS	0.0533	(1.83)	0.0569	(2.26)
NIP CNSL	0.0327	(3.93)	0.0328	(3.84)
NIP DPAT	0.0616	(1.95)	0.0473	(1.57)
NIP DYCS	0.2733	(2.41)	0.2348	(1.97)
NIP CNSL X STDN	-		-0.00006	(-0.58)
NIP DPAT X STDN	-		0.00130	(0.97)
NIP DYCS X STDN	-		0.00372	(0.89)
TEACHSTDN	17.11	(1.14)	6.60	(0.53)
TEACHNURS	5.78	(0.89)	6.76	(1.07)
CONSTANT	-30.90	(-0.15)	-26.7	(-0.15)
R^2	98.41		98.45	
MSE	41.4		38.0	

Figures in £000S

TABLE 6.6.1 TOTAL RUNNING COSTS MODEL INCLUDING TEACHING VARIABLES

Independent Variables	Major	Teaching Status Minor	Control
BED DGH	29.36 (6.42)	13.56 (3.90)	22.85 (9.87)
BED LS	-120.94 (-2.94)	-3.55 (-0.45)	5.60 (1.01)
BED SA	20.53 (2.24)	13.10 (0.90)	24.13 (1.86)
BED OBS	20.93 (2.76)	53.41 (3.18)	14.87 (3.47)
BED MI	9.72 (5.55)	39.41 (3.05)	8.56 (10.89)
BED SC	41.69 (1.57)	38.63 (2.40)	36.32 (2.17)
		All Classes	
EXC DGH		0.1086 (0.82)	
EXC SA		1.1150 (1.98)	
EXC SC		0.7427 (2.11)	
EXD DGH		0.0891 (2.83)	
EXD LS		0.0898 (2.56)	
EXD SA		0.1817 (1.19)	
EXD OBS		0.0500 (1.99)	
NIP CNSL		0.0131 (1.62)	
NIP DPAT		0.0598 (2.22)	
NIP DYCS		0.1633 (1.57)	
TEACH STDN		19.88 (1.87)	
TEACH NURS		12.79 (1.99)	
CONSTANT	- 507.9 (-0.68)	863.3 (1.38)	46.3 (0.25)
R^2	99.06		
MSE	28.32		

Figures in £000s

TABLE 6.6.2 MODELS FITTED TO TEACHING AND NON-TEACHING (CONTROL). HOSPITALS DATA.

Independent Variables	Teaching Hospitals costs Model (n=33)	Non-teaching hospital costs Model (n = 48)
BED DGH	11.0 (1.95)	25.6 (12.63)
BED LS	11.0 (1.06)	7.1 (1.61)
BED SA	28.4 (2.01)	50.3 (4.58)
BED OBS	6.3 (0.75)	17.0 (5.61)
BED MI	10.3 (2.61)	8.8 (12.96)
BED SC	26.0 (1.15)	41.4 (3.28)
EXC DGH	0.1083 (0.53)	0.4321 (2.04)
EXC SA	-0.4160 (-0.33)	2.2750 (4.30)
EXC SC	1.5725 (1.83)	1.1458 (3.50)
EXD DGH	0.0056 (0.09)	0.0510 (1.26)
EXD LS	-0.3822 (-1.31)	0.737 (2.77)
EXD SA	0.0366 (0.07)	0.2907 (2.46)
EXD OBS	0.1632 (1.82)	0.0303 (1.55)
NIP CNSL	0.0390 (2.65)	0.0031 (0.36)
NIP DPAT	-0.0143 (-0.14)	0.0810 (3.87)
NIP DYCS	0.6616 (2.55)	-0.0123 (-0.14)
TEACH STDN	28.9 (1.77)	14.8 (0.80)
TEACH NURS	9.2 (0.69)	6.9 (0.98)
CONSTANT	161 (0.17)	21 (0.71)
R^2	98.43	99.25
MSE	71.50	11.30

Figures in £(000s).

TABLE 6.6.3. TOTAL RUNNING COSTS MODEL: ADOPTED —(ACM)

Independent Variables	Estimated Coefficients and (T-Ratios)
BED DGH	19.79 (8.79)
BED LS	8.39 (2.15)
BED SA	26.71 (4.41)
BED OBS	15.17 (4.80)
BED MI	8.62 (10.84)
BED SC	29.80 (2.99)
EXC DGH	0.1639 (1.52)
EXC SA	0.3744 (0.75)
EXC SC	1.1952 (3.69)
EXD DGH	0.0427 (1.75)
EXD LS	0.0556 (1.62)
EXD SA	0.1021 (0.75)
EXD OBS	0.0424 (1.81)
NIP CNSL	0.0257 (3.46)
NIP DPAT	0.0520 (1.96)
NIP DYCS	0.2444 (2.51)
TEACH STDN	14.63(1.88)
TEACH NURS	10.63(1.73)
TEACH MAJOR	440.5 (1.62)
TEACH MINOR	-722.6 (-2.26)
CONSTANT	34.1 (0.21)
R^2	98.60
MSE	34.0

(figures in £000s)

TABLE 6.6.4. ESTIMATED AVERAGE TOTAL RUNNING COSTS OF HOSPITALS FOR 1985/86 PARTICIPATED BY TEACHING STATUS

(costs in £000s)

Hospital Type	Average Cost (Actual 1985/86)	Estimated average Costs for 1985-86 [a]		
		Non Teaching (patient care services)	Teaching Services	All
	(1)	(2)	(3)	(4)
Major	13467	11411	1999	13410
(%) [b]	-	(84.7)	(14.9)	(99.6)
Minor	12888	11304	1588	12892
(%)	-	(87.7)	(12.3)	(100)
Control	5906	5548	376	5924
(%)	-	(93.6)	(6.4)	(100.3)
Combined	8893	7919	972	8891
sample (%)	-	(89.1)	(10.9)	(99.8)

Notes

(a) Given the final cost model in table 6.6.3, the average costs were estimated by setting each variable at their mean values given on tables 5.5 - 5.7 for each type of hospital.

(1) Copied from Table 5.5, actual average total running costs of hospitals for 1985/86.

(2) Sum of estimated costs corresponding to variables abbreviated as, BEDj, EXCj, EXDj and NIP_k, ie. allocated beds, their bed-use and non-inpatient services.

(3) The teaching costs include estimated costs corresponding to STDN and NURS variables. It also includes estimated overhead costs for major teaching hospitals above the non-teaching ones.

(4) Sum of columns (2) and (3).

(5) Figures inside brackets are percentages taken from the actual total running costs (ex. 14.9% = 1999/13467).

TABLE 6.6.5 ESTIMATED EXPECTED TOTAL RUNNING COSTS OF HOSPITALS (TC) FOR 1985-86 FISCAL YEAR WITH 95% CONFIDENCE AND PREDICTION LIMITS (costs in £000s)

No.	Hospital Code	Teaching Status Major	Teaching Status Minor	Actual Costs (TC)	Estimated Costs ($\hat{TC}$)	Residual Costs ($\hat{U}$)	Confidence Limits +/-	Prediction Limits +/-
1	A103	0	0	4681.9	4183.8	498.0	1351.44	3037.1
2	A111	0	0	16128.7	15579.6	549.1	3679.74	9410.0
3	A201	0	0	6213.6	6369.5	-155.9	1914.37	8611.0
4	A203	0	0	3250.3	3392.6	-142.2	1067.56	2190.5
5	B117	0	0	4046.0	3778.5	267.5	1463.61	5151.3
6	C101	0	0	3215.8	3659.3	-443.5	1549.90	5811.3
7	C206	0	0	8035.6	7476.8	558.7	1766.02	5256.7
8	C309	0	0	1460.8	1553.1	-92.3	792.37	1356.3
9	C310	0	0	4071.6	4376.3	-304.6	2319.56	5467.6
10	C313	0	1	11247.5	10580.7	666.8	3017.16	6560.9
11	C403	0	0	6745.6	6681.0	64.6	2255.97	8210.2
12	C408	0	0	2897.6	3522.5	-624.8	1010.33	2354.1
13	C411	0	1	6796.3	7349.5	-555.1	2065.01	4007.4
14	F704	0	1	14019.4	15878.5	-1859.1	4336.33	9173.7
15	F705	0	0	3136.1	3289.1	-152.9	945.83	2456.1
16	F712	0	0	7117.7	8154.9	-1037.1	2705.74	10306.4
17	F804	0	0	1556.9	1521.0	35.9	610.45	1342.1
18	G101	0	0	6711.5	5789.9	921.6	2398.43	4955.1
19	G105	0	0	7545.2	6879.1	666.1	3031.25	9456.3
20	G107	1	0	35959.4	34206.0	1753.3	5199.98	11785.2
21	G108	1	0	5154.3	4809.5	344.7	1533.50	3040.0
22	G207	0	1	24760.7	20741.5	4015.2	4652.80	11690.5
23	G208	0	0	1857.2	2198.1	-340.9	1049.45	3776.8
24	G210	0	0	9238.1	8925.1	312.9	3663.64	11523.9
25	G302	0	0	9612.0	9187.5	424.5	3390.64	11702.4
26	G304	0	0	2278.8	2489.5	-210.6	1827.71	2911.8
27	G306	0	1	15224.3	16392.0	-1167.7	3468.35	6709.2
28	G308	0	0	3154.7	3429.0	-274.2	1007.49	2301.9
29	G405	0	1	28519.8	26520.1	1999.6	6960.28	15115.3
30	G504	0	1	14124.5	13860.9	263.6	3502.34	8011.5
31	G505	1	0	7407.8	7539.2	-131.3	2698.65	8098.6
32	G513	1	0	12618.9	10941.3	1677.5	2681.40	5060.3
33	G515	1	0	3955.9	4390.7	-434.8	1435.35	2801.2
34	G516	1	0	24983.1	23323.9	1659.2	3758.02	8187.1
35	H202	0	1	15324.8	15968.0	-643.1	2932.19	8158.3
36	H205	0	0	6824.8	6277.6	547.1	2123.66	8778.0
37	L102	0	0	4875.5	4514.1	361.3	1445.06	2948.7
38	L106	0	0	16329.9	15548.8	781.1	3326.70	7936.3
39	L204	0	0	12517.4	14907.4	-2389.9	6210.27	19227.3
40	L208	0	0	15306.2	15790.8	-484.7	3751.08	9781.8
41	L210	0	0	476.4	410.6	65.8	715.06	1091.5
42	L214	0	0	1717.0	1537.2	179.8	628.85	1336.8
43	L302	0	0	11206.9	11377.2	-170.3	2342.40	6399.9

TABLE 6.6.5 ESTIMATED EXPECTED TOTAL RUNNING COSTS OF HOSPITALS (TC) FOR 1985-86 FISCAL YEAR WITH 95% CONFIDENCE AND PREDICTION LIMITS (costs in £000s) (continued)

No.	Hospital Code	Teaching Status Major	Teaching Status Minor	Actual COSTS (TC)	Estimated COSTS ($\tilde{TC}$)	Residual Costs ($\tilde{U}$)	Confidence Limits +/-	Prediction Limits +/-
44	N101	1	0	28534.0	31940.0	-3406.0	5589.71	11689.7
45	N102	0	1	7682.4	9724.7	-2042.3	3518.40	6533.6
46	N121	1	0	4522.9	5235.9	-712.9	1961.46	3342.3
47	N161	1	0	4502.6	4236.8	265.7	1582.43	2673.2
48	N193	0	0	1304.7	1227.0	77.6	878.83	2431.1
49	N194	1	0	5166.6	5848.7	-682.1	2152.70	7618.2
50	N198	1	0	7675.6	9125.3	-1449.7	3256.80	9592.8
51	N491	0	0	1633.1	1668.4	-35.3	800.71	2561.5
52	S105	0	1	6455.7	6614.8	-159.0	2604.59	5723.7
53	S107	0	0	2791.9	3123.1	-331.1	2032.00	3362.6
54	S109	0	0	2730.9	2011.0	719.6	770.75	3996.5
55	S110	0	1	2660.3	2040.3	620.0	1622.75	2618.7
56	S112	0	0	3104.2	3521.3	-417.0	1755.77	3328.4
57	S116	1	0	19055.5	18587.5	448.0	5214.01	8921.7
58	S201	0	0	4100.0	4850.5	-750.5	2962.17	4874.1
59	S204	0	1	8672.7	9137.4	-464.7	4439.77	7259.2
60	S207	0	0	1628.6	1586.1	42.3	730.11	1629.0
61	S214	0	0	3007.3	3034.1	-26.7	994.11	4119.2
62	S225	1	0	6196.3	6357.4	-161.1	2092.77	3378.3
63	S226	1	0	34702.7	34269.2	433.5	5660.89	13010.5
64	S227	1	0	4554.4	4874.2	-319.8	1621.10	3259.3
65	S299	1	0	12975.6	12861.6	114.0	4565.77	12786.8
66	S301	0	1	12029.2	12430.6	-401.3	4238.08	8222.1
67	S302	0	0	7103.4	6039.2	1064.1	1677.42	7839.8
68	T101	1	0	25510.2	25501.9	8.2	6395.20	11570.9
69	T102	1	0	10767.0	10426.1	340.8	2866.10	5343.4
70	T114	1	0	6768.2	6474.0	294.2	1997.44	7914.5
71	T201	0	0	5408.1	4664.9	743.2	2575.48	4066.3
72	T202	0	0	9164.5	9049.3	115.2	2153.00	5410.2
73	T215	0	0	5119.9	4358.7	761.2	1162.79	5685.2
74	T311	0	0	4488.6	4663.2	174.6	1382.45	6228.7
75	T312	0	0	6347.3	4076.5	270.8	2184.91	5333.9
76	V102	0	0	11948.4	12847.0	-898.5	3041.62	6834.4
77	V106	0	0	8100.0	8854.3	-754.3	2608.95	11130.2
78	V201	0	0	11289.4	10836.3	453.0	2136.45	5983.2
79	Y102	0	0	1821.5	1955.4	-133.9	636.13	1616.8
80	Y103	1	0	8328.4	7277.7	1050.7	2393.50	8666.0
81	Y104	0	0	10198.1	10465.7	-267.6	1804.33	5906.8

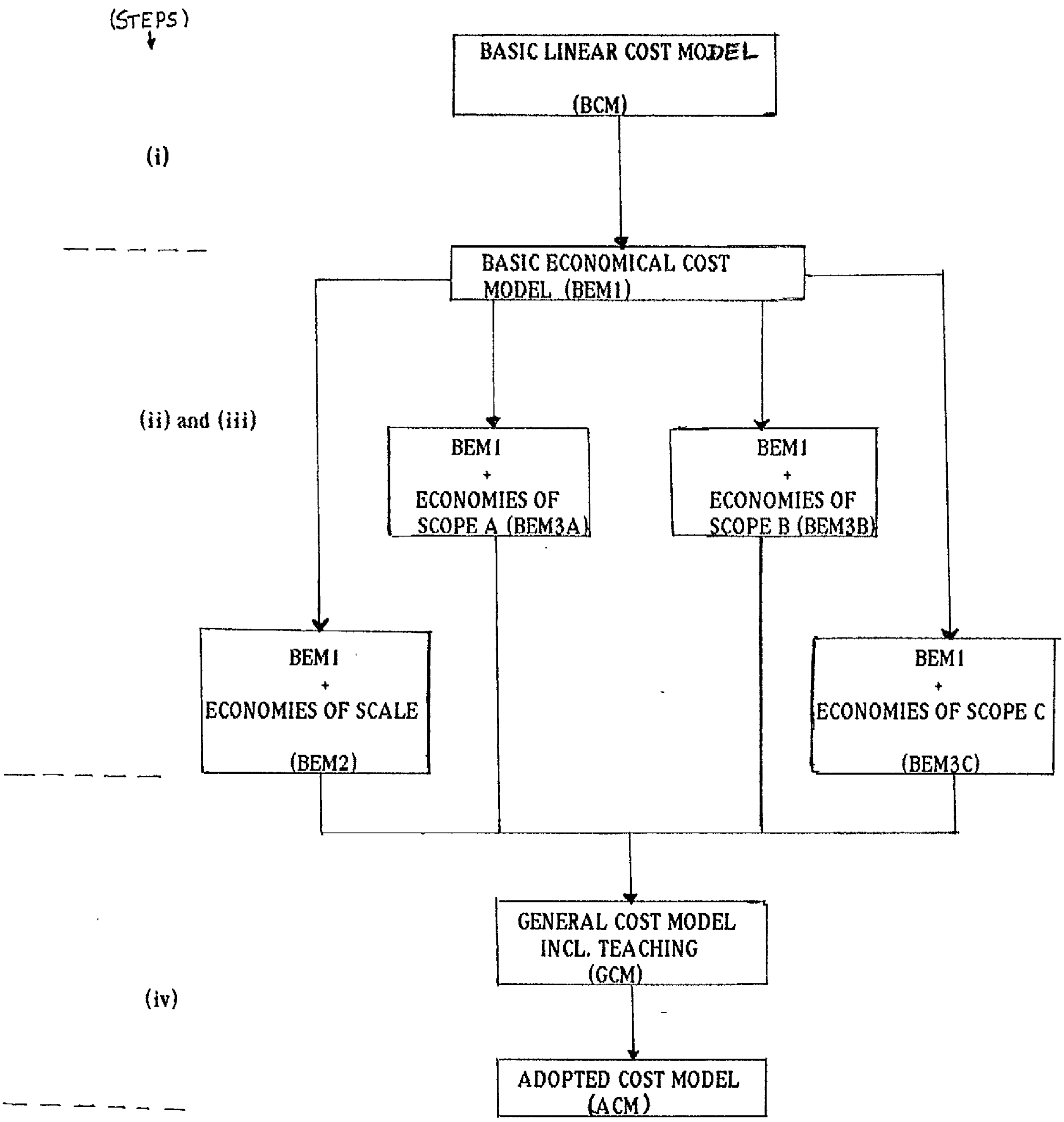
Note: On Teaching Status
0,0 - denotes Control Hospitals.
1,0 - denotes Major Teaching Hospitals.
0,1 - denotes Minor Teaching Hospitals.

TABLE 6.6.6 TOTAL RUNNING COSTS MODEL: ADDING VARIABLES INDICATING REGIONAL LOCATION OF HEALTH BOARDS

Independent Variables	Coefficients (T-ratio)
BED DGH	19.72 (8.68)
DEB LS	8.98 (2.28)
BED SA	27.53 (4.25)
BED OBS	14.86 (4.66)
BED MI	8.32 (10.19)
BED SC	25.01 (2.45)
EXC DGH	0.2744 (2.34)
EXC SA	0.1172 (0.22)
EXC SC	1.2287 (3.88)
EXD DGH	0.0591 (2.33)
EXD LS	0.0456 (1.28)
EXD SA	0.0932 (0.66)
EXD OBS	0.0541 (2.14)
NIP CNSL	0.0220(2.84)
NIP DPAT	0.0423 (1.56)
NIP DYCS	0.2231 (2.30)
TEACH STDN	10.365 (1.28)
TEACH NURS	11.766 (1.89)
TEACH MAJOR	619.7 (2.08)
TEACH MINOR	-594.9(-1.70)
TEACH GLASGOW	95.1 (0.40)
TEACH GRAMPIAN	-265.7 (-1.02)
TEACH LOTHIAN	69.0 (0.35)
TEACH TAYSIDE	773.9 (1.85)
CONSTANT	159.2 (0.90)
R2	98.72
MSE	33.0

Note: GLASGOW - Greater Glasgow Health Board
GRAMPIAN - Grampian Glasgow Health Board
LOTHIAN - Lothian Glasgow Health Board
TAYSIDE - Tayside Glasgow Health Board
Figures in £000s.

FIGURE 6.1. DIAGRAMATICAL REPRESENTATION OF ESTIMATION PROCESS OF TOTAL RUNNING COSTS MODELS



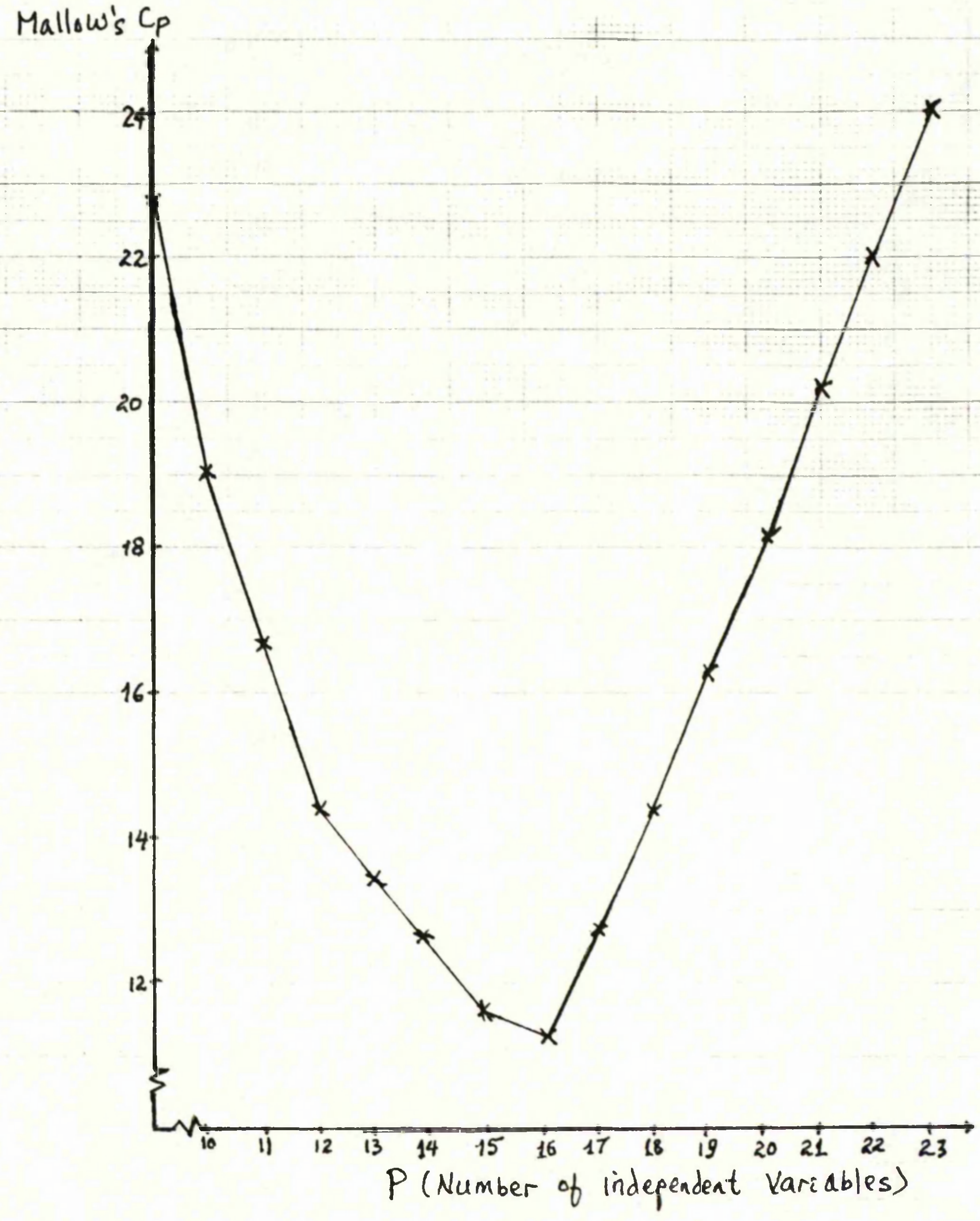


Figure 6.2. Plot of Mallow's C_p vs P

NOTE. The Mallow's C_p plotted are those that are the smallest in magnitude, among the several calculated corresponding to models fitted with P independent variables included in them.

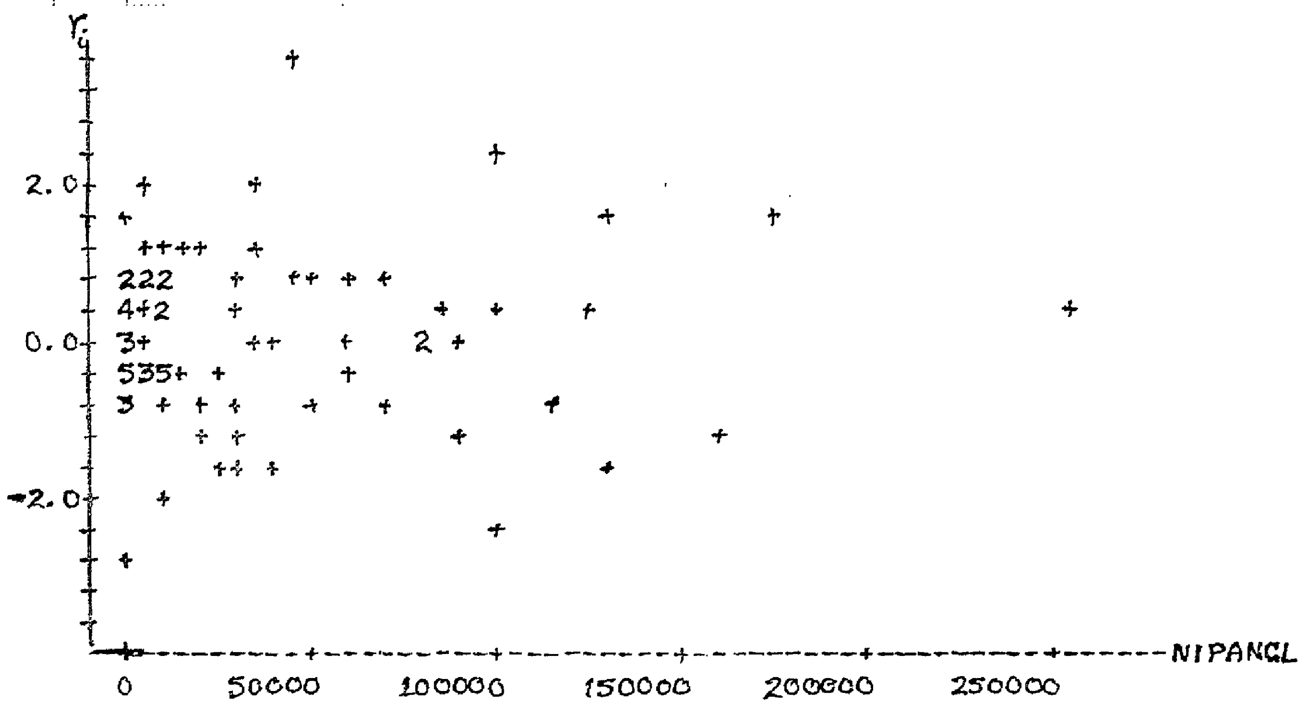


Figure 6.3. Plot of Standardised Residuals(r_i) vs NIPCNSL

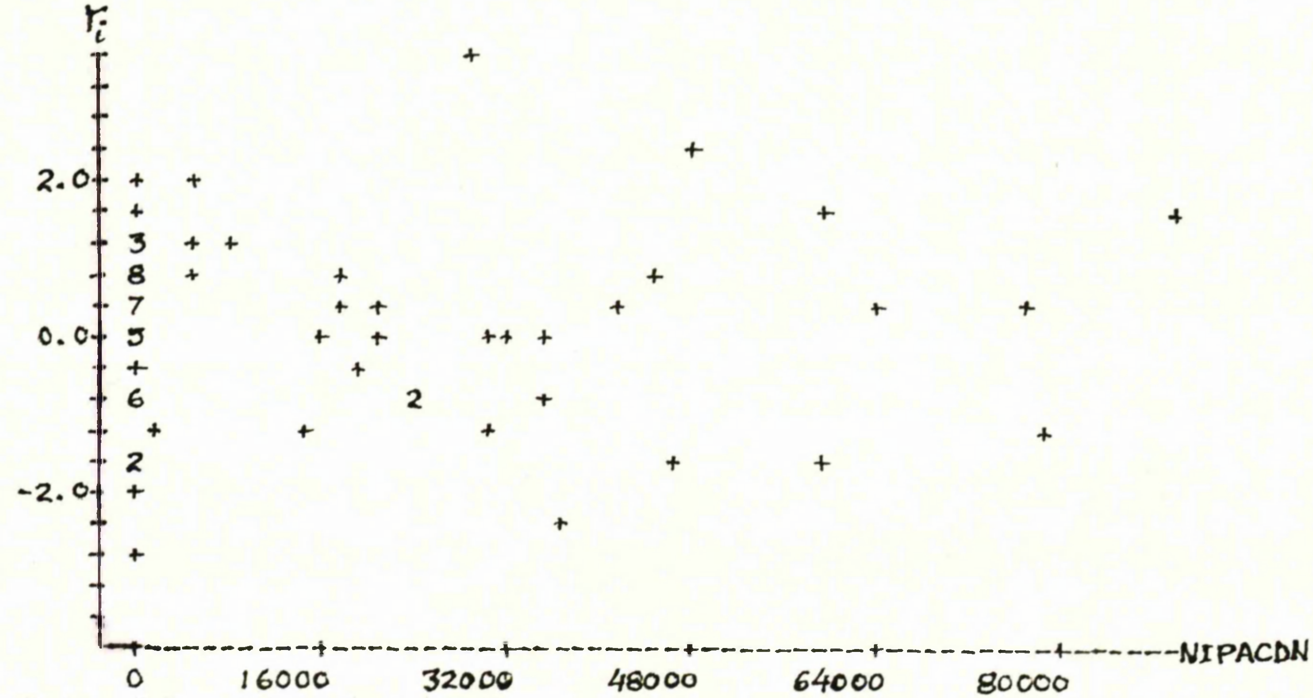


Figure 6.4. Plot of Standardised Residuals (r_i) vs NIPACDN

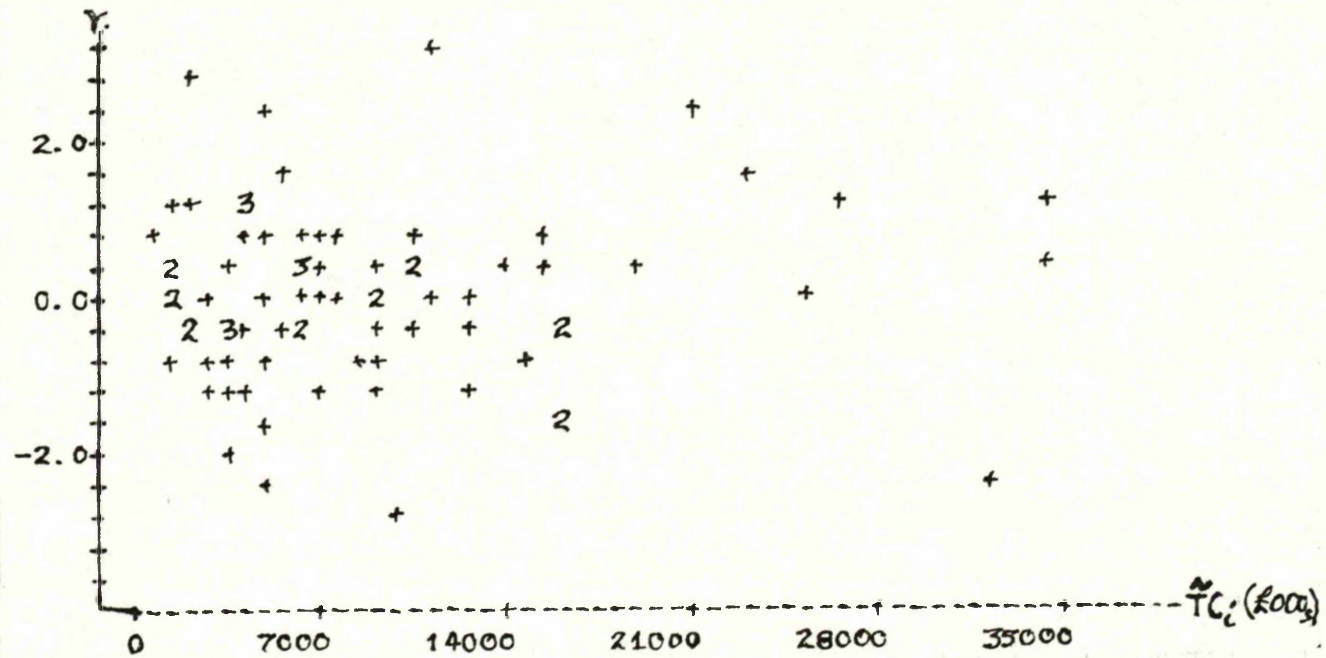


Figure 6.5. Plot of Standardised Residuals (r_i) vs Estimated Total Running Costs of Hospitals($\tilde{TC}_i$)

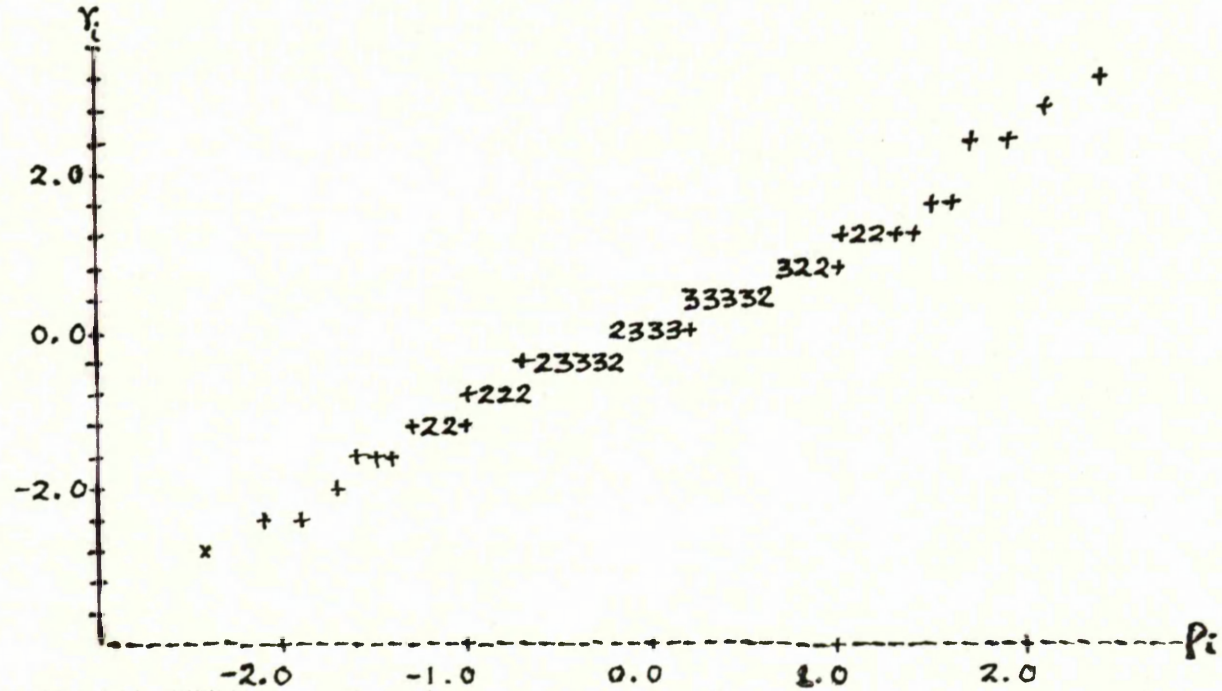


Figure 6.6. Normal Probability Plot of Standardised Residuals (r_i)

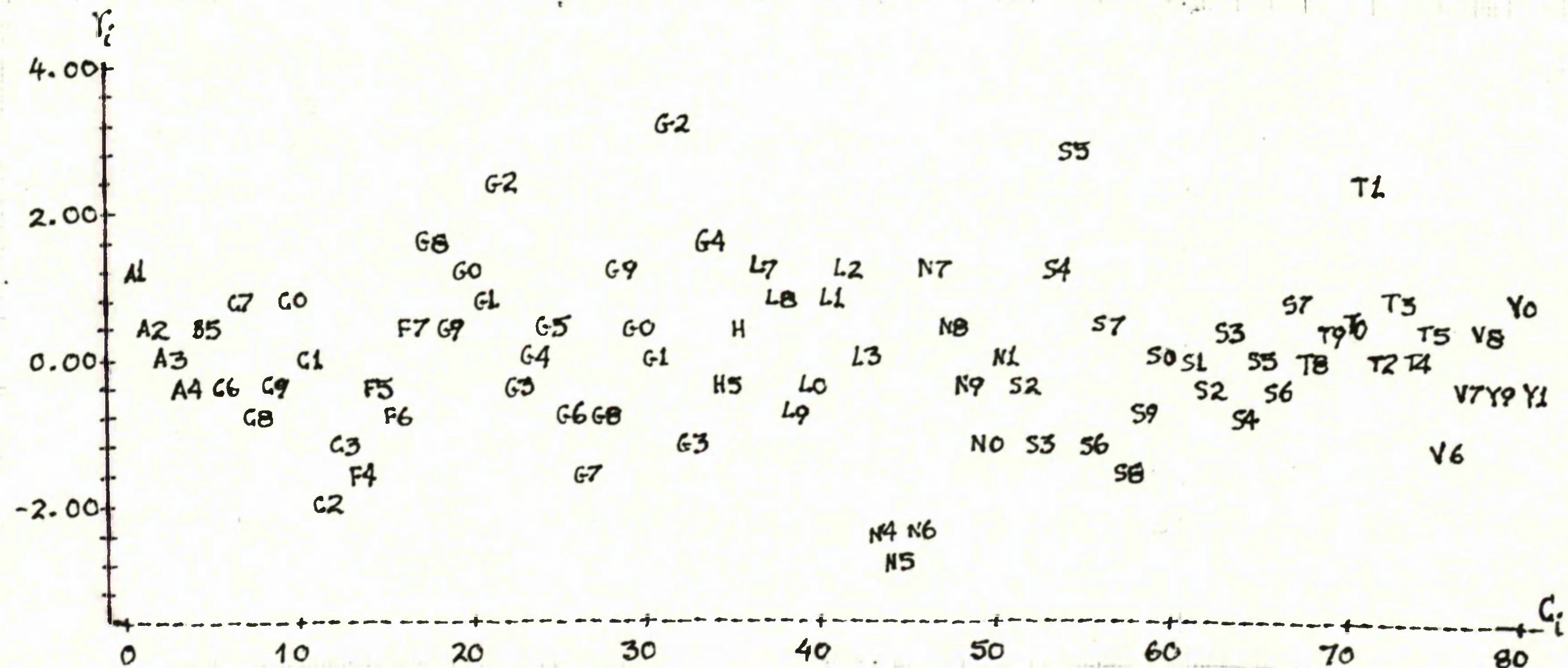


Figure 6.7. Plot of Standardised Residuals (r_i) vs Codes of Hospitals studied (C_i)

NOTE.
- A = Ayshire and Arran Health Board
- B = Borders Health Board
- C = Clyde Health Board
- F = Fife Health Board
- G = Greater Glasgow Health Board
- H = Highland Health Board
- L = Lanarkshire Health Board
- N = Grampian Health Board
- S = Lothian Health Board
- T = Tayside Health Board
- V = Forth Valley Health Board
- Y = Dumfries Health Board

APPENDIX 5. COST MODEL VARIABLES SELECTING WITHOUT FORCING RESTRICTIONS USED.

(A) Economies of Scale

The specification of the full model is the 16 linear and 18 quadratic and cubic term variables.[see Table 6.4, Model(II)]. Forward step-wise regression was applied, with F-to-Enter of 4. The 'best' subset of 12 variables selected are:

- All BEDj (6 variables),
- EXCDGH and EXCSC,
- EXDOBS,
- NIP CNSL and NIP DYCS, and,
- NIP $CNSL^2$ (NIP_CNSL X NIPCNCL),

With R^2 = 98.09%

The model is limited in interpretation. It is also conflicting, since the residual plots in fact showed $BEDSC^2$ to be the best candidate for selection, rather than NIP $CNSL^2$.

(B) Interaction between Inpatient Speciality Group Services

The specification of the full model is the 16 linear and 15 interaction variables. [see Table 6.5.4]. Forward step-wise regression was applied with F-To-Enter fixed at 4. The final subset indicated includes only 10 variables, namely:

- All BED_j except BED OBS (5 variables),
- EXC DGH and EXC SC,
- NIP CNSL and NIP DYCS, and
- BED_OBS X BED_SC, with R^2 = 98.05%.

The relationship between BED OBS and BED SC lies in the fact that special baby care unit (IBC) which might be more related to obstetrics type treatments was classified under the special category speciality groups.[see Appendix 2]. Further investigation showed all hospitals which have obstetrics speciality, have also Special Category Speciality and hence IBC Unit. So possibly the interaction could be due to this factor. Obstetrics Speciality group facilities could have been used for IBC unit services or vice versa, thus influencing the cost of hospitals.

Two approaches were taken to check whether the effect of BED OBS X BED SC variable was actually caused by the BEDIBC being classified under BEDSC. First a cost-model was fitted using BEDOBS X BEDSC added to BEMI. The coefficient of the added variable turns out to be positive but non-significant ($P > 0.05$) showing weak diseconomies of scope could exist between the two specialities.[see Table 5.B, Model (I)]. Next, IBC Unit allocated beds (BEDIBC) were removed from BEDSC and an independent variable, called BEDIBC was formed. Then three interaction variables were created from BEDIBC, BEDOBS and BEDSC, and similar model was fitted.[see the result in Table 5.B, Model (II)]. As can be seen, we obtained both non-significant and negative coefficients for the variables BEDOBS X BEDSC and BEDOBS X BEDIBC implying weak economies of scope may exist due to obstetrics and the other two (IBC and SC) specialialities bed interaction. In contrast the coefficient estimated for BEDIBC X BEDSC was positive but still non-significant at 5% confidence level, showing possible diseconomies of scope between them. None of the three interactions have individually significant contributions to the model fit. Therefore, the role of classifying IBC under SC does not have great impact in causing interactions between OBS and SC speciality group inpatient services.

(C) <u>Interaction between Inpatient and Non-inpatient Care Activities</u>

As explained in Section 6.5.2, there are 16 linear and 18 interaction variables making a total of 34 variables. Among those, variables contributing significantly to explain the variability in total running costs were to be chosen. We applied forward step-wise regression to all variables, with F-to-Enter set at 4. The technique indicated 12 independent variables among the 34 as adequate set of variables. They are:

- All six BED_j variables,
- EXCDGH and EXCSC,
- EXDOBS,
- NIP CNSL and NIP DYCS, and,
- BED DGH x NIP CNSL,

With $R^2 = 98.12\%$.

Unless, we are interested only to search for statistically significant variables the message in interpretation-wise, considering these set of variables is not clearly sufficient.

TABLE 5.B. TOTAL RUNNING COSTS MODELS USING BED_i X BED_i INTERACTION VARIABLES

Independent Variables	MODEL (I)	MODEL (II)
BED DGH	19.82 (9.89)	19.62 (8.74)
BED LS	7.65 (1.94)	8.62 (2.01)
BED SA	38.32 (6.62)	35.88 (5.43)
BED OBS	8.93 (1.55)	24.85 (4.37)
BED MI	9.14 (11.86)	9.08 (10.58)
BED SC	30.53(3.03)	25.76 (2.09)
BED IBC[1]	-	1.97 (0.11)
BED OBS X SC	0.3135 (1.75)	-0.8619 (-1.57)
BED OBS X IBC	-	-0.0719 (-0.44)
BED SC X IBC	-	4.679 (1.56)
EXC DGH	0.2858 (2.70)	0.2736 (2.31)
EXC SA	0.9057 (1.87)	1.0115 (1.91)
EXC SC	0.6547 (2.08)	0.9393 (2.53)
EXD DGH	0.0532 (2.28)	0.0522 (2.05)
EXD LS	0.0616 (1.75)	0.0618 (1.62)
EXD SA	0.2065 (1.48)	0.1957 (1.29)
EXD OBS	0.0432 (1.61)	0.1006 (3.34)
NIP CNSL	0.0339(4.55)	0.0323 (3.90)
NIP DPAT	0.0676 (2.43)	0.0668 (2.21)
NIP DYCS	0.2882 (2.84)	0.3343 (2.90)
CONSTANT	53.0 (0.29)	96.10 (0.39)
R^2	98.33	98.13
MSE	38.30	45.1

Note: The coefficients are in £,000s. T-ratio are inside parenthesis.

Note 1. BEDIBC = Staffed allocated beds for Intensive Baby Care Unit.

2. BEDOBS and BEDSC are the original variables in Model (I). But in Model (II) Intensive Baby Care Unit beds (BEDIBC) were removed from BEDSC and then BEDIBC as well as BEDOBS and BEDSC, the three interaction variables were formed.

CHAPTER 7

MODELLING COST COMPONENTS OF TOTAL RUNNING COSTS OF SCOTTISH HOSPITALS

7.1. Introduction

Hospital total running costs are constituted of mainly two components. Hospital expenditure for the salary and wages of the manpower needs, such as medical (physicians), nursing, professional and technical, administrative and other types of staff. The other component is that part of costs spent on the supply of expendable medical provisions, like pharmacy drugs and dressings, laboratory appliances, heating, power, catering, etc., facilities. It was found that the cost component corresponding to staff pay comprises nearly $3/4^{th}$ (about 74%) of the total running costs and the remaining portion goes on the supply component, as far as, the 81 Scottish hospitals being studied are concerned. This apportioning confirms with the general NHS hospitals structure as similar cost studies had already found. (Feldstein (1967) and Bailey and Ashford (1984)) with respect to inpatient costs of hospitals in England and Wales.

The preceding part of the analysis of running costs of hospitals have indicated that the level of teaching activities of hospitals could have a direct impact in generating a supplementary cost to them. It could also be possible to go one step further and see the extent of the influence, the teaching activity might have on these various cost components of the total running costs of hospitals. Several researchers have undertaken such investigation, such as Culyer et al.(1978), which was quoted earlier (Chapter 4) and Sloan et al. (1983) to name two. It was suggested from those studies that association between the effect of teaching activity to induce costs might vary in respect of different components of running costs of hospitals. For instance, Culyer et al. (1978) while analysing inpatient costs of English NHS hospitals suggested that, the teaching influence measured in terms of student load to have a statistically significant effect on costs of operating theatres, medical records, X-rays, pathology department tests, catering services, light, power, heat, building and engineering maintenance and radiotherapy services.

Other cost analysts known to us, like Feldstein (1967) and Bailey & Ashford (1984) have put emphases to the modelling aspects of cost components of hospital costs, their purpose was not, primarily to see the underlying association between teaching load and costs categories, but to analyse the structure of these cost components relating them with the hospital resources and activity measuring factors. In so doing they showed that different cost components of hospitals total costs could reflect diverse characteristics particular to each of them. For instance, Feldstein (1967,p.86) observed that "cost curves for individual input categories show that the pure labour component - ward staff costs - have the greatest diseconomies of scale while direct costs and other indirect costs generally enjoy increasing returns to scale when adjustment is made for case-flow rates." In the same manner Bailey & Ashford (1984, p255) commented about the importance of cost component modelling by saying that "This improvement[in the fit of total cost to the model specified]is due largely to the fact that the same cost structure doesn't apply to all components".

Our objective, to analyse the cost components of running costs of hospitals is to investigate the likely associaton they have with the level of teaching activity of hospitals. The above listed researcher has made contribution on how to go on with this task. Based on their experience we are interested in examining which components of running costs of Scottish hospitals generate the greatest portion of the additional teaching costs involved in training medical students and nurses. Is it possible that teaching status designation of hospitals have varying relationship with the cost components? To cite an example, does training students and nurses have a significant effect on the staff cost component of running costs of hospitals or on the supply part? And, does teaching status influence more the staff than the supply cost components, or vice versa?

To follow these objectives we resort to the modelling aspect of total running cost components. It was indicated in chapter 6 that,the specification of the cost component models to be discussed will be similar to that used for the total running costs. Also, we have said that, individual model building processes to be undertaken for the cost components to be analysed requires much more time than available to us. A total running cost model was selected and adopted in the past chapter. The assumption to prevail in using this same variable specificiation for the cost components indicates that the same factors generating the toal running costs of hospitals apply to its components. We have pointed out above, citing some analysts, that the degree of influence of some factors do not have an equal effect on all cost components. But, it is not our primary aim to provide a selected set of factors peculiar to each cost components. On the contrary we want to see especially whether factors measuring teaching activity are significantly related to certain types of cost components.

This objective is supported to some extent by the above listed cost studies. Even though, they resorted to finding influencial variables (factors) particular to certain cost components - like, say in Bailey & Ashford (1984) and Culyer et al. (1978), their starting point was a similar set of variables for all cost components. But, their exclusion of some variables from a given cost components is for statistical reasons, for example, to get good fit to the data. We want the cost compnent models for explanatory purposes, not for their prediction capacity alone, in the present circumstances. Therefore, it is thought that the approach taken by us is also justifiable.

Among the next three sections, some ideas peculiar to the estimation of cost component models from a statistical point of view will be discussed in section (7.2). The results from the modelling task in section (7.3) and finally the summary of this chapter in section (7.4) will be presented.

7.2 Some points about estimation of Cost component models

According to the final total running cost model developed in chapter 6, the equation chosen can be expressed as:

$$TC_i = \alpha_0 + \sum_{j=1}^{6} \alpha_j BED_{ji} + \beta_1 EXCDGH_i + \beta_2 EXCSA_i + \beta_3 EXC\_SC_i$$

$$+ \theta_1 EXDDGH_i + \theta_2 EXDLS_i + \theta_3 EXDSA_i + \theta_4 EXDOBS_i$$

$$+ \gamma_1 NIPCNSL_i + \gamma_2 NIPDPAT_i + \gamma_3 NIPDYCS_i$$

$$+ \tau_1 STDN_i + \tau_2 NURS_i + \tau_3 MAJOR_i + \tau_4 MINOR_i + U_i \quad \cdots (7.1)$$

where, we assumed, $U_i \sim N(O, \sigma^2 (TB_i)^{1.7})$,

U_i is the random error variable,

i stands for hospital i in the sample, i = 1, ..., 81,

j stands for the 6 speciality groups (j = 1, ... 6),

and the same definition holds for each variable (TC_i,..to..$MINOR_i$) given in section 4.8, chapter 4.

Denoting the K^{th} cost component of the total running cost of hospital i by TC_{ki}, the model specification to be specified for TC_{ki} can be written, similar to equation (7.1) as:

$$TC_{ki} = \alpha_0 + \sum_{j=1}^{6} \alpha_{jk} BED_{ji} + \beta_{1k} EXCDGH_i + \beta_{2k} EXCSA_i + \beta_{3k} EXC\_SC_i$$

$$+ \theta_{1k} EXDDGH_i + \theta_{2k} EXDLS_i + \theta_{3k} EXDSA_i + \theta_{4k} EXDOBS_i$$

$$+ \gamma_{1k} NIPCNSL_i + \gamma_{2k} NIPDPAT_i + \gamma_{3k} NIPDYCS_i$$

$$+ \tau_{1k} STDN_i + \tau_{2k} NURS_i + \tau_{3k} MAJOR_i + \tau_{4k} MINOR_i + U_{ki} \quad \cdots\cdots (7.2)$$

for K = 1, ..., t, supposing the total running costs is partitioned in to t components. Where, $U_{ki} \sim N(O, \sigma^2_k V_{ki})$, $\sigma^2 > O$,

V_{ki} is i^{th} diagonal element of an (nxn) covariance matrix, V_k

$\alpha_{0k}, \alpha_{jk}, \ldots, \tau_{3k}$, and τ_{4k} are parameter coefficients of the corresponding variables to be estimated from the data of the K^{th} cost component(TC_{ki}).

There is no change in the definition of BED_{ij}, to, $MINOR_i$ variables particular to hospital i, i = 1, ... 81.

and U_{ki} is the random error variable for the model of K^{th} component of TC_i.

Clearly $TC_i = \sum_{k=1}^{K} TC_{ki}$, for all i.

The points to be discussed in the present section, refers to the properties of random error term (U_{ki}) in the cost component models. To estimate each of the equations in (7.2), using ordinary least squares requires the classical regression assumptions to be satisfied. [see chapter 3].

The problems encountered with estimating models for cost component type exercises have been illustrated in many econometrics books, such as Johnston (1984). It was also applied in practice to the hospital sector by some, for instance, Bailey & Ashford (1984). We concentrate on three points concerning the error variable of the K^{th} cost component model, U_{ki}, departing from the following assumptions:

(a) The assumption of homoscedasticity of variance U_{ki}.
(b) The assumption of independence between U_{ki} and U_{li}.
(c) The assumption of independence between the U_{ki} and the model variables. For $k, l = 1, \ldots, t$ and, $k \neq l$.

If the above three assumptions are satisfied then each equation in (7.2) can be readily estimated through ordinary least squares (OLS) estimation applied to each cost component individually.

(a) Hetroscedasticity of Variance of U_{ki}

It is practically accepted, in the case of estimating models for total costs of hospitals that, the assumption of constant variance of the error variables doesn't hold. [see chapter 4, section 4.6]. In the cost component modelling also the same problem exists.

We can check this assumption from plots of residuals obtained from application of OLS method or from plots of cost components with a variable suspected to influence the non-constant variability. We plotted each cost components listed in tables 7.1 and 7.2 versus the total allocated staffed beds, for the 81 hospitals and looked at the result as we did for the case of total running costs. All the plots made showed a similar picture to that shown in Figure 4.1, chapter 4, for total running costs. This indicates that Homoscedasticity of variance assumption may be violated. The complication is that the variability between cost components of hospital running costs increases with the size of bed-provision the hospitals have. Therefore, in the estimation of cost components, as far as the other regression assumptons are assumed satisfied, the implementation of weighted least squares was thought feasible enough. The weights being the same as that used for fitting the total running cost models. That is, we assumed,

$$U_{ki} \sim N(0,\ \sigma^2\ (TB_i)^{1.7}),\ \text{for all } k = 1, \ldots, t.$$

We may not be too erroneous in doing this. First, diagnostic checks using plots of residuals can be undertaken and the plausibility of this application examined. Second, the plots we talked about above having similarity with the total running costs case suggests that it is not unreasonable to use the same weights as for total running costs. Thirdly, previous analysts which have common ground with our work confirmed to the same technique, i.e. adopting the same weights for all components. (see Bailey & Ashford (1984) for example).

(b) Correlated error Variables U_{ki} and U_{li}

This problem seems to be the main one in analysis of hospital cost components and related cost disagregation type modelling works. When it is said that U_{ki} and U_{li} are correlated error variables, the implication is their interdependence in such a way that:

$$Cov\ (U_{ki},\ U_{li}) = V_{(k l)i} \neq 0,\ \text{where } Cov\ (\cdot) = \text{covariance},\ l \neq K.$$

This implies that some inter-relationship exists between the components of total running costs of hospitals. Because as can be observed the sum of these components gives the total running costs. Keeping the total fixed, decrease in one component means increase in the other. Estimation of a specific cost component model without involving the other components through the use of ordinary least squares produces biased and inconsistent coefficient estimators which are also inefficient. Full reference, for example, can be found why this happens, in Johnston (1984) and other text books of econometrics or statistics.

The estimation of the model coefficients requires uses of generalised least squares technique, as far as an appropriate covariance matrix, say V is known, as explained in chapter 3, section 3.4. But if V is unknown then an alternative procedure had been proposed and used to estimate it. Except under certain conditions, as developed in Zellner (1962) and described in Johnston (1984, p337-341), the estimation technique implemented is known as Two-stage Aitken estimation (2SAE). The method follows two steps:

At first, individual cost component models of the form of equation (7.2) will be estimated by ordinary least squares regression (OLS), to obtain the estimated residuals from these models. Taking some functions of these estimated residuals, V will be approximated and generalised least squares estimators of the parameters of the cost components models are obtained, simultaneously at the second stage. These final estimators are called in the literature seemingly unrelated regression estimators (SURE). (IBID)

However, SURE was proved to reduce to OLS estimators if either, (a) the error variables from two equations are uncorrelated; which may not be true in the system of equations we have, or, (b) the same (identical) set of independent variables are included in all equations. (IBID). The latter condition (b) conforms with the specification of the cost component models variables listed in equation (7.2). A common set of 21 variables (including the constant term) was included to model each cost component. Therefore, the estimation of the parameters of the cost components models may be undertaken by fitting each equation separately, implementing OLS, adjusted for the non-constant variance. That means, employing weighted least squares regressions.

(c) <u>Simultaneous equation problem: correlation of U_{ki} and other model variables</u>

This aspect of model estimation was briefly discussed in chapters 3 and 4, sections 3.7 and 4.7 respectively. Here we indicate why the problem may exist, with reference to past cost studies.

Econometrically, the simultaneous equation problem exists, if there is grounds to believe that variables assumed predetermined (independent) in the model were related with the error variable. Let us take the equation for medical staff costs components. Hospital physcians were known to have a decisive hand on how many patients should be admitted, discharged and for how long they should stay in the hospitals. Also, the resources available to employ the staff might influence the level of staffing and the number of patients treated in the hospital. With that inter-relationship the numbers of patients discharged cannot be regarded as predetermined. The level of staffing determines the number of patients and the staff costs and vice-versa. This creates two-way causation, a simultaneous relation between the model variables specified, introducing the problem of simultaneous equations.

The problem of simultaneous equations in the hospital cost studies have been discussed in numerous research works, but few known to us have gone as far as to explicitly apply any of the plausible estimation techniques proposed. Feldstein (1967, p142) has dealt with the problem using Instrumental Variables, to estimate total inpatient cost models and concluded that if the specification of the model used "is correct, there is little reason to fear a substantial interdependence between the number of cases treated and the error in the total cost equation. The instrumental variables estimate lends support to this." On the other hand Sloan et al. (1983, p13), after considering the influence, said that, "given this endogeneity problem [of hospital outputs], we estimate reduced form cost and output functions in which the dependent variables depend on all the exogeneous variables in the system." Also, Breyer (1987) in his recent proposal stresses the need for a two-stage least squares procedure approach to be implemented in the estimation of a model for hospital costs per case.

There are numerous other studies either who did not mention the present problem of hospital cost model estimation we are considering, or who assumed its influences to be minimal without applying any appropriate technique to verify them - [exceptions are those studies mentioned in this section among references outlined]. In contrast, Lave and Lave (1970) presents evidence of the non-existence of simultaneous equation problem in hospital cost studies. For example, according to their comment (p379) it was stressed that "there is no simultaneous equation problem in estimating hospital cost functions ....", the reasons being that: "the hospitals we study are non-profit and accept all paying patients as long as there is space, ie. hospitals do not choose their rate of output, but rather are constrained to accept all cases offered. In addition it seems likely that the cost of hospitals has little effect on their demand for services". Even though that was said, other researchers have acknowledged the problem, be it through analysis of hospitals either under British, or American Health Service System, which do have differing payment conditions for health care provisin. For instance, Sloan et al. (1983) while studying 367 US community hospitals implemented the procedure of Two-stage least squares (2SLS) to estimate their cost functions for the costs of radiology departments, because of the simultaneous equation problem, as indicated in the proceeding paragraph.

We think the evidence about this concept is complex and fragmented in the hospital cost studies. Our analysis in the next chapter tries to address the problem in some detail. In the ongoing chapter, however, we present the results of cost component models estimated assuming there may not be simultaneous equation problem, weighted least squares was applied in fitting all cost component models to the data, with the weights indicated under (a) above. Then in chapter 8, assuming the problem of simultaneous equation actually prevails, we present cost models fitted using a two-stage least squares procedure. From these results comparisons are made between the two approaches implemented.

7.3 Empircal Results

The data on tables 7.1 and 7.2 outline the cost components of total running costs of the 81 hospitals to be analysed. Table 7.1 is concerned with the cost components forming the expenditure made for staffing the hospitals. They can be grouped into four categories; pay in 1985/86 fiscal year for medical, nursing, professional and technical and administrative staff employment. The total staff pay component constitutes about three-quarters (74%) of the average total running costs of the 81 Scottish hospitals. This figure breaks down, - corresponding to the above four categories, into 13.3%, 36%, 5% and 19.7% of average total running costs, respectively. According to this data the bulk of the total staff cost component, almost half, goes to employing the nurse staff.

The supply cost components are presented in table 7.2. Total expenditure for expendable facilities provision in the 81 Scottish hospitals studied amounts to a quarter of their average total running costs in 1985/86. The major part is spent on supplies for pharmaceutical provisions (9.0%). The supply cost components is put into 6 categories, pharmacy, heating, medical and surgical equipment, professional and technical departments, and remaining (others). They constitute 9%, 2.5%, 1.2%, 3.5%, 1.1% and 8.8%, respectively of the average total running costs.

Looking at the information with respect to teaching status of hospitals does not reveal much difference in the proportional distribution of their running costs between staff and supply cost components. This can be seen from table 7.3. In all three types of hospitals, major, minor and non-teaching (controls), the average expenditure for salary and wages of their manpower staff takes more than 70% of their corresponding total running costs. However, there are some slight variations between them. The data indicates that Scottish hospitals undertaking considerable teaching activity (major type) compared with the non-teaching, seem to spend a comparably smaller percentage of their average total running costs for staff employment, but more to provide supplies. Nevertheless, compared with the same non-teaching hospitals their payment for medical (junior and senior) staff, appears to be larger. This is also true for the minor teaching hospitals. On the other hand, the non-teaching, control hospitals spend a comparatively large part of their total running costs for employment of nursing staff. Since salary payment for NHS hospital staff are nationally negotiated and might not differ between them, the likely explanation for this share of costs variation could be due to staffing levels. The teaching hospitals seem to have more medical staff, while the non-teaching are equipped with less qualified medical staff ie. nurses. There is also the implication that the teaching hospitals spend more on professional and technical staff than their non-teaching counterparts.

Coming to the supply cost components comparison with respect to hospital teaching status, we realise that, the teaching hospitals (both major and minor types) have their bigger expenditure for pharmaceutical supplies - ie drugs, dressings, etc., as well as for professional and technical department and equipment supply provisions compared with the non-teaching hospitals. The non-teaching hospitals, however, appear to spend more on other miscellaneous supplies, such as cleaning, laundry, catering etc. [see table 7.2]. These costs (termed 'OTHERS') are an aggregation of spendings on which each of them accounts for at most, one percent of the total running costs of the 81 hospitals.

The modelling of the cost components follows as we said earlier through weighted least squares estimation. Where, the weights are assumed to follow Var $(TC_{Ki}) \propto (TB_i)^{1.7}$, where, (TB_i) total allocated staffed beds of hospitals i. The aim is to see whether teaching load has a varying effect on the different cost components forming the total running costs of hospitals.

The relationship between the level of teaching of hospitals and the cost components might be investigated by first looking at the correlation coefficients of the teaching variables (medical student and training nurses) and each of these cost components. This has been done. In all cases, ie, corresponding to all cost components, STDN and NURS variables have positive and significant correlation with each of them. This is true, whether, the data corresponds to the teaching or non-teaching sample of hospitals. Therefore, no differentiating factor can be deduced from this practice. It appears to suggest that an increment in the number of medical students or nurses trained results in an increase in the hospitals different staff and supply costs or vice versa. Hence, to clarify this point the cost component models were specifically fitted.

The results of the cost component models fitted to the 81 Scottish hospitals data are reported in table 7.4 for each type of staff cost components, in table 7.5 for grouped staff costs components (medical, nurse, professional and technical, as well as administrative), in table 7.6 for each type of supply cost components and finally to generalise the presentation table 7.7 presents models for total staff and supply cost components (and total running costs).

We are particularly interested in the coefficients estimated corresponding to the four teaching variables, STDN, NURS, MAJOR and MINOR, giving attention to their sign and statistical significance.

Taking each table separately; in table 7.4, it is shown that, the 20 variables selected, to estimate total runnng costs of hospitals, explain much of the variability in the cost components of hospitals. The minimum explanatory value (R^2) attained is for the professional and technical workers staff cost components (PRFTCWK), with R^2 = 78.80%, and the maximum for nurse in training costs (NRSLRNR) component, with R^2 = 99.33%. The latter is purely showing the relationship between number of nurses in training and the costs spent for employing them. It implies that an additional training nurse costs about £6,600 to employ in a given hospital. This amounts to 62% of that estimated from the total running costs [ie. (6.592/10.63) x100]. Other than this cost component, the cost of training nurses is significantly related to the senior medical (SNRMEDC) and other grade (OTHRGRD) staff costs. Both have positive magnitudes, which indicates, nurse training incurs additional costs requiring to employ more senior medical and other grade type staff. Though insignificant statistically, in most staff cost components, positive coefficients were estimated for NURS. Exceptions are for costs of other nurses (non-trained), professional and technical as well as domestic and ancillary type saff.

Undergraduate student training (STDN) was shown to significantly uplift the costs of hospitals for employing senior medical (SNRMEDC) and domestic and ancillary (DMSANCL) type staff. For the remaining staff cost components there seems to be an implication that training students may create additional staff costs, aside from staff costs of trainee nurses (NRSLRNR), all types of professional and technicals' (PRFTCH) and tradesmen (TRDSMEN).

When the teaching status of hospitals is considered, the major teaching hospitals usually have higher overhead costs than the controls corresponding to the staff cost components; which is only significant at the conventional levels for administrative and clerical staff costs (ADMCLRC). On the contrary, the minor teaching hospitals seems to have lower overhead staff costs than the controls. However, the teaching status of hospitals may not be important in influencing staff cost components.

Table 7.5. is a generalisation of table 7.4. We can deduce from this table that costs of professional and technical staff (PROFTCH) is not affected by the level of teaching activity of hospitals.

Table 7.6 presents modelling results for the supply cost components. These cost categories of hospital running costs have a similar explained variability compared with the staff costs in relation to the 20 variables used to determine them. But their significant association with the teaching variables is only through the costs of power (POWER) supply. This component has positive significant coefficient for STDN variable and cost of (PHARMACY) pharmaceutical supplies might also be affected by the hospitals teaching activity.

Table 7.7 presents cost models for total staff and supply components. There is evidence that the hospitals cost of teaching activity is borne in relation to the additional cost involved for employing staff manpower. The additional costs of teaching students estimated from the total staff costs accounts for about 81% (= 11.80/14.63 X 100) of that estimated from the total running costs, the remaining 19% appears to be due to supply costs. The major teaching hospitals results are similar to the previous cases, higher overhead staff and supply costs than the non-teaching, control hospitals. In the same manner, the cost of training an additional nurse estimated from the staff cost component amounts to 87% (= 9.22/10.63 x100) of that estimated from the total running costs model.

7.4. Summary

Two cost components of total running costs were investigated with the use of 20 variables measuring hospital resources and activities. The aim being to look for any signficant relatonship between these costs and the level of teaching activities. The results observed can be summarised as follows:

(i) With respect to partitioning of total running costs net of rates and capital costs; its major component, three quarters (3/4th) of it on the average goes on employing staff, and the remaining quarter (1/4th) do provide medical supplies. The same distribution appears to hold between the teaching and the non-teaching hospitals percentage expenditure in terms of the two cost components from total running costs (ie. about 3/4 for staff and 1/4 for supply provision in both sets of hospitals).. However, there seems to be a tendency for the teaching hospitals to spend a comparably smaller percentage of their total running costs on staff and larger on supplies than the control non-teaching hospitals.

The major part of staff costs of hospitals goes on employing nurses about a half of their total staff costs. But this figure is larger for the non-teaching hospitals. The data implies that the teaching hospitals do spend comparably more on medical and professional staff than the non-teaching. From the supply cost side, the teaching hospitals spend larger share of expenditure on pharmacy and professional and technical department supplies.

(ii) With respect to the modelling of cost components; 12 components of staff costs and 6 components of supply costs were examined. The same 20 variables selected for modelling total running costs was used to fit the cost component models. The explanatory power of the models for all cost components exceeded $R^2 = 78.8\%$.

Investigation of the estimated coefficents for the teaching variables (STDN, NURS, MAJOR, MINOR) revealed that training undergraduate students significantly affects the hospitals staff costs, but not their supply costs. The analysis suggests training one additional undergraduate student incurs an increase of £11,800 per year towards the employment of hospital staff. This figure is about 81% of that obtained from total running costs. The remaining 19% is shown to be an increase in costs due to supply provision. Training one additional nurse was estimated to increase the staff costs of hospitals by £9,220 per year per student in 1985/86, which is 87% of the estimated cost of nurse training obtained from the total running costs.

Specifically, the cost incurred in training undergraduate medical students appears to be directly related to hospital costs for the employment of senior medical and domestic and ancillary staff, while on the nurse training side, it is related to employment of senior medical and nursing staff. The level of teaching activity only appears to influence the cost of power supply.

TABLE 7.1 STAFF COST COMPONENTS OF TOTAL RUNNING COSTS OF SCOTTISH HOSPITALS[a] (1985/86 data)

Cost Components	% from Total running cost [b]	Mean Value (in £000s)	Coefficient of Variation
Junior Medical and Dental (JNRMEDC)	3.08	273.5	117
Senior Medical and Dental (SNRMEDC)	10.26	912.0	119
Nursing - trained (NRSTRND)	24.28	2159.0	71
Nursing - learners (NRSLRNR)	3.39	301.6	93
Nursing - others (NRSOTHR)	8.28	736.1	58
Professional and Technical "A" (PRFTCHA)	3.17	282.3	104
Professional and Technical "B" (PRFTCWB)	1.26	112.5	178
Professional and Technical "B" - Works (PRFTCWK)	0.51	45.0	78
Domestic and Ancillary (DMSANCL)	12.02	1068.7	79
Administrative and Clerical (ADMCLRC)	4.84	430.2	100
Tradesmen (TRDSMEN)	2.20	195.3	85
Other Grades (OTHRGRD)	0.65	58.0	107
Total Staff Cost	73.94	6574.2	81

Notes: (a) The 81 teaching and non-teaching hospitals in the sample
(b) Proportion from the average total running costs of all 81 hospitals in the sample.

Example Proportion of Junior Medical and Dental (JNRMEDC) Staff cost

$$= \frac{\text{Total JNRMEDC Cost for the 81 hospitals}}{\text{Total Running Costs for the 81 hospitals}}$$

TABLE 7.2 MEDICAL SUPPLY COST COMPONENTS OF TOTAL RUNNING COSTS OF SCOTTISH HOSPITALS[a] (1985/86 DATA)

Cost Component	Components included	% from total running costs	Mean value (£000s)	Coefficient of Variation
PHARMACY	Drugs, Dressings Insts. and sundries and CSSD	9.01	801.0	141
HEATING	Steam production (coal, oil and gas) steam to laundry etc. Hotwater,space heating and Other heating systems	2.50	222.6	78
POWER	Electricity and other fuel	1.21	107.3	103
Medical and Surgical EQUIPMENT	Medical and surgical equipment (purchase, rent and repairs). Surgical appliances, paramedical equipments (purchase,rent & repairs) furniture and other equipment purchase,rent & repair)	3.50	309.4	116
Profession and technical dept. PROFTCHS	Radiography, Physiotherapy, Occupational Therapy and Industrial Therapy, Chiropody and other professional and technical departments	1.06	93.9	153
Miscellaneous OTHERS	Catering (patient & staff),bedding & linen, (patients clothing & uniforms), laundry, cleaning, mental patients allowance, portering,property maintenance, transport & staff travel (excluding rates) (b)	8.78	783.7	70.0
Total supply	ALL	26.06	2321.9	100

Notes: a) The 81 hospitals in the sample
b) 3.77% of total running costs.

TABLE 7.3. PROPORTIONAL DISTRIBUTION OF COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPITALS BY THEIR TEACHING STATUS
(percentages given)

Cost Components*	Major Teaching %	Minor Teaching %	Control-Non-teaching %
I. TOTAL STAFF	71.7	74.2	75.9
MEDICAL**	15.4	16.1	9.7
NURSING**	31.3	33.3	41.9
PROFTCH**	5.7	5.4	3.9
ADMINISTRATIVE**	19.2	19.4	20.4
II. TOTAL SUPPLY	28.3	25.8	24.1
PHARMACY	11.4	9.8	6.3
HEATING	2.4	2.0	2.9
POWER	1.3	1.2	1.1
EQUIPMENT	1.3	1.3	0.7
PROF TCHS	4.0	3.6	2.9
OTHERS	8.0	7.8	10.2
III. TOTAL RUNNING COSTS(%)	100.0	100.0	100.0
(£000s)	13,467	12,888	5,906

Notes: * See Tables 7.1 and 7.2 for definitions of cost components. The percentages are taken from the total running costs corresponding to each type of hospital, i.e. proportion of staff cost for major teaching hospital (=71.7%) = sum of total staff costs/ total running costs) in the major teaching groups.

** Staff Cost Component Groupings are as follows:
MEDICAL = JNRMEDC + SNRMEDC
NURSING = NRSTRND + NRSLRNR + NRSOTHR
PROF TCH = PRFTCHA + PRFTCHB + PRFTCWK
ADMINISTRATIVE = DMSANLL + ADMCLRC + TRDSMEN + OTHRGRD

TABLE 7.4 MODELS FITTED TO STAFF COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPITALS -(WLS)

Independent Variables \ Dependent Variables	JNR MEDC	SNR MEDC	NRSTRND	NRSLRNR	NRSOTHR
BEDDGH	0.7677 (4.12)	1.45 (3.44)	5.74 (8.49)	-0.0769(-1.22)	1.60 (3.45)
BEDLS	0.0900 (0.28)	-0.54 (-0.75)	2.72 (2.33)	-0.1326 (-1.22)	2.76 (3.45)
BEDSA	0.8843 (1.68)	3.98 (3.34)	2.95 (1.55)	-0.1376)(-0.78)	1.22 (0.93)
BEDOBS	0.2789 (1.07)	0.04 (0.07)	6.94 (7.30)	0.0190 (0.22)	1.56 (2.40)
BEDMI	0.1083 (1.64)	0.04 (0.27)	3.00 (12.54)	-0.0828 (-3.73)	1.52 (9.25)
BEDSC	2.1300 (2.58)	0.75 (0.40)	11.29 (3.77)	-0.0325 (-0.12)	2.94 (1.43)
EXCDGH	0.0147 (1.65)	0.0804 (3.99)	0.0033 (0.10)	0.0025 (0.82)	-0.01861 (-0.84)
EXCSA	0.0239 (0.58)	0.0174 (0.19)	0.0114 (0.08)	-0.0101 (-0.73)	0.1373 (1.34)
EXCSC	0.0594 (2.21)	0.2079 (3.42)	0.1977 (2.03)	-0.004 (-0.05)	0.0260 (0.39)
EXDDGH	0.0006 (0.28)	0.0047 (1.02)	-0.0039 (-0.53)	0.0005 (0.73)	0.0013 (0.25)
EXDLS	0.0005 (0.19)	0.0083 (1.28)	-0.0005 (-0.05)	0.0014 (1.49)	0.0130 (1.84)
EXDSA	-0.0019 (-0.17)	-0.0032 (-0.12)	0.0124 (0.30)	0.0002 (0.04)	-0.0213 (-0.76)
EXDOBS	0.0008 (0.41)	0.0054 (1.22)	0.0020 (0.28)	0.0018 (2.84)	0.0113 (2.35)
NIPCNSL	0.0011 (1.78)	0.0044 (3.17)	0.0019 (6.87)	-0.0005 (-2.23)	-0.0005 (-0.30)
NIPDPAT	0.0006 (0.28)	0.0052 (1.02)	0.0081 (1.01)	0.0005 (0.65)	0.0057 (1.02)
NIPDYCS	0.0032 (0.40)	0.0218 (1.19)	0.0380 (1.30)	-0.0007 (-0.26)	0.0400 (1.99)
TEACH STDN	0.9656 (1.50)	4.45 (3.05)	2.29 (0.98)	-0.0961 (-0.44)	0.590 (0.37)
TEACH NURS	0.2629 (0.52)	3.34 (2.90)	0.60 (0.32)	6.5920 (38.52)	-2.00 (-1.58)
TEACH MAJOR	1.28 (0.06)	68.37 (1.34)	99.88 (1.22)	3.84 (0.51)	68.20 (1.22)
TEACH MINOR	22.47 (0.85)	-18.45 (-0.31)	-277.65 (-2.89)	-16.50 (-1.85)	-33.65 (-0.51)
CONSTANT	-16.31 (-1.24)	48.21 (1.62)	-14.67 (-0.31)	9.8820 (2.24)	44.56 (1.36)
R^2	94.06	97.20	97.13	99.33	89.17
MSE	0.23	1.19	3.06	0.03	1.43

Note: Figures are in £000s.
T-ratios inside parenthesis.
WLS - Estimated using weighted least squares.

TABLE 7.4 (continued)

MODELS FITTED TO STAFF COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPITALS - (WLS)

Independent Variable \ Dependent Variables	PRFTCHA	PRFTCHB	PRFTCWK	DMSANCL	ADMCLRC	TRDSMEN	OTHRGRD
BED DGH	0.40 (1.90)	-0.024 (-0.19)	0.127 (2.71)	2.619 (5.84)	1.167 (6.00)	0.46 (2.81)	0.122(2.92)
BEDLS	0.61 (1.66)	-0.019 (-1.59)	0.129)1.59)	1.747 (2.25)	-0.145 (-0.43)	0.253 (0.89)	0.039(0.54)
BEDSA	3.23 (5.40)	0.996 (2.80)	0.128 (0.97)	0.547 (0.43)	1.335 (2.43)	0.579 (1.25)	0.162(1.37)
BEDOBS	-0.35 (-1.19)	-0.335 (-1.89)	0.102 (1.55)	1.634 (2.60)	0.777 (2.85)	0.593 (2.27)	0.104(1.78)
BEDMI	0.11 (1.52)	-0.034 (-0.76)	0.078 (4.72)	1.309 (8.27)	0.263 (3.83)	0.312 (5.38)	0.040(2.68)
BEDSC	-0.13 (-0.14)	0.526 (0.94)	0.012 (0.06)	4.326 (2.18)	0.902 (1.05)	0.366 (0.50)	0.036(0.19)
EXC DGH	0.0170(1.72)	0.0049 (0.82)	0.0029 (1.31)	-0.0391 (-1.83)	0.0137 (1.48)	0.0011 (0.14)	0.0005(0.25)
EXCSA	0.0310(0.66)	-0.0135 (-0.48)	-0.0052 (-0.50)	0.0640 (0.65)	0.0456 (1.06)	-0.0006 (-0.02)	-0.0053(-0.57)
EXCSC	0.0490(1.62)	0.0600 (3.30)	0.0028 (0.41)	0.1328 (2.06)	0.0815 (2.91)	-0.0037 (-0.16)	0.0088(1.46)
EXD DGH	0.0003 (0.11)	0.0014 (1.01)	-0.0003 (-0.54)	0.0008 (0.17)	0.0052 (2.48)	0.0015 (0.83)	0.0007 (1.65)
EXDLS	0.0017 (0.52)	-0.0018 (-0.92)	0.0001 (0.09)	0.0077 (1.17)	0.0053 (1.78)	-0.0005 (-0.21)	0.0004(0.63)
EXDSA	-0.0014 (-0.11)	0.0046 (0.60)	0.0013 (0.46)	0.0125 (0.46)	0.0001 (0.01)	0.0072 (0.72)	0.0006(0.23)
EXDOBS	0.0014 (0.65)	-0.0018 (-1.41)	0.0011 (2.36)	0.0076 (1.64)	0.0016 (0.77)	0.0004 (0.26)	-0.0003(-0.61)
NIP DPAT	0.0023 (3.35)	0.0018 (4.29)	0.0002 (1.02)	0.0039 (2.61)	0.0039 (2.61)	0.0009 (1.60)	0.0002 (1.49)
NIPDYCS	0.0049 (1.94)	0.0006 (0.38)	0.0001 (0.12)	0.0079 (1.47)	0.0021 (3.25)	0.0012 (0.60)	0.0001 (0.22)
	0.0147 (1.60)	0.0089 (1.62)	0.00003(0.02)	0.0199 (1.03)	-0.0001 (-0.01)	-0.0011 (-0.15)	0.0008 (0.43)
TEACH STDN	-0.6105 (-0.83)	-0.0725 (-0.17)	0.0510 (0.32)	4.366 (2.82)	0.1202 (0.18)	-0.5003 (-0.88)	0.2407 (1.66)
TEACH NURS	-0.3144 (-0.54)	0.4782 (1.39)	-0.1540 (-1.21)	-0.794 (-0.65)	0.5807 (1.09)	0.3927 (0.88)	0.2433 (2.13)
TEACH MAJOR	48.35 (1.88)	6.64 (0.43)	-6.29 (-1.11)	-22.09 (-0.41)	4.89 (2.76)	-4.52 (-0.23)	-5.50 (-1.08)
TEACH MINOR	0.39 (0.01)	-22.09 (-0.41)	0.77 (0.12)	-126.81 (-1.99)	-46.40 (-1.68)	-19.94 (-0.86)	-1.59 (-0.27)
CONSTANT	15.09 (1.01)	-4.69 (-0.53)	2.403 (0.73)	14.36 (0.45)	-7.71 (-0.56)	-15.08 (-1.30)	-2.51 (-0.85)
R^2	92.99	90.24	78.80	95.81	96.66	85.00	91.62
MSE	0.301	0.107	0.015	1.34	0.252	0.180	0.012

Note: Figures are in £000s.
T ratios inside parenthesis
WLS - estimated using weighted least squares.

Table 7.5 Models fitted to Staff Cost Components of Total Running Costs of Hospitals -(WLS)

Independent variables \ Dependent Variables	Medical Staff (MEDICAL)	Nursing Staff (NURSING)	Professional & Technical Staff (PROFTCH)	Administrative & Other Clerical Staff (ADMINISTRATIVE)
BED DGH	2.230 (4.54)	7.720 (9.24	0.506 (1.85)	4.37 (6.45)
BED LS	-0.454 (-0.54)	5.361 (3.94)	0.719 (1.52)	1.89 (1.62)
BED SA	4.867 (3.53)	4.030 (1.82)	4.354 (5.66)	2.62 (1.37)
BED OBS	0.319 (0.47)	8.522 (7.72)	-0.588 (-1.54)	3.04 (3.19)
BED MI	0.149 (0.86)	4.431 (15.94)	0.158 (1.64)	1.92 (8.03)
BED SC	2.88 (1.33)	14.204 (4.08)	0.409 (0.34)	5.63 (1.87)
EXC DGH	0.0951 (4.08)	-0.0125 (-0.34)	0.0253 (1.94)	-0.0238 (-0.74)
EXC SA	0.0412 (0.38)	0.1386 (0.80)	0.0123 (2.86)	0.1037 (0.68)
EXC SC	0.2673 (3.80)	0.2233 (1.97)	0.1123 (2.86)	0.2194 (2.25)
EXD DGH	0.0053 (0.99)	-0.002 1(-0.25)	0.0014 (0.46)	0,0083 (1.13)
EXD LS	0.0088 (1.18)	0.9139 (1.16)	-0.00003(-0.01)	0.0128 (1.24)
EXD SA	-0.0051 (-0.17)	-0.0087 (-0.18)	0.0045 (0.27)	0.0204 (0.50)
EXD OBS	0.0062 (1.21)	0.0151 (1.85)	0.0007(0.25)	0.0093 (1.33)
NIP CNSL	0.0055 (3.42)	0.0010 (0.40)	0.0043 (4.76)	0.0070 (3.14)
NIP DPAT	0.0058 (0.99)	0.0143 (1.52)	0.0056 (1.70)	0.0132 (1.63)
NIP DYCS	0.0250 (1.18)	0.0772 (2.27)	0.0236 (2.00)	0.0195 (0.67)
TEACH STDN	5.420 (3.21)	2.780 (1.02)	-0.632 (-0.67)	4.23 (1.80)
TEACH NURS	3.602 (2.70)	5.191 (2.42)	0.010 (0.01)	0.42 (0.23)
TEACH MAJOR	69.65 (1.18)	171.93 (1.81)	48.68 (1.47)	32.88 (0.40)
TEACH MINOR	4.08 (0.06)	-327.77 (-2.93)	-21.42 (-0.55)	-194.76 (-2.02)
CONSTANT	31.90 (0.93)	39.77 (0.72)	12.82 (0.67)	-10.94 (-0.23)
R^2	97.75	98.18	98.52	96.70
MSE	1.59	4.10	0.50	3.07

Note: Figures are in £000s
T- ratios inside parenthesis
WLS -Estimated using weighted least squares.

TABLE 7.6 MODELS FITTED TO SUPPLY COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPITALS (WLS)

Independent Variables \ Dependent variables	PHARMACY	HEATING	POWER	PROFTCHS	EQUIPMENT	OTHERS
BEDDGH	2.003(3.75)	0.846 (5.56)	0.170 (1.88)	0.0001 (0.01)	0.8415 (3.15)	1.56 (5.24)
BEDLS	-1.254 (-1.36)	-0.056 (-0.21)	0.157 (1.00)	-0.1300 (-0.86)	-0.0088 (-0.02)	2.16 (4.20)
BEDSA	2.834 (1.88)	0.773 (1.80)	0.375 (1.48)	0.837 (3.42)	3.539 (4.70)	4.48 (2.95)
BEDOBS	1.494 (1.99)	0.497 (2.33)	0.203 (1.60)	-0.318 (-2.61)	0.391 (1.04)	1.62 (3.87)
BEDMI	0.016 (0.08)	0.300 (5.57)	0.085 (2.70)	0.024 (0.77)	0.232 (2.46)	1.31 (12.39
BEDSC	1.767 (0.75)	0.743 (1.10)	0.061 (1.15)	0.910 (2.36)	2.149 (1.82)	1.05 (0.79)
EXCDGH	0.0343 (1.34)	-0.0045 (-0.62)	0.0063(1.47)	-0.0020 (-0.49)	0.027 (2.11)	0.0191 (1.34)
EXCSA	-0.0905 (-0.77)	0.0593 (1.77)	-0.0292 (-1.47)	0.0120 (0.63)	0.0630 (1.07)	0.0638 (0.97)
EXCSC	0.2092 (2.72)	0.0317 (1.45)	0.0240 (1.85)	0.0212 (1.70)	0.0680 (1.76)	0.0191 (0.44)
EXDDGH	0.0170 (2.93)	0.0003 (0.21)	0.0009 (0.92)	0.0015 (1.64)	0.0057 (1.97)	0.0045 (1.40)
EXDLS	0.0114 (1.39)	0.0023 (1.01)	0.0007 (0.48)	0.0013 (0.95)	0.0011 (0.26)	0.0036 (0.76)
EXDSA	0.0403 (1.24)	-0.0060 (-0.65)	0.0063 (1.15)	0.0048 (0.90)	0.0281 (1.73)	0.0175 (0.96)
EXDOBS	0.0002 (0.03)	-0.0007 (-0.47)	0.0010 (1.02)	-0.0017 (-1.84)	0.0009 (0.34)	0.0114 (3.69)
NIPCNSL	0.0031 (1.76)	-0.0007 (-1.35)	0.0003 (1.06)	0.0016 (5.60)	0.0013 (1.53)	0.0021 (2.18)
NIPDPAT	0.0055 (0.85)	0.0018 (0.99)	0.0016 (1.52)	0.0007 (0.66)	0.0015 (0.47)	0.0021 (0.59)
NIPDYCS	0.0562 (2.43)	0.0017 (0.25)	-0.0010 (-0.25)	0.0089 (2.37)	0.0079 (0.68)	0.0255 (1.98)
TEACH STDN	2.677 (1.45)	0.317 (0.60)	0.791 (2.54)	-0.0718 (-0.24)	-1.055 (-1.14)	0.1750 (0.17)
TEACH NURS	1.878 (1.29)	0.260 (0.63)	0.100 (0.41)	0.2239 (0.94)	-0.2815 (-0.39)	-0.7701 (-0.95)
TEACH MAJOR	66.55 (1.03)	8.00 (0.43)	-11.36 (-1.04)	-10.10 (-0.96)	16.39 (0.51)	46.04 (0.91)
TEACH MINOR	-124.71 (-1.64)	-81.10 (-3.75)	2.06 (0.16)	-1.35 (-0.11)	20.58 (0.54)	- 1.70 (-0.04)
CONSTANT	-29.24 (-0.78)	5.66 (0.53)	3.24 (0.51)	-11.13 (-1.82)	-19.10 (-1.01)	12.61 (0.27)
R^2	94.80	88.98	87.20	92.41	90.75	96.27
MSE	1.91	0.155	0.054	0.050	0.476	0.593

Note: Figures are in £000s. T ratios inside parenthesis
WLS — Weighted Least Squares.

TABLE 7.7 MODELS FITTED TO COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPITALS: WLS

Independent Variables \ Dependent Variables	TOTAL RUNNING COSTS	TOTAL STAFF COSTS	TOTAL SUPPLY COSTS
BED DGH	19.79 (8.79)	14.36 (8.44)	5.42 (6.32)
BED LS	8.39 (2.15)	7.52 (2.55)	0.87 (0.59)
BED SA	26.71 (4.21)	15.88 (3.31)	10.83 (4.48)
BED OBS	15.17 (4.80)	11.29 (4.73)	3.88 (3.22)
BED MI	8.62 (10.84)	6.66 (11.08)	1.96 (6.47)
BED SC	29.80 (2.99)	23.12 (3.07)	6.68 (1.76)
EXC DGH	0.1640 (1.52)	0.0837 (1.03)	0.0801 (1.95)
EXC SA	0.3740 (0.75)	0.2958 (0.79)	0.0782 (0.41)
EXC SC	1.1952 (3.69)	0.8222 (3.36)	0.3730 (3.02)
EXD DGH	0.0428 (1.75)	0.0128 (0.69)	0.0300 (3.22)
EXD LS	0.0557 (1.62)	0.0355 (1.37)	0.0202 (1.54)
EXD SA	0.1021 (0.75)	0.0111 (0.11)	0.0910 (1.74)
EXD OBS	0.0424 (1.81)	0.0313 (1.77)	0.0111 (1.24)
NIP CNSL	0.0256 (3.46)	0.0178 (3.18)	0.0078 (2.77)
NIP DPAT	0.0520 (1.93)	0.0388 (1.91)	0.0132 (1.28)
NIP DYCS	0.2445 (2.51)	0.1453 (1.98)	0.0992 (2.67)
TEACH STDN	14.63(1.88)	11.80 (2.01)	2.83 (0.95)
TEACH NURS	10.63 (1.73)	9.22 (1.99)	1.41 (0.60)
TEACH MAJOR	440.3 (1.62)	323.1 (1.57)	117.2 (1.13)
TEACH MINOR	-722.7 (-2.26)	-539.9 (-2.23)	-182.8 (-1.50)
CONSTANT	34.10 (0.21)	73.5 (0.61)	-39.65 (-0.66)
R^2	98.60	98.44	97.53
MSE	34	19.3	4.92

Note Figures to be in £000s.

T-ratio inside parentheses

WLS = Estimated using Weighted least squares.

CHAPTER 8

INFLUENCE OF SIMULTANEOUS EQUATIONS PROBLEM:

APPLICATION OF TWO-STAGE LEAST SQUARES ESTIMATION PROCEDURE

8.1 Introduction

The problem of simultaneous equations (SEP) was discussed in the past several chapters. To summarise on what was said; chapter 3 illustrated the theoretical background on how a system of economic models can be estimated (fitted) under the effect of SEP. In chapter 4 the likely existence of simultaneous relationships between the variables of the total running costs function was stressed. It was pointed out then that there could be conditions prevailing on which the hospitals may have to decide about their level of service provision from time to time, especially concerning matters like, the number of patients to be admitted, discharged, for how long they should be staying, as well as their case-mix in different specialities. This could happen, say due to external pressure, budget constraint from the central source. These may lead us to conclude that the variables adopted to represent a hospital's level of output (or activity); (i) patients discharged and (ii) occupied bed-days, from inpatient services, and (iii) outpatient attendances from non-patient services should be regarded as endogenous variables.

In econometric theory, endogeneity of variables imply their characteristics to be determined by the functioning and variables of the models specified. In the case of exogenous variables the models being considered assumes that their values are predetermined and may not be affected by other factors (variables). It has nothing to say about them. The simplest form of total running costs model given in equation 4.4, chapter 4, for instance, assumes that a certain hospital with say, EXC, extra inpatient cases is expected to have spent a certain running cost, say, TC, keeping other factors constant. There is no extra conditions attached. But through an increase in demand, or input prices or the like, the hospitals have to make decisions on the number of patients it can serve.

Therefore, the single total running cost model used is not explaining the actual structural operation of the hospitals. Costs and other unidentified factors influence the number of discharged cases and vice versa. This implies the variables originally specified as independent are not uncorrelated with the random error variable in the model.

To continue the summary discussion of the previous chapters about this problem, we have also pointed out that the consideration of it do not involve in the structural cost models to be developed, the question of scale and scope measuring variables. So, the model specification to be used for the total running costs and its components would be the 20 linear order variables selected under chapter 6, assuming no effect of simultaneous equation problem. The complication due to SEP influence , while modeling total running costs of hospitals may not be too serious, since the two-way causation between running costs and patients discharged or outpatient attendances may be minimal. [see views of studies on this, in chapter 7 , Section 7.2] It is in the light of these circumstances that the final total running cost model developed through the weighted least squares principle and the omission of scale and scope measuring variables, using step-wise regressions and the hypothesis tests made might be justifiable theoretically.

The problem may however be severe when the analysis of cost components, such as, medical staff, nursing etc. is considered. Because, in that event clearly the relationship between hospital staff and patients discharged incorporates some direct elements. If that does hold these influences should be interpreted with respect to methods devised for estimating model parameters with SEP. [Drymes (1970, p272-277), for example explains about hypothesis tests and related aspects on parameters estimated under 2SLS method. But in the present circumstances, time and space constrained us to follow otherwise]

The implementation of techniques to deal with SEP have two main objectives. The first can be termed comparison of results. Chapters 6 and 7 provided empirical results for models estimated corresponding to total running costs and its subsequent components. It was presumed - to undertake the tasks of estimating model parameters - that no SEP exists in the structure of hospital costs described by the respective models. Next by discrediting this assumption we will try to deduce the difference in the resultant outcome. Comments will be made whether the models estimated under both conditions satisfy the required economic expectations. The second objective is to invite more work to the problem by contributing the present work. Most hospital cost studies, we have referred to, had either denied its existence in the hospital sector, or ignored it after acknowledging its influence. Understandably each may have its own reasons. [see previous chapter 7].

The following three sections of this chapter presents the empirical results obtained from applying a two-stage least squares (2SLS) estimation procedure to the models of total running costs and its components. Section 8.2, provides the structural and reduced forms of the models specified to implement this process, while in section 8.3 the estimated models are discussed. Finally section 8.4 outlines some points of interest from the whole chapter.

8.2 Structural and Reduced form of Models

Two forms of the models specified are involved with regard to parameter estimation under the influence of SEP. The first called structural form of equations shows the inter-relationship between endogenous variables themseleves as well as the exogenous ones. The second, called reduced form of equations, explains the endogenous in terms of all predetermined (exogenous) variables. Consider the models for total running costs and its component costs given in equations (7.1.) and (7.2), respectively. Owing to the present assumption being followed, variables abbreviated by EXC_j, EXD_j, and NIP_k, respectively, named 'Excess' inpatient cases, 'Excess' inpatient occupied days and non-inpatient attendances are no more predetermined. They are also endogenous variables as total running costs (TC) and the cost components (TC_k).

Putting the three equations as follows in a matrix notation, we have:

$$\underline{TC} = \text{BEDTEACH}\ \alpha_5 + \text{CAS}\ \beta_5 + \underline{U} \qquad \ldots\ldots\ldots (8.1)$$

$$TC_k = BEDTEACH\underline{\alpha}_{ks} + CAS\,\underline{\beta}_{ks} + \underline{V}_k \quad \ldots\ldots\ldots \quad (8.2)$$

$$\underline{TC} = \sum_{i=1}^{t} \underline{TC}_k \quad \ldots\ldots\ldots \quad (8.3)$$

where, BEDTEACH is matrix of observations for BED_j and $TEACH_m$ variables, (6X81) and (4X81) elements, respectively,

CAS is matrix of observation for the EXC_j, EXD_j and NIP_k variables, in equations (7.1) and (7.2), of (10X81) elements.

where, $\underline{\alpha}_s$ and $\underline{\beta}_s$ are vector of coefficients corresponding to variables under equation (8.1),

and $\underline{\alpha}_{ks}$ and $\underline{\beta}_{ks}$ are vector of coefficients corresponding to variables under equations (8.2), and,

k = 1, ... t, number of cost components.

Assumed, $\underline{U} \sim \underline{N}(\underline{0}, \sigma^2(\underline{TB})^{1.7})$, $\sigma^2 > 0$,

and, $\underline{V}_k \sim \underline{N}(\underline{0}, \sigma^2_k(\underline{TB})^{1.7})$, $\sigma^2_k > 0$.

Equations (8.1) to (8.3) now represent the **structural form** of the model under consideration with respect to hospital costs. These equations do not fully explain the underlying situation in the operation of hospitals since the new endogenous variables needs to be specified with additional structural equations. There are 10 variables, represented by **CAS** :- **EXCDGH, EXCSA, EXCSC, EXDDGH, EXDLS, EXDSA, EXDOBS, NIPCNSL, NIPDPAT** and **NIPDYCS**. Assuming a two-way causation relationship exists between costs and these variables, new additional factors (variables) should be searched and used to determine them.

The above outlined variables are thought to measure hospital outputs.

Similar studies have devised functions expressing them in terms of factors regarded as affecting their values such as hospital beds, medical, nursing, and other. staff, as well as supplies. This attempt usually follows use of production functions, such as the well known Cobb-Douglas production function. However, few have come up by advocating that this is an adequate and implicit functional relationship to be followed. For instance, Feldstein (1967, p123), judged his analysis by saying that: "Too little is known about the behavioural characteristics of hospital production for us to be certain that any particular stochastic specification is the correct one". This conclusion was arrived at after undertaking at least three widely accepted production functions for hospital outputs. He stressed then: "A more general model, with beds and medical staff as the only exogenous inputs, was finally adopted." (IBID).

We commented on the above point not to disregard the previous approaches made but to clarify why the following simpler specification was preferred for our purpose. According to 2SLS estimation procedure, we need equations suitable enough to provide us with adequate predicted values of variables in CAS. The specification to be outlined for these expresses each variable as function of its past (or lagged) observed values, allocated staffed beds (BED_j) and level of teaching activity ($TEACH_m$). That means taking EXC_j, EXD_j and NIP_k as defined in previous occasions, we postulated that the following functional relationship might approximately hold expressed in a matrix format:

$$\underline{EXC}_j = \pi_{1j}\underline{BED}_j + \pi_{2j}\underline{EXC}_{j(79)} + \underline{TEACH}_m\underline{\pi}_{3jm} + \pi_{4j}\underline{TC} + \underline{l}_j \quad \ldots\ldots \quad (8.4)$$

where $\underline{EXC}_{j(79)}$ stands for vector of observation of exces inpatient cases for speciality group j calculated from the 1978/79 Fiscal Year, 12 months period, data of Scottish hospitals.

assumed, $\underline{l}_j \sim \underline{N}(\underline{0}, \sigma^2_{1j}V_{1j})$, $\sigma^2_{1j} > 0$

Also, $$\underline{EXD}_j = \phi_{1j}\underline{BED}_j + \phi_{2j}\underline{EXD}_{j(79)} + \underline{TEACH}_m\underline{\phi}_{3jm} + \phi_{4j}\underline{TC} + \underline{e}_j \quad \ldots \quad (8.5)$$

where $\underline{EXD}_{j(79)}$ stands for vector of observations of excess inpatient occupied bed days for speciality group j calculated from the 1978/79 Fiscal Year, 12 months period, data of Scottish hospitals.

assumed, $\underline{m}_j \sim \underline{N}(\underline{0}, \sigma^2 e_j V_{ej})$ $\sigma^2 e_j > 0$

and $\underline{NIP}_k = BED_j \underline{\Psi}_{1kj} + \Psi_{2k} NIP^*_{k(84)} + TEACH_m \underline{\Psi}_{3km} + \Psi_{4k} \underline{TC} + \underline{n}_k$ . . (8.6)

where, $\underline{NIP}_k(84)$ stands for vectors of observation of non-inpatient attendances in the K^{th} outpatient department, in 1983/84 Fiscal Year, 12 months period data of Scottish hospitals. [* see at the end of table 8.1].
Assumed , $\underline{n}_k \sim \underline{N}(\underline{0}, \sigma^2_{nk} V_{nk})$. Where V_{1j} , V_{ej} , and V_{nk} are all(n xn) Covariance matrices, corresponding to error random variables 1_j , e_j , and n_k, spesfied in equations (8.4) to (8.6).

m in Π_{3jm}, Φ_{3jm}, and Ψ_{3km}, signify the four teaching variables in TEACH$_m$, and j in Ψ_{1kj} in equation (8.6) denotes the use made of all six BED_j Variables . Therefore , these coefficients and Π_{ij}, Φ_{ij}, and Ψ_{ik} are structural parameters to be estimated from models corresponding to equation (8.4) to (8.6), respectively. i = 1 ...,4 correspond to the speciality group j and outpatient type k under consideration. The choice of 1979 and 1984 data, respectively for inpatient and non-inpatient related lagged variables has more to do with the availability of data than any statistical reasons. The statistical aspect of it assumes that lagged endogenous variables are predetermined.

The linear specification chosen, instead of logarithmic relationship usually preferred in modeling hospitals outputs (like the present variables being considered) is due to two reasons. The first can be deduced from the magnitudes of EXC_j and EXD_j variables obtained from the data. As can be seen from table 5.6, some hospitals have both EXC_j and EXD_j variables with values less than zero. Therefore, the logarithmic function does not apply, unless of course a transformation of some sort is applied. The second, can be attributed to the above quotation of Feldstein (1967). As no certain specification can be derived (ascribed to) the linear approximation could do as well, instead of going to further complexities. From the 81 hospitals data produced we observed that, both the present variable and their lagged values are highly linearly correlated (not reported). For all variables, the sample correlation coefficient for data of current and lagged variables reaches up to the maximum of 0.97; all significant at 5% confidence level. It is also clearly plausable that, hospitals present performance should depend on its past achievements unless some special constraints, such as closure of facilities due to financial cut from the central sources were imposed on them.

Equations (8.4) to (8.6) constitute part of the structural models of the system of equations determining the relationship between hospital costs and their outputs. The variables assumed exogenous are: the 6 BED_j, the 4 $TEACH_m$ and the 10 lagged endogenous variables corresponding to variables included in CAS [see beginning of this section]. Listing them we have: **BEDDGH, BEDLS, BEDSA, BEDOBS, BEDMI, BEDSC,** $\mathbf{EXCDGH_{79}}$, $\mathbf{EXCSA_{79}}$, $\mathbf{EXCSC_{79}}$, $\mathbf{EXDDGH_{79}}$, $\mathbf{EXDLS_{79}}$, $\mathbf{EXDSA_{79}}$, $\mathbf{EXDOBS_{79}}$, $\mathbf{NIPCNSL_{84}}$, $\mathbf{NIPDPAT_{84}}$, $\mathbf{NIPDYCS_{84}}$, **STDN, NURS, MAJOR** and **MINOR.** The definitions of these variables are similar to that listed under section 4.8 ,except changing the time reference from 85/86 to 78/79 or 83/84.

Denoting the lagged variables of CAS by CAS_{-1}, therefore, the reduced form of the structural equations is simply a reformulation of each endogenous variables, ($\mathbf{TC}$, $\mathbf{TC_k}$, $\mathbf{EXC_j}$, $\mathbf{EXD_j}$ and $\mathbf{NIP_k}$) as a function of those assumed exogenous ones ($\mathbf{BED_j}$, $\mathbf{TEACH_m}$ and $\mathbf{CAS_{-1}}$) For example, the reduced form of the total running cost model in equation (8.1), can be written as:

$$\underline{TC}_r = BEDTEACH\, \underline{\alpha}_r + CAS_{-1}\underline{\beta}_r + \underline{U}_r \quad \ldots\ldots\ldots\ldots (8.7)$$

assuming $\underline{U}_r \sim \underline{N}(\underline{0}, \sigma_r^2 \Psi)$, $\sigma_r^2 > 0$

where, $\underline{\alpha}_r$ and $\underline{\beta}_r$ designate the reduced firm parameters of the model. Its reparametrization is in accordance with the explanations given in chapter 3, section 3.7.

Using the two-staged least squares estimation process, first, the predicted values of CAS, say $\widetilde{CAS}$ were determined employing BED_j, $TEACH_m$ and CAS_{-1} variables. Second, these predicted variables were substituted in place of CAS in equations (8.1) and (8.2) to fit models for total running costs and its cost components. [see section 3.7, chapter 3].

This process was applied using the 81 Scottish hospitals data. In the first stage, EXC_j, EXD_j and NIP_k were predicted. In the second stage these variables in addition to BED_j and $TEACH_m$ variables were included to estimate parameters of the cost models. These second stage estimated parameters are point estimates for the structural parameters of equation (8.1) and (8.2). Their interpretation doesn't alter from the previous cases discussed in chapters 6 and 7, respectively.

The estimation in the second stage of the cost models also implemented, further, the weighted least squares estimation approach. This is because, the error variables in the cost models are still assumed to have non-constant variance. The same weights, $(TB)^{-0.85}$ was incorporated, where, TB denotes total allocated staffed beds of hospitals.

Before passing to the following section, to present the empirical results of models fitted, we comment on the data of lagged endogenous variables, denoted as CAS_{-1} . Table 8.1 is descriptive data of these new exogenous variables, and some others. Comparison can be made between data on respective variables given in tables 5.6 and 5.7 with the present one. With respect to EXC_j variables, there is agreement between the two periods data. It seems there is not much change in the Scottish hospitals average case flow rate because also the allocated staff beds (not reported) was practically unchanged. There is a slight difference with respect to EXD_j variables compared between 1986 and 1979, especially due to EXDLS and EXDMI. We cannot pinpoint the cause of this alteration, because of the unavailability of the raw data corresponding to the year 1978/79 on inpatient occupied bed days. But, the national average bed occupancy ratio compared with the $EXD_{j(79)}$ variables data indicated that the difference between the two years to be small. [Data not reported on national bed occupancy ratio and case flow rate here. Given in Ho (1983) and Milne et al. (1986)].

8.3. Empirical Results

Tables 8.2 to 8.7 presents estimated models of the total running costs and their components for the 81 Scottish hospitals being studied. The two-stage least squares estimation procedure discussed in section 8.2 was individually applied to each cost model, representing the dependent variables. In the first stage the other part of dependent variables corresponding to EXC_j, EXD_j and NIP_k were predicted accordingly. These latter results are not reported here, because of our interest on the former one, i.e. results from cost models fitted. All the necesary statistical assumptions have been formally checked through mainly residual plots of the fitted models.

Considering the results in table 8.2, its first column is for total running costs. Since our objective was to comprise the outcome of estimating models with respect to the two different assumptions - existence and non-existence of simultaneous equations problem, the results of this section will be interpreted aligned with evidences attained in chapters 6 and 7. [Example, table 7.7 compares with table 8.2]. Therefore, what can be seen from the present total running cost model fitted are outlined in the following points:

(i). In most cases the estimated coefficients have been reduced in magnitude. Four variables, namely EXCDGH, EXCSA, EXDDGH, and EXDLS have now coeficients negative but insignificant. These might have been considered unexpected, if they were realised to be significant statistically.

(ii) Two variables, BEDDGH and BEDMI have almost unchanged coefficients, while that of BEDSC increase by about 46%. Also all the non-inpatient variables attained increased magnitudes.

(iii) The interesting result to us is that obtained for $TEACH_m$ variables. The STDN variable has now coefficients increased in magnitude and statistically significant unlike the previous case (ie. in chapter 6). The result implicates an additional undergraduate medical student to have cost about £25,190 per year in 1985/86, if the Scottish hospitals or any given central authority have a capacity to decide on the number of patients being served. No change was observed with respect to the nurses in training variable's (NURS) estimated coefficient. It still implies a cost of about £10,000 per year per training nurse to the hospitals concerned. But it has somehow lost importance statistically. The result seems to indicate that the main determinant of the cost of teaching activity of hospitals may be due to training medical students. As can be seen, major teaching hospitals have no more significant higher overhead fixed costs of teaching than the control hospitals. Inspite of this, it may have still incurred teaching costs above the controls. On the contrary, the minor teaching hospitals seem to have a much lower overhead costs than the non-teaching, control hospitals. The difference between them increased almost two times, in absolute value, compared with the results shown in table 7.7.

(iv) The model explanatory power have not altered in magnitude due to the different assumptions implemented. Both total running cost models estimated here and in chapter 7 explained more than 98% of the variation in costs. The same is true with the mean squared errors.

The other two columns of table 8.2 are correspondingly for the cost components of total running costs; total staff and supply cost component models estimated through the the same principle. Comparison of results between the present approach and that used in chapter 7, can readily follow the above pattern of comments given in (i) to (iv), for the total running cost model. For example, point estimates of most variables have been reduced and so are their significance levels. Similar to (iii) the STDN variable shows increment in coefficient estimates and statistical significance. In chapter 7, Section 7.4., it was reported that the estimated coefficient of STDN from the total staff cost component was about 81% of that obtained from the total running costs model. At the moment, this percentage has diminished to 71% and that of the total supply cost component proportion increased to almost 29% of the total.

Table 8.3 and 8.4 presents models fitted for the various components of hospitals total staff costs. The former provides results disaggregating staff costs into its 12 cost categories, and the latter is a grouping of them in to four cost categories, medical, nurse, professional and technical and administative staff costs. With respect to these components, (ie both aggregated and disaggregated), our interest lies on their association with the teaching related variables of the models fitted. In general comparison of table 8.3 and 8.4, respectively, with tables 7.4 and 7.5 in chapter 7, manifests the same kind of alterations in magnitudes and statistical significance of coefficients discussed above for table 8.2. Therefore, going in to further detail may not be necessary. The association between staff cost components and teaching_activity measuring variables also doesn't show any new information not pointed out in chapter 7. Here, also teaching variables (STDN and NURS, particularly) are seen to significantly affect the costs spent to employ senior medical, learner nurses, domestic and ancillary, and other grade staff. The coefficients estimated from these components are increased for STDN and mainly unchanged for NURS. Referring to table 8.4, it was indicted that the same pattern emerged as in table 7.5, that costs incurred in medical and administrative type staff are affected by the number of medical students being trained, while the costs on nurse staff are affected by the number of nurses in training. Understandably these latter results have to do with the influence of the direct association between the NURS variable and the cost component depicting the learner nurses staff (NRSLRNR) because the other two nursing staff costs (NRSTRND and NRSOTHR) are seen to be unrelated with NURS, unless the cost of NRSLRNR is included in their grouping.

Table 8.5 presents results of models fitted to the components of supply costs of hospitals. This table's output are to be compared with that of table 7.6. We would just like to note that no special feature can be observed that were not covered in the above paragraphs, regarding the estimated coefficients when compared with table 7.6. The level of teaching seems to affect the supply cost components, only due to supply of power, ie electricity and other fuels. We might note also that the cost of supply provision for professional and technical departments seem to be dependent on the number of training nurse. This may be the only difference between tables 8..5 and 7.6, concerning the significant association of supply costs and level of teaching.

The next section will try to summarise our observation on the outcome of this chapters' analysis.

8.4 Summary

The starting point of this chapters analysis was to assume that hospitals' level of outputs are not predetermined. So they depend on availability of resource or other factors that could be affected by the hospitals' decision making body. Econometrically that is to mean, the variables measuring them are correlated with the error variable in the total running costs model. Ordinary least squares was not the appropriate technique to estimate this model. Therefore, two-stage least squares (2SLS) was selected and applied accordingly.

In the process of developing the system of simultaneous equations need to apply the 2SLS approach, it was acertained that a hospitals present level of outputs might be adequately approximated based on their level of outputs in the past years, their allocated staffed beds and the teaching activity they undertake. We pointed out other reasons why this specification was followed rather than the usual production function type approach.

Since, the objective was to compare results of this chapter with that of the last two chapters - assuming no simultaneous equations problem, some discrepancies observed between the two were outlined. There were three general points compared with the preceding two chapters' results:. (i) the estimation procedure applied to the cost models, under the present condition produced estimated coefficients that are mainly reduced in magnitude for variables corresponding to inpatient services (BED_j, EXC_j and EXD_j), with few exceptions, (ii) The non-inpatient measuring variables (NIP_k) have coefficients increased in magnitude and (iii) An increment is observed for coefficients of teaching activity variables with respect to STDN.

Taking the total running costs models, the estimated coefficients provide point estimates of the marginal costs of the respective hospital resources or services provision. The results imply therefore, the marginal costs of inpatient services is lower than what was observed before, while that of non-inpatient type services may have been more costly.

Of particular interest is the last point (iii). We saw that the additional cost of the Scottish teaching hospitals may be due to training medical undergraduate students alone. The potential of the number of training nurses to generate additional cost of teaching was seen to be statistically limited, even though no change has been observed in magnitude of the coefficient corresponding it. Applying the same approach described in chapter 6, section 6.6, the present estimation indicated that, if major teaching hospitals assumed to have trained on the average 52 undergraduate medical students and 73 nurses, then their additional teaching costs may be estimated at about £2.15 million (=(25.19 x 51.5) + (10.31 x 72.5) + 108.7) x 1000) per hospital in 1985/86. This figure is about 16% of the major teaching hospitals' actual average total running costs. An increment of 1% over that approximated in section 6.6. Similarly, for the minor teaching hospitals we arrived at an additional teaching cost of about £1.95 million per hospital, which is 15.3% of the average actual total running costs of minor teaching type of hospitals. An increase of 3%. (see section 6.6). This is of course, ignoring their implied lower overhead costs, compared with the non-teaching hospitals. For the control type hospitals the estimated additional teaching costs is calculated at about £0.4 million per hospital, 6.7% of their average actual running costs in 1985/86, which is almost unchanged compared with that in section 6.6. [see section 6.6, Table 6.6.4]

Two-stage least squares estimation procedure was assumed from the beginning that to be the appropriate method for fitting cost component models, especially the staff cost components. This was applied in practice. However, a comparison of the cost component models fitted in Chapter 7 and the present one doesn't indicate greatly differing results in estimates of coefficients which are not covered while discussing the comparison of total running costs model between these two chapters. Some cost components were observed to be significantly affected by the hospitals' teaching load,. These components are almost the same as those discussed under Chapter 7.

What might differentiate the results given in chapters 6 and 7 from those in chapter 8 here are that, the estimated model parameters in the former two chapters seem to satisfy economical expectations, whereas we see from tables 8.2 to 8.5 that some coefficients are negative in magnitude and statistically significant. Such problems are limited with respect to the models fitted and presented in chapters 6 and 7.

Finally, we would like to point out that our attempted investigation of the simultaneous equations problem in hospital cost studies should be seen as a start but not as yielding conclusive evidence from the empirical results. Further work with the help of large samples of hospitals and more explicit specification of models of hospital outputs may be required to be sure about them.

TABLE 8.1 DESCRIPTIVE DATA OF LAGGED ENDOGENOUS VARIABLES (IN CAS_{-1})

Variables	Average Value	Coefficient of Variation
EXC DGH_{79}	449.0	374
EXC LS_{79} **	51.6	279
EXC SA_{79}	9.8	1616
EXC OBS_{79} **	74.7	508
EXC MI_{79} **	6.4	3236
EXC SC_{79}	76.1	546
EXD DGH_{79}	835.0	821
EXD LS_{79}	- 97.0	1413
EXD SA_{79}	175.0	693
EXD OBS_{79}	802.0	320
EXD MI_{79} **	3.0	27777
EXD SC_{79} **	139.0	8986
NIP $CNSL_{84}$	70093	132
NIP $ACDN_{84}$	12261	172
NIP $DPAT_{84}$	4497	152
NIP $DYCS_{84}$	122	164

Notes on the data:

(i) The source of data for 1978/79 does not include information from three hospitals, namely:

- Cross House hospital (A111)
- Inverclyde Royal hospital (C313)
- Rutherglen Maternity (G308)

These were estimated from a simple repression of 1978/79 data on 1985/86 via the remaining 78 hospitals out of the 81. Their recent values were used to estimate the past.

(ii) The source of data for 1983/84 does not classify non-inpatients into five groups. Only four classes are given called Outpatient, Accident and Emergency, Daypatient and Day Case patient. All four are used in the structural and reduced form equations . That means, $NIPCNSL_{84}$ denotes the outpatient class, which were thought to include Consultancy and Ancillary outpatient attendances.

(iii) Variables not used in the model fitting process are denoted (**)

(iv) The source of data are Scottish Health Service cost bulletin for 1983/84 and past research output from HO (1983) for 1978/79.

TABLE 8.2 MODELS FOR HOSPITAL TOTAL RUNNING COSTS AND ITS COMPONENTS: TWO-STAGE LEAST SQUARES ESTIMATION (2SLS)

Independent Variables	Dependent Variables: Total Running Costs	Total Staff Cost Component	Total Supply Cost Component
BED DGH	15.70 (5.08)	11.64 (5.09)	4.06 (3.38)
BED LS	9.27 (2.25)	7.84 (2.57)	1.43 (0.89)
BED SA	13.50 (1.24)	6.79 (0.85)	6.72 (1.59)
BED OBS	7.71 (1.53)	5.95 (1.59)	1.76 (0.90)
BED HI	8.64 (9.87)	6.60 (10.18)	2.05 (6.02)
BED SC	43.42 (3.57)	32.29 (3.58)	11.20 (2.37)
$\widetilde{\text{EXC DGH}}$	-0.1727 (-0.81)	-0.1703 (-1.07)	-0.0025 (-0.03)
$\widetilde{\text{EXC SA}}$	- 0.5548 (-0.65)	0.0895 (0.14)	-0.6439 (-1.95)
$\widetilde{\text{EXC SC}}$	0.8299 (1.70)	0.5364 (1.49)	0.2930 (1.55)
$\widetilde{\text{EXD DGH}}$	-0.0486 (-0.78)	-0.0339 (-0.73)	-0.0147 (-0.60)
$\widetilde{\text{EXD LS}}$	-0.1222 (-0.86)	-0.0736 (-0.70)	-0.0485 (-.0.88)
$\widetilde{\text{EXD SA}}$	0.4328 (1.45)	0.2416 (1.09)	0.1913 (1.65)
$\widetilde{\text{EXD OBS}}$	0.1173 (2.68)	0.0900 (2.78)	0.0274 (1.61)
$\widetilde{\text{NIP CNSL}}$	0.0463 (4.67)	0.0305 (3.97)	0.0158 (3.93)
$\widetilde{\text{NIP DPAT}}$	0.0549 (1.85)	0.0468 (2.13)	0.0082 (0.71)
$\widetilde{\text{NIP DYCS}}$	0.4973 (2.33)	0.3634 (2.30)	0.1340 (1.62)
TEACH STDN	25.19 (2.29)	17.80 (2.19)	7.38 (1.73)
TEACH NURS	10.31 (1.54)	8.27 (1.67)	2.04 (0.78)
TEACH MAJOR	108.70 (0.37)	93.9 (0.44)	14.50 (0.13)
TEACH MINOR	-1463.2 (-4.46)	-974.3 (-4.02)	-489.0 (-3.84)
CONSTANT	-103.20 (-0.61)	4.45 (0.04)	-107.98 (-1.66)
R^2	98.53	98.43	97.31
MSC	35.4	19.4	5.35

Note: Figures are in £000s.
T-ratios inside parentheis
~ indicates the corresponding variable has been predicted at the first stage of 2SLS.

Example: EXC DGH is the predicted form of EXC DGH.

TABLE 8.3 MODELS FITTED TO STAFF COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPITALS, (2SLS)

Independent Variables \ Dependent Variables	JRNMDCL	SNRMDCL	NRSTRND	NRSLRNR	NRSOTHR
BED DGH	0.5759 (2.41)	0.841 (1.51)	5.72 (6.31)	0.055 (0.69)	1.296 (2.11)
BED LS	0.0540 (0.17)	-0.154 (-0.21)	3.08 (2.55)	-0.078 (-0.74)	2.916 (3.57)
BED SA	1.1183 (1.34)	0.745 (0.38)	3.36 (1.06)	0.112 (0.40)	1.891 (0.88)
BED DBS	0.1472 (0.38)	-1.310 (-1.44)	7.42 (5.01)	0.221 (1.70)	1.231 (1.23)
BED MI	0.0807 (1.19)	0.119 (0.75)	3.09 (12.08)	-0.063 (-2.83)	1.466 (8.43)
BED SC	1.9500 (2.08)	3.832 (1.75)	10.08 (2.83)	-0.215 (-0.68)	3.199 (1.33)
EXC~DGH	0.0196 (1.19)	-0.0048(-0.13)	-0.0114(-0.18)	0.0090(1.64)	-0.018(-0.42)
EXC~SA	0.0421(0.64)	-0.0825(-0.54)	0.2229(0.90)	-0.0069(-0.32)	0.3053(1.8)
EXC~SC	0.0091(0.24)	0.2047(2.33)	0.2602(1.82)	0.0023(0.18)	-0.1060(-1.10)
EXD~DGH	0.0032(0.67)	-0.0166(-1.47)	0.0004(0.02)	0.0021(1.32)	0.0140(1.11)
EXD~LS	0.0141(1.29)	-0.0440(-1.72)	0.0050(0.12)	0.0033(0.90)	0.0442(1.57)
EXD~SA	-0.0189(-0.82)	0.0922(1.71)	-0.0538(-0.61)	0.0005(0.07)	-0.0262(-0.44)
EXD~OBS	0.0054(1.61)	0.0090(1.48)	0.0045(0.35)	0.0031(2.78)	0.0320(3.64)
NIP~CNSL	0.0011(1.35)	0.0090(4.93)	0.0017(0.57)	-0.0009(-3.40)	0.0005(0.26)
NIP~DPAT	0.0014(0.60)	0.0050(0.86)	0.0053(0.61)	0.0007(0.97)	0.0110(1.86)
NIP~DYCS	0.0259(1.58)	0.0560(1.46)	0.0604(0.97)	-0.0053(-0.96)	0.0748(1.77)
TEACH STDN	0.4996(0.59)	6.886(3.47)	1.996(0.62)	-0.2551(-0.90)	-0.354(-0.16)
TEACH NURS	0.5715(1.11)	2.359(1.96)	0.516(0.26)	6.405(37.14)	-2.091(-1.57)
TEACH MAJOR	-11.4400(-0.51)	24.34(0.47)	108.75(1.28)	5.419(0.72)	17.56(0.30)
TEACH MINOR	3.6300(0.14)	-171.89(-2.91)	-318.58(-3.31)	-10.595(-1.26)	-16.35(-0.25)
CONSTANT	-20.7500(-1.60)	22.49(0.74)	-30.19(-0.61)	7.001(1.62)	32.83(0.98)
R^2	94.60	97.30	97.13	99.40	89.45
MSE	0.21	1.15	3.05	0.02	1.40

<u>Note</u>: Figures are in £000s
T-ratios inside parenthesis
~ indicates the corresponding variable has been predicted at the first stage of 2SLS.

TABLE 8.3 (contd.) MODELS FITTED TO STAFF COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPITALS-(25LS)

Independent Variables	Dependent Variables						
	PRFTCHA	PRFTCHB	PRFTCWK	DMSANCL	ADMCLRC	TRDSMEN	OTHGRD
BED DGH	0.082 (0.30)	-0.089 (-0.49)	0.174 (3.10)	1.613 (2.80)	0.879 (3.62)	0.353 (1.74)	0.138 (2.75)
BED LS	0.510 (1.40)	-0.220 (-0.91)	0.131 (1.76)	1.394 (1.81)	0.156 (0.48)	0.019 (0.07)	0.041 (0.61)
BED SA	1.401 (1.46)	0.595 (1.11)	0.116 (0.59)	-2.443 (-1.21)	-0.277 (-0.33)	-0.007 (-0.01)	0.076 (0.43)
BED OBS	-1.311 (-2.93)	-0.629 (-2.13)	0.116 (1.27)	-0.278 (-0.29)	0.219 (0.55)	0.046 (0.14)	0.082 (1.00)
BED MI	0.092 (1.19)	-0.056 (-1.10)	0.079 (5.00)	1.187 (7.26)	0.276 (4.01)	0.290 (5.06)	0.041 (2.85)
BED S̃C	1.771 (1.64)	0.968 (1.36)	0.108 (0.49)	6.946 (3.06)	1.707 (1.79)	1.661 (2.09)	0.220 (1.11)
EX C̃DGH	-0.027 (-1.44)	-0.003 (-0.23)	0.006 (1.52)	-0.119 (-2.97)	-0.009 (-0.57)	-0.014 (-0.98)	0.002 (0.46)
EX C̃SA	-0.014 (-0.19)	-0.080 (-1.60)	-0.040 (-2.62)	-0.008 (-0.05)	-0.141 (-2.12)	-0.056 (-1.01)	-0.051 (-3.72)
EX C̃SC	0.003 (0.07)	0.037 (1.29)	-0.001 (-0.12)	0.091 (1.00)	0.099 (2.58)	-0.066 (-2.08)	0.004 (0.47)
EXD D̃GH	-0.007 (-1.29)	-0.003 (-0.87)	-0.001 (-0.88)	-0.016 (-1.40)	-0.007 (-1.32)	-0.002 (-0.39)	-0.001 (-1.05)
EXD L̃S	-0.023 (-1.81)	-0.013 (-1.59)	3.8E-5 (0.01)	-0.030 (-1.13)	-0.022 (-1.98)	-0.005 (-0.59)	-0.003 (-1.26)
EXD SA	0.065 (2.46)	0.003 (0.19)	0.010 (1.79)	0.058 (1.05)	0.056 (2.38)	0.044 (2.25)	0.011 (2.32)
EXD Õ̃BS	0.006 (1.62)	-0.003 (-1.06)	0.002 (2.45)	0.019 (2.39)	0.007 (2.02)	0.002 (0.69)	-0.0004 (-0.152)
NIP C̃NSL	0.004 (4.20)	0.002 (3.79)	0.0002 (1.12)	0.007 (3.74)	0.004 (4.81)	0.002 (2.81)	0.0004 (2.40)
NIP D̃PAT	0.006 (2.27)	-0.0001 (-0.07)	0.0005 (0.95)	0.011 (1.95)	0.003 (1.49)	-0.003 (-1.41)	0.0004 (0.77)
NIP D̃YCS	0.044 (2.37)	0.010 (0.81)	-0.005 (-1.30)	0.100 (2.40)	0.012 (0.73)	-0.002 (-0.18)	-0.004 (-1.04)
TEACH STDN	0.464 (0.48)	0.350 (0.54)	0.043 (0.22)	6.26 (3.22)	1.447 (1.67)	-0.238 (-0.33)	0.341 (1.90)
TEACH NURS	-0.514 (-0.86)	0.732 (1.87)	-0.235 (-1.93)	-0.26 (-0.21)	0.209 (0.40)	0.393 (0.90)	0.178 (1.63)
TEACH MAJOR	22.720 (0.88)	4.540 (0.27)	-4.181 (-0.79)	-95.18 (-1.75)	45.100 (1.97)	-17.55 (-0.92)	-6.202 (-1.31)
TEACH MINOR	-55.77 (-1.92)	-59.47 (-3.10)	-0.543 (-0.09)	-204.95 (-3.35)	-104.02 (-4.04)	-30.11 (-1.40)	-5.645 (-1.06)
CONSTANT	16.58 (1.11)	0.16 (0.02)	-1.12 (-0.37)	12.49 (0.40)	-10.29 (-0.78)	-19.81 (-1.80)	-4.93 (-1.80)
R^2	93.51	88.90	83.00	96.14	97.10	87.33	93.28
MSE	0.28	0.12	0.01	1.24	0.22	0.15	0.01

Note: Figures are in £000s.

T-ratios inside parenthesis

~ Indicate the corresponding variable has been predicted at the first stage of 25LS

TABLE 8.4 MODELS FITTED TO STAFF COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPIALS (2SLS)

Independent Variables Staff	Dependent variables Medical Staff (MEDICAL)	Nursing Staff (NURSING)	Professional & Technical Staff (PROFTCH)	Administrative & Other Clerical (ADMINISTRATIVE)
BED DGH	1.42 (2.18)	7.08 (6.60)	0.1670 (0.45)	2.98 (3.46)
BED LS	-0.10 (-0.12)	5.91 (4.14)	0.4220 (0.85)	1.61 (1.40)
BED SA	1.86 (0.82)	5.36 (1.42)	2.2130 (1.69)	-2.65 (-0.88)
BED OBS	-1.63 (-1.10)	8.87 (5.07)	-1.8241 (-3.00)	0.07 (0.05)
BED MI	0.20 (1.08)	4.49 (14.77)	0.1154 (1.09)	1.79 (7.35)
BED SC	5.78 (2.26)	13.07 (3.10)	2.8460 (1.94)	10.53 (3.11)
EXC~DGH	0.0148 (0.33)	-0.0202 (-0.27)	-0.0243 (-0.94)	-0.1406 (-2.35)
EXC~SA	-0.0405 (-0.23)	0.5212 (1.77)	-0.1342 (-1.31)	-0.2572 (-1.09)
EXC~SC	0.2138 (2.09)	0.1566 (0.93)	0.0389 (0.66)	0.1271 (0.94)
EXD~DGH	-0.0134 (-1.02)	0.0163 (0.75)	-0.0113 (-1.50)	-0.0256 (-1.46)
EXD~LS	-0.0299 (-1.00)	0.0525 (1.07)	-0.0358 (-2.09)	-0.0604 (-1.53)
EXD~SA	0.0734 (1.17)	-0.0795 (-0.77)	0.0780 (2.16)	0.1697 (2.04)
EXD~OBS	0.0171 (1.86)	0.0392 (2.58)	0.0055 (1.05)	0.0281 (2.30)
NIP~CNSL	0.0103 (4.71)	0.0003 (0.08)	0.0064 (5.16)	0.0135 (4.66)
NIP~DPAT	0.0060 (0.96)	0.0170 (1.65)	0.0064 (1.78)	0.0174 (2.10)
NIP~DYCS	0.0820 (1.83)	0.1299 (1.76)	0.0498 (1.93)	0.1018 (1.71)
TEACH STDN	7.39 (3.19)	1.39 (0.36)	0.8560 (0.65)	8.18 (2.66)
TEACH NURS	2.93 (2.08)	4.83 (2.08)	-0.0165 (-0.02)	0.52 (0.28)
TEACH MAJOR	12.90 (0.21)	131.7 (1.31)	23.0800 (0.66)	-73.83 (0.91)
TEACH MINOR	-168.26 (-2.44)	-345.5 (-3.04)	-115.7800 (-2.93)	-344.73 (-3.77)
CONSTANT	7.74 (0.05)	9.64 (0.17)	15.6200 (0.77)	-22.54 (-0.48)
R^2	97.79	98.13	95.03	97.04
MSE	1.57	4.27	0.51	2.76

Note: Figures in £000s
T-ratios inside parenthesis
~ indicates the corresponding variable has been predicted at the first stage of 2SLS.

TABLE 8.5 MODELS FITTED TO SUPPLY COST COMPONENTS OF TOTAL RUNNING COSTS OF HOSPITALS (2SL5)

Independent Variables \ Dependent Variables	PHARMACY	HEATING	POWER	PROFTCHS	EQUIPMENT	OTHERS
BED DGH	1.40 (1.82)	0.7234 (3.36)	0.1310 (1.10)	-0.1452 (-1.20)	0.6917 (2.17)	1.26 (3.10)
BED LS	-1.20 (-1.17)	0.0717 (0.27)	0.1256 (0.79)	-0.1501 (-0.93)	0.3540 (0.83)	2.22 (4.11)
BED SA	3.16 (1.17)	0.4949 (0.65)	-0.0438 (-0.10)	0.4596 (1.08)	2.3860 (2.13)	0.26 (0.19)
BED OBS	0.82 (0.65)	0.3933 (1.12)	0.0137 (0.07)	-0.6266 (-3.18)	0.3082 (0.59)	0.85 (1.28)
BED MI	0.03 (0.15)	0.3286 (5.39)	0.0967 (2.86)	0.0017 (0.05)	0.2732 (3.03)	1.31 (11.42)
BED~SC	2.59 (0.86)	1.2428 (1.47)	0.5537 (1.18)	1.1881 (2.50)	2.1760 (1.74)	3.45 (2.16)
EXC~DGH	0.0212 (0.40)	-0.0118 (-0.79)	-0.0044 (-0.53)	-0.0114 (-1.37)	0.0200 (0.95)	-0.0170 (-0.60)
EXC~SA	-0.2400 (-1.14)	0.0256 (0.43)	-0.0650 (-1.98)	-0.0303 (-0.91)	-0.1494 (-1.71)	-0.1848 (-1.66)
EXC~SC	0.0993 (0.82)	0.0158 (0.47)	0.0248 (1.32)	0.0149 (0.78)	0.1019 (2.03)	0.0363 (0.57)
EXD~DGH	0.0067 (0.43)	-0.0018 (-0.41)	-0.0035 (-1.44)	-0.0019 (-0.77)	-0.0020 (-0.30)	-0.0122 (-1.49)
EXD~LS	0.0033 (0.09)	-0.0009 (-0.10)	-0.0093 (-1.70)	-0.0071 (-1.28)	-0.0127 (-0.87)	-0.0218 (-1.17)
EXD~SA	-0.0084 (-0.11)	0.0104 (0.50)	0.0214 (1.85)	0.0046 (0.39)	0.0716 (2.32)	0.0918 (2.34)
EXD~OBS	0.0083 (0.76)	-0.0021 (-0.70)	0.0020 (1.17)	-0.0017 (-1.02)	0.0063 (1.39)	0.0147 (2.55)
NIP~CNSL	0.0058 (2.26)	0.0002 (0.25)	0.0010 (2.46)	0.0022 (5.42)	0.0024 (2.21)	0.0043 (3.13)
NIP~DPAT	0.0019 (0.26)	0.0014 (0.70)	0.0017 (1.50)	-0.0003 (-0.25)	0.0005 (0.17)	0.0029 (0.74)
NIP~DCYS	0.0758 (1.43)	-0.0001 (-0.01)	-0.0008 (-0.10)	0.0141 (16 9)	0.0163 (0.74)	0.0288 (1.03)
TEACH STDN	3.44 (1.26)	0.4847 (0.63)	1.25 (2.95)	0.2929 (0.68)	-0.3210 (-0.28)	2.23 (1.54)
TEACH NURS	2.64 (1.59)	0.1984 (0.43)	-0.09 (-0.33)	0.4715 (1.80)	-0.5924 (-0.86)	- 0.59 (-0.67)
TEACH MAJOR	10.69 (0.15)	1.0500 (0.05)	-20.46 (-1.82)	-11.5300 (-1.02)	10.7900 (0.36)	23.96 (0.63)
TEACH MINOR	-259.09 (-3.18)	-71.55 (-3.13)	-14.12 (-1.11)	-32.4300 (-2.53)	-34.1300 (-1.01)	-77.65 (-1.80)
CONSTANT	-46.37 (-1.11)	-5.48 (-0.47)	0.21 (0.03)	-5.3100 (-0.81)	-29,5800 (-1.71)	-21.46 (-0.97)
R^2	94.03	87.75	87.47	91.86	92.68	96.20
MSE	2.19	0.17	0.05	0.05	0.38	0.61

Note: Figures are in £000, T-ratios inside parenthesis.

~ Indicates the corresponding variable has been predicted at the first stage of 2SL5

CHAPTER 9

CONCLUSIONS

The objective of the present chapter is to outline a summary of concluding remarks from the empirical evidences obtained from the analysis of the 81 Scottish teaching and non-teaching hospitals data for the fiscal year 1985-86.

9.1 Comparison of raw data

The comparison of descriptive data made between teaching and non-teaching hospitals clearly indicated that generally the former group of hospitals in Scotland have on the average higher running costs, allocated staffed beds, patients treated (both inpatient and non-inpatient) and occupied bed-days. Also, the average number of medical students and trainee nurses are higher on those teaching hospitals than the non-teaching hospitals. Thus, it can be said that the teaching hospitals in Scotland take a larger share of the resources available for national health care and provide relatively the major part of the patient care and teaching services the community required.

However, this simple comparative evidence cannot fully show whether the higher level of average total running costs of teaching hospitals was due partly to their considerable teaching activity, so leading us to accept them as having higher costs of providing their respective services. In fact, there was evidence from the comparison of average unit costs (per case and per patient week) that the teaching hospitals seem to have higher cost per patient week but smaller cost per case in comparison to the non-teaching (control) hospitals (table 5.2). This was in marked contrast to the information presented in past similar studies, suggesting that both unit costs to be larger in teaching hospitals. This pattern holds in Scotland between major and minor teaching hospitals, the former set of hospitals seem to have larger values for both unit costs compared with the latter set (Tables 5.1-5.10). Therefore, we were led to consider the results of the models fitted for more concrete evidence.

9.2 Results of model estimation

Conclusions concerning the cost models fitted to the 81 Scottish hospitals analysed were outlined at the end of each chapters 6 to 8. The following points will therefore summarise them.

(i) Two assumptions were considered in estimating the cost functions and hence different estimates were produced in Chapters 6 and 7, assuming simultaneous equations problem, and in Chapter 8, where such problem was accepted to exist. A question arises here. Among the two estimated coefficients presented for each cost variable, one under each of the two assumptions, which one may be an appropriate one to use for practical purposes?, one can ask.

We put our judgment under three perspectives: first, there may be evidence for assuming the existence of the simultaneous equations problems in the hospital cost modelling. Therefore, the two-stage least squares procedures fitted models gives consistent estimats for coefficients of model variables. Second, even though this produced consistent estimated coefficients, the conclusions arrived at from both approaches are similar, [see section 8.4], and third, acceptance of specific assumptions would not necessarily produce appropriate results unless it also satisfies some a priori expectations. This last point of view was taken from models estimated under two-stage least squares procedure for some cost components, showing negative and significant coefficients, which were thought unlikely occurrences.

Thus, having these in mind, we preferred the results obtained under weighted least squares estimation, ignoring simultaneous equations problem for further consideration. The literature available to us in this respect in the last resort takes the same view, [see section 7.2]. However, further work is recommended with more detailed model specification, for variables representing hospital outputs which were assumed to be endogenous, than what we did.

Therefore, the conclusions to be drawn next refers to the results of models estimated for total running costs and its components without assuming simultaneous equation problems presented in Chapters 6 and 7.

(ii) Based on the Scottish hospitals data analysed the total running costs of hospitals were shown to be approximated as a linear function of factors indicating the levels of hospital resources and activities. Therefore, this also led us to comment on the absence of conclusive evidence about existence of economies or diseconomies of scale and scope effect in hospitals sector.

(iii) The set of independent variables finally selected (chapter 6, table 6.6.3) showed how the three main services given in the Scottish hospitals, i.e. inpatient care, non-inpatient care and teaching, might behave to determine structure of hospital costs. . Concerning inpatient care speciality services, running costs between hospitals appear to vary depending mainly on the scale of resources available, and the amount or number of staffed beds allocated in its specialities. The extent of using these beds, measured by the amount of patients discharged, seemed to be influential in determining running costs as far as the hospitals provided DGA, supra-area and Special Category speciality group services. Similarly, the level of occupied beds significantly affects hospital costs, if there were provided DGH, Longstay, Supra-Area and Obstetrics specialities inpatient services. The effect of outpatient services on hospital running costs was more emphasised through the amount of visits made to the Consultancy, Daycase and Daypatient hospital Outpatient Departments, (Table 6.6.3).

(iv) There was no potential evidence from the analysis suggesting that the marginal costs of providing these inpatient and non-inpatient health care services was higher (expensive) in teaching or non-teaching Scottish hospitals studied. (Section 6.6.1).

(v) Results from modelling total running costs supported the hypothesis that the level of teaching activity of hospitals may indeed contribute in generating additional running costs. Recalling chapters 6 and 7, we saw that according to the 81 Scottish hospitals data for 1985-86, an additional undergraduate student training might cost about £14,600 per year, but could reach up to £31,000 with 95% confidence level. By the same token an additional nurse in training might cost about £10,300 per year but could be as high as £23,000 under the same confidence level. We also saw that being a major teaching hospital, generated an extra overhead cost of about half a million pounds.

On the basis of recommendations made through the working party on Revenue and Resource Allocation (WPRA),(SHHD, 1977) teaching hospitals in Scotland have been known to receive an allowance to provide facilities for training undergraduate medical students and performing other similar duties. This allowance in 1985-86 prices was known to have been distributed at about £26,400 per student. It seems from this that our analysis does come up with supportive evidence for doing so, because compared with the above confidence limit reported for marginal cost of student, it could be seen that this figure (allowance) lies inside this limit.

However, from the analysis, training nurses and teaching status of hospitals were observed to influence total running costs. If the contention of the allowance made for Scottish hospitals at present by SHHD is only for training medical undergraduate students, it might need to be reassessed in the light of this evidence. Therefore, the analysis estimates that, on the basis of 1985-86 expenditure level, the major and minor teaching hospitals might require to allocate, respectively, about 14.9 per cent and 12.3 per cent of their total running costs on the average, annually. Furthermore, the non-teaching hospitals, particularly those used as control groups in this study, on the average might need to spend 6.4 per cent of their total running costs per annum for their teaching activity, obviously training nurses. (Table 6.6.3 and table 6.6.4).

(vi) It was further observed that the influence of location and management related factors differentiating Health Boards may not have direct impact on hospital total running cost. (Table 6.6.7).

(vii) The modelling components of total running costs of hospitals illustrated some evidences towards differing influences of the level of teaching activity of hospitals in generating additional teaching costs. Undergraduate medical student training was observed to generate additional medical staff and administrative staff costs, while the nurses in training apparently affected the costs spent in employment of medical and nursing staff. From the supply provision component, expenditure on supply of power was related to teaching load. Thus, according to the hospitals analysed, we might guess that 81 per cent of the marginal costs of undergraduate medical students seem to be attributable to the employing of hospital staff, while the remaining 19 per cent was for supply provisions. The corresponding breakdown was respectively about 87 per cent and 13 per cent for marginal costs of nurses training. The comparably higher overhead running costs of major teaching hospitals was also attributable to mainly (about 73%) their staff costs components. (section 7.3).

We think these observations made and the results of model estimates outlined could help in formulation and decision making, particularly related resource allocation between the various hospital services by those concerned. It could also assist for comparative purposes for future works on Scottish or other hospitals teaching costs.

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