HOSPITAL EFFICIENCY, MARGINAL COSTS AND HOSPITAL SYSTEMS PLANNING UNDER UNIVERSAL COVERAGE

CONCEPTS, METHODS AND POLICY

A Thesis

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by

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF ART

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CONCEPTS, METHODS AND POLICY

ABSTRACT

The thesis of this work is that hospital inpatient costs, expressed as average cost per hospital case, are affected by both policy and environment in a system in which individual hospital costs differ due to differences in casemix, in efficiency, and in patient characteristics. Further, it asserts that there are possibilities to manipulate costs favourably through policy analysis and application.

This is an exploratory work which concentrates on identifying key economic parameters and assaying their policy implications using standard techniques of economic analysis. The theory pertaining to hospital economic behaviour and to relationships between cost and significant hospital variables is discussed. More attention, however, is paid to methodological problems, particularly multicollinearity among the variables.

The results suggest that long run marginal costs of hospitals are not significantly different from average costs and, therefore, that size of hospitals is only an important determinant of cost insofar as it promotes more efficient utilization. Short run marginal costs, however, are well below average costs at all observed levels of utilization. Therefore, within the hospital sector, at least, the best policy measures that could be taken by politicians and health care

administrators to improve efficiency would be those which aimed at optimum utilization of existing capacity rather than those which aim at the creation of larger central facilities in the hope of achieving reduced costs per case.

CHAPTER 1

INTRODUCTION

In the 1960s and early 1970s health care costs in most countries in the Western world climbed dramatically. The increases were not merely in line with the rate of inflation, but, in most cases, outpaced the general increase in prices. For example, in Britain costs rose at an average annual rate of 7.0 per cent during 1961-1965. (Abel-Smith, 1967; Anderson, 1972). Today's popular wisdom would suggest that countries such as Britain, where health care is not only financed, but largely organized by government, would be more prone to cost escalation. However both the United States, where the private and voluntary sectors are large, and Canada, where government acts as a fiscal intermediary between patients and providers, have seen similar if not greater cost increases.

Between 1960 and 1974 total Canadian health care costs, paid by both consumers and government rose from $2.1 billion to $8.2 billion (current dollars) an average annual increase of 11 per cent. By way of comparison, U.S. costs rose from $27 billion to $99 billion during the same period, an average annual increase of 10.5 per cent. About 80 per cent of the Canadian costs, by 1973, were met by government programs; the proportion was considerably less in the U.S. where private insurance still finances a large portion of care provided.[1]

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[1] Statistical material pertaining to historical costs in Canada and the U.S. is derived from: Expenditures on Personal Health Care in Canada, Dept. of National Health and Welfare, Research and Statistics Directorate, Ottawa, 1975.

Some of this cost increase is accounted for by population increases. Still, during 1960-1975 costs in Canada rose from $118 per capita to $572 per capita; about 9.2 per cent per year. The comparable U.S. figures were $149 and $472 (or 9.3 per cent per year). During this period Canada's average annual rate of inflation (Consumer Price Index) was estimated at 3.5 per cent (Statistics Canada, Prices and Price Indices). The Health Care price index increased at an average annual rate of 4.3 per cent during the same period (Statistics Canada Cansim Data Retrieval).

Increases of this magnitude represent a real relative diversion of national product. In 1960 Canadians spent 5.5 per cent of Gross National Product on health care. By 1975 the proportion was 6.9 per cent. Three personal health care items, hospital costs, physician and dentist costs and drug costs represent about 75 per cent of overall health care cost and, by 1973, about 5.3 per cent of Canada's G.N.P.

The experience in Manitoba paralleled that of the nation. Manitoba expenditures on the three personal health care items mentioned above rose from $77 million in 1960 to $264 million by 1973 -- or to 6.5 per cent of total personal income. Per capita costs went from $86 to $264; about 9.1 per cent per year. The 1973 Manitoba per capita cost was somewhat less than Ontario's ($298) and somewhat higher than Saskatchewan's ($229).

By 1973, considerable concern had been demonstrated by both the industry and government about "runaway" health costs. Blueprints for reorganization of health care, intended principally to control cost escalation, had appeared in several provinces, Manitoba included, and at the national level. Some not inconsiderable efforts were being devoted to attempts to implement some aspects of cost control strategy.

For example, the 1970 Federal Task Forces on the cost of Health Services recommended both institutional changes to provide the incentives to use resources more efficiently and technological changes which would alter the mechanisms of health care delivery (Canada, 1970). These recommendations were echoed in the 1970 Economic Council of Canada Review which also wanted to provide incentives for the substitution of less costly personnel for highly trained professionals, where appropriate, thereby improving the efficiency with which care is delivered.

Also in 1970 Canada's two largest provinces issued major reports on the state of the health care sector. Ontario's Committee on the Healing Arts was primarily concerned with educational and regulatory arrangements affecting the health disciplines, but also considered economics to be within its purview (Ontario, 1970). The Committee pointed to increasing sophistication in the care available, the growing complexity of skills and equipment to provide it, and the peculiar economics of the health care sector in which market price allocation plays only a limited role, as key causes of cost escalation. The Committee recommended experimentation with new forms of organization and systematic evaluation in order to improve the system's efficacy and efficiency.

Quebec's Castonguay Report (1970) was issued in the same year. This report, too, focused on organization as the key to efficiency and control of costs. With regard to hospital and other institutional costs it recommended that ambulatory health care centres undertake greater responsibilities, that the numbers of acute care hospital beds be reduced and that preventive care services be augmented.

By 1972 concern with rising health care costs and the enormity of effort apparently required to check them had reached the proportions of a national debate. In that year, the landmark "Hastings Report" appeared (Hastings et.al. 1972). It cited duplication, lack of co-ordination and inappropriate incentives to providers as principal causes of rising health care costs. Its principal recommendation was that health services be integrated at the local level under a single jurisdiction: the "Community Health Centre" concept. Such an approach, Hastings claimed, would direct patients to the appropriate service, avoid unnecessary hospitalizations and excessive use of curative services, and ensure utilization of appropriate preventive care and substitution of lower cost for higher cost services where appropriate.

While the perspective of the economist was not lacking in Hastings' report, a rigorous analytical framework based on acceptable behavioural and technological postulates was. Critics have attacked the Hastings document because it failed to develop a model explaining why a publicly funded health centre, any more than a hospital, should seek objectives which are compatible with cost minimization and appropriate resource utilization (see, for example, Migué and Bélanger, 1972).

Manitoba's 1972 White Paper on Health Policy (Manitoba, 1972) anticipated and enlarged on the recommendations of the "Hastings

Report". It focused on integration and administrative linkage at the local level.

Despite the flurry of attention directed at health care costs in the early 1970s, the rate of increase was not slowed. Health care costs continued their rapid escalation until 1976 or 1977. This was possibly due to the economic expansion and associated increases in government revenues occurring during 1972-1975 throughout Canada. In most quarters a basic belief remained that while the health care cost situation was of some concern, it was not yet critical and governments could still provide the wherewithal to fund ever-growing health care budgets. Cost increases accelerated. The average annual rate of cost increase for services funded by the Manitoba Health Services Commission (M.H.S.C.) was 20 per cent per year between 1973 and 1976 -- or 10.3 per cent net of inflation (M.H.S.C. Annual Reports, 1973, 1977; Statistics Canada, Prices and Price Indices) as measured by the Consumer Price Index.

Throughout both the earlier period (1960-1973) and the latter period, hospital costs have escalated more rapidly than other health care costs. Their contribution was significant; in Manitoba, hospitals account for 63 per cent of all health care costs funded by M.H.S.C. During 1960-1973 hospital expenditures increased at an average annual rate of 11 per cent (compared to 9.6 per cent for the total) and stood at $166 million by 1973.

The rate of hospital cost inflation also accelerated during the mid-1970s. From 1973 to 1976 it was 20.7 per cent per year (or 11.0 per cent, netting out increases in the consumer price index). This compared with average annual increases in physician costs of 10.6 per cent and in administrative costs of 14.2 per cent (M.H.S.C. Annual Reports).

TABLE 1-1

HEALTH CARE COSTS IN MANITOBA BY COMPONENT: 1973, AND RATE OF INCREASE, 1960-1973

Component	Total Cost (Millions of Dollars)	Per Cent of Total Cost	Average Annual Rate of Increase 1960-1973 (%)
Personal Health Care	264	100	9.6
All Hospitals	166	63	11.0
Physicians	64	24	9.4
Dentists	16	6	8.2
Drugs	19	7	6.9

Source: Health and Welfare, Canada: National Health Expenditures in Canada 1960-1973.

Economists and others have sought to understand the reasons for rapid escalation of hospital costs. Some are simple and straightforward. For example, populations have increased and the population has aged. These two factors have no doubt accounted for some of the increase. Yet, in Manitoba the population increase between 1960 and the present has been less than one per cent per year. The aging of the population is a long run process and its implications are slight on a year-to-year basis. In 1961 the proportion of Manitoba's population which was aged 65 years or more was 9.0 per cent (1961 Census of Canada). By 1976 this had increased to only 10.2 per cent (M.H.S.C. 1976 Statistical Supplement).

If the issue of hospital costs is approached through a basic accounting framework it is apparent that changes in cost must be due to either changes in price and/or changes in quantity of service used. Changes in quantity used can be generally related to changes in the health condition of the population (morbidity or "objective" need) (Fuchs, 1975) and to predisposing and enabling variables which affect demand for service (Wirick and Barlow, 1964) especially the incentives to use or not to use services facing consumers and providers (Berki, 1972; M. Feldstein, 1971; Klarman, 1970; McNerney, 1962; Sorkin, 1975; Migué and Bélanger, 1972). Changes in price depend on the prices of inputs into hospital care (e.g., doctors, nurses, hospitals' lab and x-ray equipment) and the productivity of these inputs. Technology is a variable with more complex effects. It can improve productivity, thereby reducing prices; or it can introduce new processes, stimulating demand and increasing both prices and quantities consumed as well as increasing the derived demand for complementary factors of production (Fuchs, 1975; Klarman, 1974; Russell, 1976; Russell and Burke, 1975; Blomquist, 1979).

Changes over time in quality of hospital care or intensity of service appear to have played a particularly important role in hospital cost increases (M. Feldstein, 1971; Elnicki, 1974; Salkever, 1972). The extent of these changes can be appreciated by studying changes which have taken place in labour inputs to hospital care in recent years. Similar if not greater increases have occurred in utilization of other factors of production, but labour absorbing 75 to 80 per cent of Canadian hospital costs (Soderstrom, 1978) can be taken as representative. As Table 1-2 shows, paid hours per patient day increased by more than 2.6 per cent per year in Manitoba hospitals between 1969 and 1976. These increases can reflect either productivity declines or the changing nature of the hospital product.

TABLE 1-2

AVERAGE ANNUAL INCREASE IN PAID HOURS PER PATIENT DAY PUBLIC GENERAL HOSPITALS IN CANADA AND MANITOBA 1969-1976

	Canada	Manitoba
	per cent annual increase	
Total Hospitals	1.21	2.64
Nursing Divisions	1.13	1.52
Diagnostic and Therapeutic Divisions	5.78	8.93
Administration and Support Divisions	0.65	4.91

Source: Statistics Canada 83-212, 83-217.

Since 1976 much of the furore surrounding health cost increases in general and hospital cost increases in particular has subsided. Annual expenditure increases have fallen from the twenty per cent range to below five per cent (M.H.S.C. Annual Reports) -- a rate which is well below general price inflation. Between fiscal 1978 and 1979 hospital cost increases were drastically cut back, to only three per cent. The reduction in escalation has, no doubt, been associated with more stringent government control over increases of hospital budgets; the actual economic path of causation is, however, difficult to trace. One possibility is that rising real prices to the user (due to lower quality and longer queues for service) reduced demand. Another is that, relative to hospital budgets, the cost of health care resources increased prompting economizing measures, including reduced output.

The success of governments in controlling costs without apparent significant harm to either the health status of the population or to the functioning of the hospitals raises questions as interesting as the original cost spiral which occurred during a period of more relaxed government attitudes. In both cases they are: what are the peculiar economics of the production of health services? What are the behavioural attributes of hospitals that underlie these economics; and what are the implications for hospital cost performance and government policy?

A number of behavioural reasons have been postulated for rising health costs. A growing population with larger incomes, more education, greater sophistication and better access to care fostered by universal hospital and medical coverage is one group of reasons. Higher priority for health matters in both public and private decisions may have led to a view that health expenditures have greater utility than was previously believed (Grossman, 1972). The greater utility, as expressed in the decisions of the 1960s and early 1970s to opt for universal medicare and a major building program for hospitals and medical schools, has led one writer (Evans) to suggest that greater utilization, quality and costs are due to increased production of health personnel and facilities in earlier years. These personnel have some influence over the extent of their employment and have persuaded society to opt for more and better health care (Migué and Bélanger, 1972; Illich, 1976).

There is a wage "catch-up" theory that argues that much of hospital cost increases are due to the larger than normal wage increases in the recent past which have brought the earnings of lower-echelon health care workers into line with those of workers in other industries (Blomquist, 1979; Sorkin, 1975).

However, the conventional wisdom used to explain rising costs is the structure of economic incentives facing both producers and consumers of health care. Consumers do not see a price at the point of service and may consequently demand more care than they would were they facing a price that reflected true costs. Even if prices reflected marginal social costs, however, the consumer's inability to evaluate the utility of care may result in "excessive" demand (Migué and Bélanger, 1972). Health care providers in general and hospitals in particular exist in an economic environment and pursue objective functions which do not promote efficiency (Berki, 1972; Feldstein, 1971; Arrow, 1963; Cyert, 1972; Davis, 1972; Dowling, 1976; Lee, 1971; Newhouse, 1970; Pauly, 1973).

The purpose of the present work is not to examine the behavioural aspects underlying the economics of hospital care, but rather to indicate what the implications of the present behavioural and funding environment are for hospital cost performance and to suggest government policy that could improve that performance. Most current models of hospital economic behaviour suggest that hospital management is not required to be efficient, that some of the hospital budget is discretionary. That being the case, it would be expected that variation in costs among hospitals would not be completely explained by the usual determinants such as size, product variation and role. The thesis of this work is that both overall and individual hospital costs can be affected by managerial performance and government policy as well as environmental givens such as casemix and patient or provider characteristics. The approach used in developing the thesis will be a standard cost estimation using regression analysis on a number of significant factors and using the 1977 data from 80 Manitoba acute care hospitals as a sample.

While the method of analysis itself is straightforward, both the theoretical framework and the details of methodology continue to pose problems for researchers in this field. Consequently, this work will first place the analysis in its wider theoretical framework. An understanding of models of hospital economic behaviour is useful background to the analysis. Second, some of the major methodological concerns will be reviewed. Finally the results of the model are reviewed and placed in a policy context.

Chapter 2 reviews some of the recently developed economic models of hospitals and then proceeds to assess results and analytical techniques used in previous hospital cost analyses. Chapter 3 explains the model used in the present analysis, reviews concepts and controversies associated with the selection of variables, and discusses the major methodological problems associated with estimating the results. Chapter 4 presents the results and discusses economic and policy implications. Finally, Chapter 5 reviews the model and presents suggestions for improvement and refinement.

CHAPTER 2

A REVIEW OF SOME THEORIES OF HOSPITAL BEHAVIOUR AND COST IMPLICATIONS

Although health matters have engaged the attention of economists since at least the 1930s, the beginnings of health economics as a separate discipline do not appear to have occurred until about 1960. Kenneth Arrow's landmark article "Uncertainty and the Welfare Economics of Medical Care" appeared in 1963; McNerney's volume Hospital and Medical Economics in 1962. Interest in the subject quickened and articles and anthologies began to emerge at a more rapid pace. Klarman (1965) and Mushkin (1964) were two early and seminal contributors.

Although health economics has come a long way towards status as a discipline since that time, it will not come as a surprise that fifteen or twenty years is still insufficient time to answer some of the key questions economists have been asking. Many of these questions centre around what appears to many observers to be an obvious characteristic, that the provision of health care is an inefficient process. After all, it is argued, health care costs, and hospital costs in particular, increased consistently during the 1960s and 1970s at a rate more rapid -- and sometimes much more rapid -- than the general level of prices. In most of the western, industrialized world, health care is largely funded either directly by government or by some other third party payor such as a private insurance company. Many individuals feel that government involvement in itself is an inducement to inefficiency. The health industry is insulated from the market system of rewards and admonitions, and neither the consumer nor the provider has great incentive to use resources efficiently.

Ro (1977) has clearly articulated the health care industry's central problem of efficiency. He recognizes that health care is not the only sector or industry in which market imperfection tolerates provider inefficiency and may, under certain circumstances, lead to income redistribution from consumers to providers. However, he says:

> "....the exceptional thing about the health care industry is the matching of an imperfect market condition, in which there is no mechanism to ensure provider efficiency, with the condition of discrepancies between the price received by suppliers and that paid by consumers out of pocket. The co-existence of two anomalies creates further allocative problems since the health care sector is the type of service industry whose productivity lags behind that of the manufacturing industry under even the best of conditions." (p.7)

Ro goes on to point out that in an economy's sectors of less rapidly rising productivity either outputs will vanish (because relative prices must rise) or their cost increases continuously. If demand is inelastic or third party payments sustain demand in the face of rising output, expansion of output with cost increases is possible and indeed highly likely. These productivity effects have been described in detail with respect to service industries by Fabricant (1962) and Fuchs and Wilburn (1967).

Lags in technical productivity growth explain price increases, but do not necessarily imply inefficiency nor do they imply that relatively simple manoeuvres of government policy could favourably affect costs. The existence of institutional arrangements which do not ensure efficiency do not in themselves guarantee inefficiency. What is required is an explicit model of hospital behaviour within the institutional framework attributed by Ro, and a means of testing that model.

Discussion of such a model or models provides a useful backdrop to the present analysis. But before proceeding to that discussion it is useful to relate it to the objectives of this analysis: understanding the variations in the cost of hospital care among Manitoba acute care hospitals and applying that understanding to policy formulation. Inefficient operation is, in fact, one among several possible explanatory variables. According to Pauly (1970):

> "....the major evidence /of inefficiency/ appears to be the wide range of unit costs, of output and of the components of output experienced by hospitals which appear to be otherwise similar in terms of the input prices they face and the quality of output they produce."

Thus, a review of a few pertinent theories of hospital economic behaviour, as well as a review of earlier work which attempted to explain hospital cost variation is merited.

HOSPITAL OBJECTIVE FUNCTIONS AND THEIR EFFECT ON COSTS AND OUTPUT

Having asserted that average cost variability is the major empirical evidence of hospital technical inefficiency, Pauly goes on to argue that the presence of "slack" is neither a necessary nor a sufficient condition to explain variability in average costs. He suggests that high cost hospitals do not necessarily have more slack (even after adjusting for factors beyond the hospital's control); but may be the victims of "differences in the productivity of specialized resources, particularly administration". This is a rather fine line to draw, since, presumably, technical inefficiency can include lack of productivity of specialized (or any other) inputs.

However, Pauly's argument that there existed at the time he wrote (1970) no empirically verifiable model of hospital behaviour carries a little more weight. He suggests that as long as the hospital is a maximizer of either profit or "constrained" output, its tendency would be to use inputs in the technically most efficient way to produce the maximum possible output. However, as is discussed in greater detail in Chapter 3, hospital output is an elusive concept; third party payors, particularly in the United States have caused themselves considerable grief by treating inputs such as laboratory tests, x-rays, or even nursing hours, as output. Reimbursement schemes based on such "output" may result in their efficient production -- indeed in their "maximization" -- but are hardly calculated to "produce" a hospital case efficiently.

NET REVENUE MAXIMIZATION

A simple intuitive look at hospital behaviour would suggest that there is enough in the incentive structure facing hospitals to at least allow for slack. Suppose that a hospital is non-profit, as are more than 85 per cent of U.S. hospitals (Berry, 1973) and virtually all Canadian hospitals (Soderstrom, 1978). Suppose, also, that for whatever reason, the hospital is a profit (or net revenue) maximizer. Perhaps net revenue is used to acquire sophisticated equipment or to expand the hospital. A board of trustees or even common practice may require the establishment of a rest account to meet contingencies or to enable the procurement of more prestigious technology or medical staff.

In most North American communities hospitals are monopolists, or at the very best monopolistic competitors. Thus the net-revenue maximizing non-profit hospital may earn more than normal profits. If these profits are all placed into hospital facilities, it is easy to see how allocative inefficiencies may arise.[1] Technical inefficiencies must arise from a different process.

Recent work in the area of theory of the firm (for example, Cyert and Hedrick, 1972) has argued that even profit maximizing firms in a monopolistic or oligopolistic setting have more flexibility in their objectives than the firms in the textbook cases of pure competition. They suggest that the objectives of shareholders (in the case of hospitals, the public, or trustees) differ from those of management (administrators). In a setting of imperfect competition, managers can allocate some of the firms' resources to preferred expenses. These allocations will, of course, affect output, price and cost. Some of the suggested objectives can readily be seen to be compatible with technical inefficiency and many will appear (intuitively) to apply to hospitals: size of firm, growth, power, security, prestige and professional excellence. This type of a behavioural model is consistent with virtually any maximand of a hospital, but is most easily viewed in the context of a net revenue maximizing facility.

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[1] If patients are unable to evaluate the utility of hospital care (an assumption which is not difficult to maintain) then hospitals and doctors will produce more hospital cases than would otherwise be optimal. Acting as self-interested agents for the patient, they would, naturally recommend greater utilization of hospital care. See for example, Monsma (1970) or Densen et.al. (1962).

If managerial discretion has little or no weight in a net revenue maximizer's objective function, the result will be efficient production of output. Efficiency from a social perspective will then depend on how the hospital measures output. The elusiveness of this concept, as stated earlier means that even net revenue maximizers may have incentives toward inefficiency.[1]

OUTPUT MAXIMIZATION

Output maximization may occur in a non-profit organization where production itself has become an ultimate goal, since the organization purports to "serve the people". The implications of this model are fairly straightforward. Consumption or allocative efficiency may not be achieved, but this model implies the pursuit of technical efficiency. Since the hospital wishes to produce the maximum possible output it will be motivated to minimize unit production costs and prices.[2]

This model takes its immediate departure from more general quantity maximizing models of the firm and has been sometimes expressed with a quality of care constraint. P. Feldstein (1968) treats quality

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[1] Gordon Tullock (1970) argues that managerial discretion expenditures are the result of imperfect supervision by shareholders. To eliminate them, however, may require the expenditure of more resources than are being consumed by the discretionary expenditures.

[2] Here prices may be viewed as either unit prices paid by consumers or third party payors, regardless of the definition of output used. They may also be regarded as the lump sum budget received from government divided by production. In the later case "price" is clearly minimized by maximizing production and vice versa.

as a given. Both he and Brown (1970) view the doctor as an independent agent of the patient. The doctor, therefore, influences demand by purchasing resources on behalf of his client, but it is the hospital administrator who attempts to maximize quantity. Presumably the choice of output maximization as a goal is determined by the view of administrators and the public that hospital care is a 'merit' good. Thus, although not recognized by these writers, this maximand is probably related to 'prestige' concerns (see below).

One writer who does recognize the connection is Reder (1965). He has suggested that the maximand of a hospital is output, expressed as patients treated per unit of time and weighted according to the professional prestige accorded to the physician by each case. This in turn implies a trade-off between quality and quantity of care.

Long (1964) has argued that at any given time, quality is invariate; that is, it represents a constraint. However, above any observed level of quality there is a trade-off between quality and quantity. This, strictly speaking, is a departure from the output maximization in model in one respect: the impact on price (cost) is indeterminate. Output will be determined by the nature of the utility function incorporating quality and quantity. However, because of the difficulty in objectively specifying quality, the costs (over and above those determined by a strict output maximizing model) may be a mixture of real product "improvement" and apparent technical inefficiency.

Rice (1966) also argued that trade-offs exist; however, the basic analytics of his model are strictly related to output maximization. In a simple classical exposition, the intersection of total cost and total revenue curves determines output where no surplus is required. If a surplus is required to finance expansion, output is somewhat less (assuming the total revenue curve cuts the total cost curve from above). The provision of a subsidy or the existence of a maximum allowable deficit increases equilibrium output and the effect on costs is, of course, determined by the slope of the total cost curve.

MAXIMIZATION OF A FUNCTION OF OUTPUT AND QUALITY

Newhouse (1970) incorporates quality much more explicitly into his model. The hospital administration is assumed to have some collective trade-off between quality and quantity which can be represented by an indifference mapping. This assumption minimizes or neglects the conflicts that can exist between, say, administrators and physicians or administrators and trustees.

Of greater interest, however, is Newhouse's development of his production possibility surface. A given quality (as expressed by a vector of characteristics) will lead to a given average cost curve and will also be associated with a specific downward sloping demand curve. These curves uniquely determine output and average cost. If the same quality can be achieved at lower cost (e.g., the average cost curve shifts downwards) the output maximizing criterion comes into play and output will expand. Conversely, if a higher quality is achievable at the same cost, demand increases, thereby leading to an increase in output. Given quality and cost, administrators will seek to maximize output.

Shifts in quality which also result in changes in cost will produce a new equilibrium. The locus of these equilibria represents the technical trade-off curve. In elegant classical micro-economic form, the equilibrium point is the tangency of the technical trade-off curve and the indifference mapping.

Newhouse argues that this model produces technical efficiency; its departure from optimality is in terms of allocative efficiency. Technical efficiency will be achieved because of the output maximizing criteria. Any cost differences between hospitals producing the same output are, ipso facto, due to quality differences. In fact, Newhouse measures quality by observed cost. The process fails to recognize that since quality may be determined by other than competitive factors, so-called quality differences may reflect no more than over-servicing or inappropriate factor utilization.

M. Feldstein's model of hospital behaviour (1970) was developed to explain the phenomenon of rapid hospital cost inflation and regional hospital cost variation. Feldstein's model and the empirical analysis based on that model suggest that hospital cost inflation can be explained by a dynamic short-term price adjustment to excess demand, with factor price increases being the result, rather than the cause of inflation.

Feldstein's is another model that incorporates both quality and quantity of service into the hospital management's utility function. Exogenous increases in demand raise the equilibrating price of service. In the short run hospital capacity is fixed; therefore the hospital's response is to increase quality by increasing both quantity and quality of inputs, even as output remains constant. In the long run, the hospital administration has the option of increasing capacity (and therefore output) or increasing quality of care, or some combination of the two. This it does according to the same set of indifference trade-off curves as described by Newhouse.

Feldstein's complete model included twelve equations describing demand, price adjustment, cost components and capacity increases. He estimated only the first two of these components: demand and price adjustment systems. The parameter estimates bore out his first hypothesis, that increased demand results, in the short run, in increases in prices with virtually no increases in output. This empirical evidence, however, says nothing about changes in quality. The effect on efficiency of such a model is clearly identical with Newhouse's.

In conclusion, maximization of some function which includes both quality and quantity can lead to inefficiencies where quality is defined by the administration or the physician, since it is quite conceivable that rational consumer, faced with paying his own bill, would opt for lower quality and lower cost. That hospitals are maximizers of output alone does not seem to accord with reality; further, this hypothesis would not explain significant hospital cost variation. However, it is useful since it may explain the behaviour of some hospitals (e.g., the more efficient hospitals) within the framework of a more general theory.

CONSPICUOUS PRODUCTION - PRESTIGE

Maw Lin Lee's model (1971) eliminates quantity from the objective function and focuses entirely on quality and related attributes. Because these attributes are minimally, if at all, related to output, the effect of this behavioural assumption on output is indeterminate. In fact, it appears that output must be specified exogenously and is not related to a hospital's size, "prices" or quality of care. The hospital's maximand is status or prestige and these are determined by the availability of expensive and highly specialized equipment and personnel, achieved in effect, by increasing the supply and cost of inputs to the production process.

According to Lee, this acquisition of inputs often takes place without adequate regard for the value of output that will result. This is facilitated by public confidence in the hospital as a non-profit agency concerned with life and death matters, by the existence of third party intermediaries who pay the bulk of hospital costs yet are not motivated strongly to question them and finally by the practice of average cost pricing in cost or charge based hospitals. This latter practice spreads the cost of a new service or piece of equipment over a wide range of hospital services.

The hospital administrator seeks to maximize the hospital's status relative to other hospitals it perceives as a "peer group". This maximization is done subject to a revenue constraint. The determinants of the revenue constraint are not, however, explicit, since output is indeterminate within the context of the model. This in fact is the weakest part of the model since its pure (or average cost) is determined by the cost of inputs required for status and production purposes divided by an exogenously determined output. Output and price are related by a highly inelastic demand curve which, in theory, permits price to rise without limit. This, as Jacobs (1974) points out, is the weakest aspect of Lee's model.

From the point of view of theory development, however, the model is useful, since it draws from observations and predicts a result that has been hypothesized on other grounds -- hospital inefficiency. It is clear from the assumptions of the model that the hospital will use more inputs than required, that it will maintain idle capacities and that its cost per unit will be higher than those of an output maximizer or a constrained output maximizer.

MAXIMIZATION OF PHYSICIAN INCOMES

Apart from Reder's, none of the articles discussed above take any conscious consideration of different actors within the hospital structure. One article that emphasizes the role of the physicians in a model of hospital behaviour is the result of work by Pauly and Redisch (1973). They assume that the hospital's medical staff has control of the hospital and operates it in such a way as to maximize net income per member of the physician staff.

Pauly and Redisch's analysis concentrates on equilibrium in the market for physicians' services under conditions of closed staffing, with and without discriminatory sharing and open staffing. Generally, co-operative ventures seeking to maximize income per associate will hire all other factors of production up to the point that their marginal revenue equals their price. Under a closed staff policy, this optimization rule also holds true for physicians. In the case of discriminatory sharing, the hospital will maximize the same objective function as a profit maximizing firm.

Pauly and Redisch do not deal explicitly with the effects of this type of motivation on output. However, other writers dealing with similarly defined objective functions have (Ward, 1958; Vanek, 1970). In general, it can be shown that if physicians' wages as determined in the community are identical with the maximum income determined by Pauly's closed staff model, then the number of physicians employed will be identical in profit maximizing and co-operative firms. The situation will differ from the classical profit maximizing situation whenever the market wage does not equal the maximum average physician income. If a profit maximizing hospital in identical circumstances is making a profit, this implies a market wage that is less than the equilibrium wage in the co-operative. The analagous profit-maximizer would hire more physicians and use less capital and other inputs to produce the same output. Classical indifference curve analysis will show that the closed staff model is less efficient technically when market wages and maximum average closed staff income diverge.

In the short run, such differential could be maintained. For example, if average physician earnings in a closed system exceeded the market wage, the difference could be maintained by refusal to provide privileges to other physicians. In the long run, however, given competitive conditions in the overall hospital industry, new hospitals would be established by those physicians unable to secure privileges in the closed staff hospitals. Thus, the tendency would be for average closed staff incomes to approximate the market wage in the long run. Thus, cost and output of a hospital dominated by the physicians co-operative type of objective function will be equivalent to that of a profit maximizing firm. However, long run equivalence does not preclude continual periods of short-run maladjustment.

Moreover, the more usual circumstances in which a hospital finds itself are not those of perfect competition. Vanek has shown that a co-operative of this type does not exploit a monopoly as efficiently as a capitalist producer. This is because a co-operative monopoly will not respond to changes in demand by altering its production function as a capitalist monopoly will do in order to maximize supernormal profits.

Finally, as Pauly and Redisch note, the system is open to a breakdown in co-operation which will tend to raise the amount of non-physician inputs employed above the equilibrium amount. Moreover, when third party payments are the rule, the discipline of the market is lost, hospital prices can rise as physicians hire more and more inputs to produce higher quality output at greater cost and yielding greater incomes to themselves.

Thus, the Pauly-Redisch model of the hospital as a physicians co-operative can theoretically, under the right conditions, yield efficiently produced output. Under certain conditions, however, (e.g., degree of monoploy and third party payments) this model is systematically biased towards technically inefficient operation.

THE MULTI-FUNCTION MODEL

More sophisticated models recognize that the hospital has several constituencies: the public, patients, trustees, physicians, and other staff. Each of these constituencies has its own objectives; sometimes these objectives are in conflict, sometimes they reinforce one another. Minimization of conflict among competing objectives may be one major goal of hospital administration. This would explain the advantages for hospitals and physicians as well as patients to be derived from permanent overcapacity (and therefore higher average costs). Overcapacity can apply also to costly equipment and fixtures (Migué and Bélanger, 1974).

Maintenance of excess capacity of plant, equipment and, indeed staffing, is one very good way of minimizing conflict over different goals sought by trustees, support staff, medical staff, administration and patients. Those goals which are shared include: ready availability of beds and equipment, a more relaxed work pace and making available the best possible service. Of course, a more leisurely work pace and a variety of office perquisites have been claimed to represent the managerial discretion budget in private corporations pursuing profit-oriented goals as well. However, supervision by directors and the discipline of the capital market are two factors which would tend to make a private corporation less subject to these phenomena. Other objectives such as the pursuit of optimum technical solutions to health problems and the emphasis of professional excellence can run counter to optimum economic solutions. Victor Fuchs (1975) refers to these pursuits as symptomatic of a <u>monotechnic</u> viewpoint.

Several of the models reviewed above have emphasized the non-profit nature of the hospital industry. The reasons for granting non-profit status to hospitals have been variously stated as: 1) protection to consumers who are unable to evaluate the utility of hospital services to them; 2) the virtuous nature of the service, e.g., its perceived status as a merit good (Migué and Bélanger, 1974). A model emphasizing management discretion need not focus exclusively on non-profit institutions. Nevertheless, the lack of profit motive may strengthen the influence of other goals of management.

In the hospital, unlike in the private sector, the managerial discretion budget may equal the entire excess of revenue over minimum cost. Thus, a hospital can opt to produce at the lowest level of output consistent with net revenue maximization in which case the surplus is available for the pursuit of some of the other objectives discussed above. Alternatively, a hospital may opt to produce at the highest possible level of output, which will reduce costs to a minimum level and eliminate the discretionary budget.

Indeed, this spectrum of possible goals allows the output maximization model as one end of a continuom. "Efficient" hospitals may pursue the goal of output maximization, that being the discretionary behaviour of their managements; while less "efficient" hospitals may be pursuing goals such as prestige or conflict minimization (Williamson, 1964). The trade-off between the two types of goals will be determined partly by the circumstances of the hospital (e.g., the nature of third party payments) and partly by the utility function of hospital management. This generalized behaviour model is, in fact, consistent with the observed behaviour as reported in subsequent chapters of this thesis.

The generalized model also has at least some features which correspond with empirical results derived elsewhere. M. Feldstein (1971) has shown that increases in demand resulted in higher costs per unit of output rather than in increased output. This, in fact, is what a generalized theory would predict, since increases in demand increase the availability of discretionary budget more than they increase the minimum level of output. The results of the budget squeeze faced by Manitoba hospitals during 1976-1979 also accord with this theory; quantity of hospital services provided was virtually unaffected.

This theory is also general enough to incorporate the "conflict-minimization" model and the maintenance of permanent excess capacity.

Berki (1972) posits a similar model of hospital behaviour. A hospital, according to Berki, can be assumed to operate under two external financial constraints: maximum acceptable yearly operating deficit and a limit on capital budget. In addition these external constraints are supplemented by internal constraints which require that the preferences of the hospital's several constituencies be met at some minimum acceptable level. These preferences are usually non-harmonious and, in fact, taken in sum represent the hospital's objective function. Given this multiplicity of pressures on a hospital's decision taking and resource allocation apparatus and, as Berki states, in

> "...the absence of market signals of social valuation in a truly atomistic market of 'buyers' and 'sellers', in the absence of public definitions of social valuations in other than

vague generalities, and in the absence of direct or indirect enforcement mechanisms of even such imprecise conceptions of social valuation, congruence between economic efficiency and hospital efficiency can only occur through a unique happenstance." (p.13)

The preferences of Berki's different 'constituencies' turn out to be none other than the same maximands specified by other writers as being applicable to the hospital as an entity. In fact, Berki has provided a synthesis of existing theory. He says:

"...while there is less than a general agreement among the analysts on what it is that hospitals seek to maximize, there begins to appear something like a consensus that the physician's decision-making role in the medical care process and the hospital's constituencies' desire for prestige are the important, if not unique determinants of its objective functions." (p.19)

Berki's synthesis represents a fairly compelling theoretical argument for inefficient hospital operation, that is, for output and pricing decisions which are sub-optimal.

REIMBURSEMENT MECHANISMS

Many of the behavioural attributes reviewed above are sufficient (although not always necessary) to explain hospital inefficiencies. However, the absorption of costs by third parties, whether through charge-based reimbursement, cost-based reimbursement or annual budget negotiation, only reinforces the motivation ascribed by the various theories. In the words of Migué and Bélanger (1974) "institutions are then able to increase the quantity cost combination infinitely and without much resistance" (p.59).

Cost-or charge-based systems are likely to be worse than annually negotiated budgets since they link reimbursement directly to inputs used; thus annual costs are open ended (Dowling, 1974; Hellinger, Berry, Worthington, 1976). This being the case, it is a simple matter for management to increase inputs and revenues without increasing output -- a clear case of technical inefficiency. This system also allows management to increase output beyond optimal levels, but this is more often a question of allocative inefficiency.

The development of a charge-based system which is clearly tied to output raises one of the oldest conundrums in health care economics: what is output? This basically philosophical issue has never been satisfactorily resolved. Although both cases and patient days have been commonly employed as units of output, some analysts (see Bush et. al., 1973) would argue that these, too, are intermediate inputs, although they are further along in the production process to the final good -- health itself. This issue is further taken up in Chapter 3. At the present we can say that if we assume cases to be final output, then any reimbursement system which is tied to inputs into cases, (e.g., nursing hours, laboratory tests) will tend to encourage technical inefficiency in the hospital.

A number of reimbursement systems based on units which correspond more closely with a hospital's output have been proposed and referred to as "prospective budgeting" (Ro and Auster, 1969; Lave et. al., 1973). Dowling (1974) has classified some of these according to their effect on cost influencing variables. None had a completely satisfactory effect on all eleven variables included in Dowling's classification. For example, a case-based reimbursement system would lead to increases in the number of cases treated even if that were not particularly desirable from the point of view of allocative efficiency. Alternatively, a capitation system would result in fewer cases being admitted and could have effects in quality of care and amenity levels. All alternatives to cost-or charge-based reimbursement, however, would result in increased efficiency according to Dowling.

One of Dowling's proposed alternatives was that the total hospital budget be set prospectively. Of course it is just this type of "prospective budgeting" that has been the system in hospital finance in Canada ever since each individual province adopted universal hospitalization schemes. In Manitoba this occurred in 1959 with the passing of the federal Hospital Insurance and Diagnostic Services Act which guaranteed federal cost-sharing. This type of financing does place a ceiling on hospital costs for the year to which the budget applies. However, whether budgets are developed locally or on a line by line basis, the approach has been incremental. This means that the Manitoba Health Services Commission (M.H.S.C.), for example, which is government's hospital funding agency in the province, will approve percentage increases over the previous year's budget. The usual process is that each hospital will submit a budget request which is based on the previous year's costs adjusted for anticipated increases in output and factor costs and the addition of new programs or enrichment of existing programs. M.H.S.C., for its part, will set a ceiling on overall cost increases. The budgets of individual hospitals are negotiated within this context.

This process tends to build in historical pricing and investment decisions which may not be efficient, and to perpetuate them. A common practice of administrators is to base arguments for budget increases on increased demand for particular services (inputs) within the hospital; this suggests that the system may have originally been an adaptation of a charge-based system. In addition, the bargaining system itself is one that allows a shrewd bargainer to perpetuate slack within his institution, whether this slack is taken in the form of more perquisites, higher "quality" or less rigid discipline within the institution.

SUMMARY: BEHAVIOURAL MODELS

In sum, several established behavioural models suggest that hospitals will not be technically efficient. Most of these models present a theory of behaviour but very little empirical verification. Feldstein, perhaps, is the sole exception.

Even the Task Force Reports on the Cost of Health Services in Canada (1970), commenting on the perceived inadequacy of hospital management, failed to present evidence on all counts. The Task Force considered that hospital management was not organizing hospital resources efficiently; that hospitals fail to control inventory and purchases adequately, that management techniques were obsolete, and that management science literature was full of operations research techniques not applied in hospitals. Further, the Task Force charged, hospitals failed to utilize nursing staff either efficiently or appropriately and failed to co-operate to reduce duplication of costly facilities. However, their most damning evidence is the same as that mentioned by Pauly (1970): that of wide variations in average costs.

HOSPITAL COST ESTIMATION MODELS

The possibility of hospital objective functions which yield sub-optimal production functions has implications for cost functions. Cost functions are normally defined for the most economically efficient combination of inputs utilized in the most technically efficient manner (Berki, 1972). However, the strong possibility that hospitals do not meet either of the above criteria (as suggested in the previous section), means that estimates of cost functions based on observed data are not true 'technical' cost functions but rather 'behavioural' cost functions (Evans, 1971). Nevertheless, these 'behavioural' functions have considerable value, not the least of which lies in evaluating and developing policy. In addition to estimating the impacts of various determinants on hospital cost, they can also indirectly infer degrees of relative inefficiency (e.g., one hospital compared to another), although they say nothing about absolute inefficiency. The existence of relative inefficiency is not sufficient (or even necessary) to prove absolute inefficiency, as Pauly (1970) has stated (see previous section). However, the existence of relative inefficiency makes a good case for its existence as well as for a general, synthesized theory of hospital behaviour.

While empirical verification of models of hospital economic behaviour has been scarce, the same cannot be said of attempts to infer hospital cost functions. These have been many and varied; the variance usually being related to how problems of definition of quantities and availability of data -- some unique to the hospital industry -- are solved.

The major problems encountered in estimating cost curves are:

(1) the extreme heterogeneity of the hospital product;

(2) the unsuitability of some commonly used measures of hospital outout;

(3) the unavilability of data which accurately portray both inputs and outputs;

(4) the selection of variables influencing cost.

Each of these major areas of difficulty gives rise to a number of subproblems. Hence the following reviews of the work of previous writers include a general discussion of their approach to these difficulties as well as an assessment of their findings. More detailed consideration of particular methodologies is deferred to Chapter 3.

Paul Feldstein (1961) estimated both short and long run hospital cost functions, using total expenses less depreciation as his independent variable. Feldstein made no explicit attempt to correct for hospital product heterogeneity.

His short run cost functions were calculated using the cost of individual departments within a 242-bed hospital as dependent variables. The independent variable was patient days. Feldstein found that short run marginal costs were a small fraction (20-25 per cent) of average costs and that this fraction was invariant over the range of department sizes studied. Thus average costs decreased over the range of departments as well. One serious problem with this approach was that departments such as plant operation and medical records are only indirectly dependent on patient day loads.

Feldstein also used patient days as his independent variable in his estimate of long-run cost functions based on data from sixty hospitals. He found a constant long-run marginal cost which was less than average cost. No corrections were made for variability in service complexity and Feldstein avers that this influences his cost estimates and, since larger hospitals tend to provide more complex services, leads to an underestimate of economies of scale.

Carr and P. Feldstein (1967) dealt with the problem of product heterogeneity in two ways. The first was to include the crude number of individual service facilities, such as laboratory, x-ray or physiotherapy in their regression equation. The second was to stratify their sample into five groups, each with "similar" service capabilities. In both sets of equations, they included other measures of hospital capability: number of outpatient visits, existence of a nursing school, internship and residency programs, medical school affiliation and number of student nurses. The dependent variable was total costs adjusted for regional wage differences. Average daily census, weighted by number of facilities was the measure of scale.

Carr and Feldstein were primarily interested in whether or not hospitals exhibited economies of scale. Both regression approaches indicated economies; the second approach suggested that optimal hospital size increases with the number of available services.

Of the two approaches, the second is preferable. While five groups may be insufficient to capture all the dimensions of product variability, they do reduce that variability and, intuitively, provide an improvement over a single regression. Moreover, to use the absolute number of service facilities to capture their influence is a dubious procedure; each service facility will likely affect costs in some way, but it is virtually impossible that the effects will be equal.

R. E. Berry has written several articles on the behaviour of hospital costs. The first to receive wide circulation (Berry, 1967) was principally concerned with separating the effects of size and service mix and complexity. Berry's approach was to identify groups of hospitals that had identical service facilities. Since there were 28 types of facility there are literally millions of groups that could exist. From the 5,293 U.S. hospitals in his sample, Berry identified 3,419 groups. Most, of course, had only one or two hospitals in them and were inappropriate for analysis. However, Berry identified forty groups with identical facilities, each group having at least five facilities and at least ten hospitals. He regressed average costs (his measure of average cost is not discussed in detail) against patient days and showed for all but four groups that the coefficient of patient days was negative. This he took as evidence of economies although most parameters were small and only eleven out of forty were significant at the five per cent level. Naturally, in most cases output accounted for less than half of the variation in average cost; Berry was not trying to explain the total variation.

Berry's approach advances that of Carr and Feldstein a little farther, by using a much greater degree of disaggregation. However, his method does not consider the relative importance of each facility among the hospitals of each group.

In a subsequent article (1970) Berry discussed a more general cost function including efficiency, quality and factor costs as well as scale and service mix. He estimated an equation using average cost per day as the independent variable and including as independent variables: average daily census, average daily census squared (the scale measures); 27 dummy variables representing the availability of services; seven dummy variables representing accreditation of various types; average length of stay, outpatient activity, births, number of student nurses, medical students, and other patients. Berry himself recognizes the limitations of his dichotomous variables and their potential for multicollinearity. Although his R^2's were barely improved over those in the previous article the significance of his scale parameters was much greater.

In a subsequent article (1974) Berry reported in much more detail findings with respect to the other variables in the model. His cost-scale relationship was a shallow U. Short term variation in average cost was measured by the number of empty beds, which is one way of correcting for short-term variations. However, it could introduce a distortion in the scale parameters since larger hospitals are almost certain to have larger absolute numbers of empty beds, and some of the higher costs associated with scale would be erroneously attributed to empty beds.

Berry computed significant parameters -- almost all positive -- for most of the dichotomous variables associated with quality, such as accreditation. Fewer significant parameters were calculated for teaching activities although almost all were, again, positive. The availability of virtually all service facilities added to cost; about half of these parameters were significant.

These two articles are significant in that they first mention factor analysis as a means of reducing a multitude of variables describing product mix and usually containing considerable multicollinearity to a workable number with less multicollinearity.

Berry continued to pursue his interest in using service mix classifications as a means of standardizing hospital output. In 1973, he presented an article reporting work in which he classified hospitals with various numbers of facilities by the type of facility they had. His conclusion, not surprisingly, was that the more facilities a hospital had the more complex the facilities were the larger the hospital and the more complex the tasks it performed. Hospitals tend to add facilities in a systematic fashion and may be classified according to whether they have: 1) only basic services (e.g., clinical, laboratory); 2) basic plus quality enhancing services (pharmacy); 3) basic plus quality enhancing plus "complex" services (e.g., cobalt therapy); 4) all the above plus community services (e.g., home care). These groupings, Berry claimed, were relevant for further economic analysis, since they differed systematically with respect to determinants of cost.

Francisco (1970) carried out his analysis of 4,710 U.S. hospitals' 1966 data using approaches similar to those of Carr and Feldstein (1967) and Berry (1970). His main interest was economies of scale. He ran four separate analyses. The first regressed total costs, then average costs against patient days for 25 Berry-type hospital groupings. Curves of first, second and third degree were plotted with the curve yielding the best results in each group being chosen. Although 21 of 25 total cost regressions had intercepts which were consistent with declining average costs, only four were significant at the five per cent level. Only seven patient-day parameters were significant and all pertained to smaller hospitals.

Other analyses involved reducing the number of groups and including an index of facilities and services. All suggested that economies of scale occur among smaller hospitals but constant returns prevail for larger hospitals.

Lave and Lave (1971) were critical of approaches such as Francisco's, Berry's and Carr and Feldstein's. They showed that such service/facility surrogates as number of services and teaching status explained less than 50 per cent of the variation in proportions of common surgery, common diagnosis, in surgical complexity and in the extent of surgery performed. Thus, they conclude that adjustment for service capability does not render patient days homogeneous.

Ingbar and Taylor (1968) analyzed costs in 72 Massachusetts short-term general hospitals. Data were pooled for two years (1958-1959) and 100 independent variables accounting for scale, operating characteristics and service mix were specified. Many were included despite the author's admission that there was no a priori basis for their inclusion.

The 100 independent variables were reduced to 14 factors accounting for 85 per cent of the inter-hospital variation of the original variables. These factors were associated with size/volume, utilization, length of stay, and a number of measures of hospital activity.

Ingbar and Taylor specified three major models. In the first the dependent variable was operating cost per available bed-day (available bed-days is equal to 365 x the number of beds). Three measures of service activity explained 70 per cent of cost variance and the only "scale" factor significant in the equation was medical and surgical doctors' expense per patient day.

The second model used expense per actual patient day as the dependent variable. This model showed number of beds and number of beds squared were significant in addition to the previously mentioned variables. The cost/capacity curve was a very shallow inverted U-shape.

The third model regressed expense per patient day against hospital occupancy rate and found that the latter was a highly significant explanatory variable.

Ingbar and Taylor's analysis can be criticized principally for their measures of service mix differentiation. These cardinal measures actually included some which were expenses of various programs and many program activities were measured in units. Thus, it can be argued that one measure of cost was being regressed against other cost measures and robbing the operational variables of potential significance. Moreover, these measures may include substantial 'waste motion' or relative inefficiency.

Virtually all hospital cost analyses have specified multiple linear regression analyses. K. K. Ro (1968) is one writer who used multiplicative and interactive equations as well as basic linear equations. Ro found that his multiplicative equations provided better explanations of cost differences.

Ro's sample was 68 hospitals in Western Pennsylvania and eleven years' data on those hospitals. His measure of output, like that of most other writers, was patient days per year. Only unaffiliated hospitals were considered, but apart from that, no correction was made in the models for differences in casemix, severity or quality.

Ro specified his model using 25 independent variables in five major categories. Hospital characteristics included number of beds, number of admissions, number of births, occupancy rate, turnover (case flow) and average length of stay. Possible quality measures were dummy variables representing the presence of medical and nursing schools. Demographic variables included an income measure and a measure of urbanization of patient population. The final two categories were activity units and measures of service facility mix. These variable were often measured in terms of dollars or units per 100 patient days. Consequently, like many of Ingbar and Taylor's variables, they incorporate measures of cost and are liable to include considerable 'waste motion'.

The inclusion of these variables casts doubt on the conclusions which were: 1) long run average cost curves decline over the whole sample of hospitals ranging in size from 36 to 794 beds; 2) higher caseflow means lower costs; 3) hospitals with nursing schools have higher costs; 4) hospitals serving urban populations have higher costs.

Cohen (1967) also wanted to isolate the effects of hospital size on cost. His approach involved two innovations: 1) the standardization of total cost to reflect regional wage rate variations and

2) the development of an adjusted measure of output (rather than use of a vector of activity/service descriptors) to account for product heterogeneity.

Cohen adjusted total cost by factoring out the difference between the median starting salary of each occupation over the entire sample and each hospital's starting wage in each occupation weighted by the hospital's total employee-hours in that occupation. This, of course, ignores the effects of substitution of capital for more expensive labour, but as a first approximation may account for regional wage differences without excessive distortion. Cohen's procedure makes sense where hospitals in the sample are in different regional labour markets. Perhaps it is a technique that could be applied to other factors of production as well.

Cohen adjusted output using the following formula:

$$S^k = \sum WiQi^k$$

where: S^k = adjusted output in hospital k;

Wi = the weight of the i^{th} service;

Qi^k = the quantity of the i^{th} service in the k^{th} hospital.

Weights were derived using the average cost of services in those hospitals in his sample which reported such services divided by the average cost of a patient day.

There are two serious problems with this approach. The first is that the averages and weights were calculated from rather arbitrary accounting data. The second is more serious. Weighting according to actual output causes the same types of distortions as those found in Ingbar and Taylor. In Cohen's case, however, the bias is much more systematic since his only independent variable consists of measures which could embody different levels of inefficiency from hospital to hospital, where as Ingbar and Taylor had included other independent variables not measured by cost.

Cohen performed a number of regressions of total cost against his output measure using a sample of 53 hospitals in the Northeastern U.S. Not surprisingly, his R^2's were very high. Quadratic regressions on 1962 data showed U-shaped average cost curves reach a minimum of 290 beds for New York hospitals and 165 beds for other northeastern hospitals. These findings may be questioned, given that Cohen had to estimate some of his data, but this is not as serious a problem as is the bias introduced by his adjusted measure of output.

In a subsequent paper Cohen (1970) improved the mechanics of his formula by improving the quality of data. The conceptual problems with the formula were mentioned, but the formula was not amended.

Cohen also added measures of quality of care such as a dummy variable for medical school affiliation and set of weights for such affiliation. Regression equations were run not only against total weighted output but also for output of the various departments. The major conclusions are that allowing for weighting of output increases the optimum size of hospital and weighting for quality increases it still further. Berki (1972) points out that medical school affiliation is a very rough indicator of quality.

The first published study of hospital cost functions in Canada was done by R. D. Fraser (1971). Fraser developed cost and production functions for various groupings of Canadian hospitals: by province, by type of ownership, by type of operation and by bed size class. Three measures of total cost were used as dependent variables: 1) total operating costs plus estimated depreciation; 2) total operating costs plus ten per cent of estimated plant and equipment value; and 3) total operating costs alone. There were four measures of output: patient days, admissions, rated bed capacity, and a weighted output measure using the identical weights developed by Cohen (1967) for New York hospitals, and thus transplanting them into Canada. In some regressions dummy variables for the presence of a nurse training or intern training program were included.

Fraser found R^2's of between .434 and .998 in the 310 cost functions he estimated. His first three measures of output (days, cases and beds) gave rise to equations showing increasing average costs. The equations using the Cohen-type composite output measure yielded a variety of average cost curve shapes. Addition of a capacity utilization variable, either occupancy rate or length of stay, tended to produce decreasing or U-shaped average cost curves. Fraser also attempted to measure the impact of quality of care on costs using two types of infection rates along with hospital death rates as proxies for quality. Surprisingly, he found that quality was negatively associated with average costs. Most writers hypothesize that the reverse relationship exists, probably because, in general, quality is thought of in terms of attributes and amount of inputs rather than in terms of outcomes as measured by Fraser.

The major work of M.S. Feldstein (1968) focused on many aspects of hospitals' economics: efficiency, long and short run cost functions, production functions, linear programming and aggregate health system modelling. Feldstein introduced several innovations to the study of hospital costs. His dependent variable was average costs per case, a convention which will be followed in this work for reasons which are detailed in Chapter 3. Feldstein was the first analyst to attempt to correct for differences in hospital product by including casemix proportions in the independent variable. Feldstein was also the first analyst to explicitly use the relationship between his estimated and observed values of the dependent variable as a measure of relative hospital efficiency. A by-product of Feldstein's model is estimates of the average cost of producing different types of cases. Feldstein uses no direct or indirect measures of quality or service facility mix on the grounds that: 1) quality differences do not necessarily reflect patient or third party payor preferences; and 2) casemix can account for legitimate product heterogeneity. In his analysis which concentrates on hospital productivity (Chapter 2) he explores the relationships between casemix and average costs per case finding an R^2 of .275. He also estimated a number of departmental casemix-cost functions.

Feldstein's use of casemix as a weighting device has been critized on several counts. First, it does not account for severity, a dimension of output which the service or activity mix approaches of Ingbar and Taylor, Ro and Cohen could at least claim to have crudely addressed. Second, an aggregate specification of casemix, such as that used by Feldstein may not appropriately account for the heterogeneity of output, even along the dimension of case-type. Third, because there will usually be correlation among the casemix proportions, the problem of data multicollinearity could be severe.

In fact, Feldstein's casemix data did possess considerable multicollinearity, although not as much as might be expected. Despite that, he proceeded to estimate successively more elaborate cost functions from his sample of 177 hospitals in England and Wales. His usual measures of scale were beds and beds squared; occasionally monotonic non-linear forms such as the log of beds were used. Using beds and a casemix vector as independent variables, Feldstein estimated a U-shaped average cost curve with a minimum at 300 beds; the parameters of the bed variables were insignificant. The introduction of caseflow (cases per bed per year, which in the case of Feldstein's data was largely a function of average length of stay) improved the significance of the parameters and raised the minimum cost size to around 1,000 beds.

Feldstein also intensively explored the nature of short run cost curves, using both quadratic and linear forms of specifications and including, again, scale and casemix variables. His principal conclusion was that marginal costs were significantly less than average costs: about 12 per cent if the additional case is served without increasing occupancy (i.e., by reducing length of stay of all cases) and about 21 per cent if length of stay remains the same and occupancy increases.

In a later study (1977) Feldstein adapted his techniques to an analysis of costs of 55 short-term Massachusetts hospitals. He added age/sex proportions to his array of independent variables. He disaggregated his casemix to over 200 proportions. Obviously, such analysis would be impossible unless the number of independent variables were reduced. This was done by the method of principal components; 10 diagnostic principal components accounted for 54 per cent of the casemix variation among hospitals. Moreover, these components are orthoganal, so the problem of multicollinearity is reduced. Some information is, of course, lost.

Surprisingly, Feldstein did not include caseflow in this analysis. He did include beds, length of stay and urban location but concluded that virtually all variation accounted for by the included variables is due to casemix. One-third of variation was unaccounted for and reflects "differences in efficiency or quality that are not correlated with case mix".

Feldstein was the first writer of stature to pay more than incidental attention to factors besides scale and utilization in explaining costs. Evans (1971, 1972), however, went much further in his careful specifications of cost models and detailed attention to most of the independent variables.

Evans (1971) referred to the functions he developed for 1967 Ontario hospitals as quasi-cost functions or behavioural cost functions, rather than true "technical cost curves". This, he argues, is because of: 1) the behaviour of hospitals which is, in general, not cost-minimizing; and 2) because hospitals, unlike electric power plants, are not quantity takers but may attempt to influence demand for their product.

Evans used a factor analysis technique which reduced 41 casemix proportions and 40 age/sex groups to 16 factors. He used both cost per case and cost per day in separate regressions. He also included length of stay and occupancy rates separately in the analysis. This allowed him to make inferences about the effects of intensity of service.

Evans found that casemix accounted for up to 80 per cent of variation in cost per case and 57 per cent of variation in cost per day. Length of stay and occupancy rate were significant (more significant together than caseflow alone). However, they did not add much to the explanatory power of the model once casemix was accounted for. Capacity had very little to do with costs, although the parameters for number of beds were usually significant.

He did not specify the role of hospitals within his model, e.g., he did not differentiate between teaching and non-teaching, or rural and urban facilities.

Evans concluded that the close fit of his equations and the sizeable role of casemix attested to the tendency of budgetary review to promote inter-hospital conformity. (The present study found that some adjustment towards uniformity had occurred, but it was far less than Evans found.)

Evans notes, of course, that this type of analysis cannot reveal whether or not all hospitals are inefficient and their adjusted costs simply distributed around a mean which is itself inefficient. Further, he notes that the hospital data used cannot correct for production of unnecessary cases. These forms of inefficiency can only be inferred; the first from residuals of this type of analysis and the second by means of utilization analysis.

A 1972 article by Evans and Walker reported a similar analysis of British Columbia hospitals. The results obtained were almost identical. The diagnostic factors accounted for 76 per cent of inter-hospital inpatient cost variation. Age factors which accounted for 36 per cent of variation in an independent regression, added 8 per cent to a regression already containing the diagnostic factors. The addition of beds, average length of stay and occupancy rate added a further 7 per cent for a total of 93 per cent of variation explained. Caseflow was slightly inferior as an explanatory variable to the combination of occupancy rate and length of stay. The equations showed slight diseconomies of scale. Thus, Evans and Walker say they have demonstrated marked similarity of results in two provinces that have very different mixes of hospitals.

The significance of this article, however, is its introduction of a radically new technique for measuring casemix. Casemix is measured by an information theoretic device which defines the degree to which hospitals are specialized or serve complex cases. This device has not been tested thoroughly for the extent to which it represents casemix, but the tests which were made indicated that it conformed with a priori beliefs about which cases were most complex and which hospitals served them.[1] Evans and Walker define two measures of hospital complexity and three of specialization.

Evans and Walker also include measures of outpatient, educational and capital cost in some of their equations. They are entered

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[1] The tests were: 1) correlation with bed size, occupancy rate and degree of educational activity; 2) correlation (by inspection only) with hospitals by rank of case complexity expected to be served with case in a generally accepted rank order.

as independent variables and their intent is to measure the impact of the presence of such costs on inpatient operating costs. They are also used to test the validity of the accounting conventions used to separate outpatient and capital costs from other hospital costs. Both conventions were brought into question by their results. Educational variables caused hospital costs to increase, presumably by increasing indirect costs which are not ascribed to the educational activity.

Evans' and Walker's best regression equation of costs per case included the diagnostic and age/sex factors, beds, beds squared, average length of stay, occupancy rate, caseflow, educational costs and outpatient costs. Their R^2 was an impressive .943. Addition of the information theoretic complexity variable which offered the best additional explanatory power raised R^2 to .961, a statistically significant increase, although one could not improve much on the earlier estimate. Moreover, none of the parameters was disturbed by the addition of the complexity variable except bed size which became even less significant than previously.

On the other hand, the case and age/sex factors lost considerable significance when the complexity measures were inserted; apparently they provide similar information. Replacement of the factors by the complexity measure causes a significant reduction in R^2 (from .961 to .929). However, Evans and Walker argue that such replacement avoids the arbitrary process of factor analysis; a process which becomes more cumbersome and less relevant the more casemix is disaggregated. The complexity measure, on the other hand, is conceptually valid for an infinite level of casemix (or age/sex mix) disaggregation.

Of course, the whole information theoretic structure rests on the assumption that more complex cases tend to be treated in larger hospitals while smaller hospitals will also handle a smaller range of case types. This assumption, though not rigorously tested, appeared to be borne out in the British Columbia data.

Retention of the age/sex factors in the equation raised R^2 to .955 and all variables were significant except bed size and some of the short run activity variables (length of stay and occupancy rate).

Evans and Walker again found that caseflow was not an important determinant of costs. Marginal costs were some 30-50 per cent of average costs when variation occurred in length of stay, but 80-90 per cent when variation occurred in admissions or caseflow. This implied "either considerable hospital flexibility in adjusting inputs to shifts in the number of admissions, or alternatively a high degree of success in forecasting rates of admission". Evans and Walker conclude that the latter is more likely since hospitals tend to have high fixed costs.

Given the results of these two studies, it is not surprising that Evans and Walker conclude that casemix and complexity and age/sex mix of patients explain virtually all cost variation and that neither short run (caseflow) nor long run (beds) scale behaviour is very significant. It is also not surprising that they suggest that centralized budgetary review is successful in standardizing cost behaviour.

This rather extensive review of hospital cost studies has shown a marked concentration by analysts on economies of scale. Findings differed widely because of varying specification of outputs, different attempts to standardize output and inclusion of different types of independent variables. M. S. Feldstein and, to a greater extent, Evans and Walker, have shifted the emphasis to some of the other determinants of both short and long run functions. Walker, in particular, is interested in developing his approach to develop a more efficient reimbursement system for hospitals (1974). Lave and Lave (1973) have proposed such a system, using, however, a less sophisticated approach to the cost function than Walker and Evans.

Apart from these proposals, however, there is little explicit discussion in the literature about use of cost-function information in hospital policy and planning. The model that will be estimated in subsequent chapters will be applied to some typical policy problems.

CHAPTER 3

MODEL AND METHODOLOGY

Following a review of methods and findings of other writers, the following equation was specified as a means of estimating average and marginal costs and testing the effect of the policy environment on them.

$$\text{HOSPAC} = \text{INTER} + \sum_{i=1}^{n} \text{BiCi} + \text{Bn} + 1 \text{ URBAN}$$
$$\text{Bn} + 2 \text{ TEACHING} + \text{Bn} + 3 \text{ EXTCU} + \text{Bn} + 4 \text{ ADJLOS}$$
$$+ \text{Bn} + 5 \text{ BEDS} + \text{Bn} + 6 \text{ FLO}$$

where: HOSPAC = the average cost per case in each of eighty Manitoba hospitals.

INTER = the regression equation intercept.

Ci = the proportion of each hospital's cases in each of eleven defined case-types (later reduced to nine), with the residual case-types accounted for by the intercept.

URBAN = a dummy variable; URBAN = 1 if the hospital is located in Winnipeg or Brandon; otherwise = zero.

TEACHING = a dummy variable; 1 if the hospital is a teaching hospital (Health Sciences Centre or St. Boniface); otherwise = zero.

EXTCU = a dummy variable; 1 if the hospital has an attached extended treatment unit; otherwise = zero.

ADJLOS = the average length of stay in each hospital, adjusted for all factors except age of patient -- and thus a unique descriptor of the age mix of patients using each hospital.

BEDS = the number of beds in each hospital.

FLO = the hospital's caseflow. This is a measure of degree of intensity of hospital utilization and its specific definition is total cases served by the hospital divided by number of beds actively used. More specifically it is total adult and child cases divided by adult and child beds (babies and bassinets are excluded).

Four principal variations on this equation were also estimated. In two of them HOSPAC was replaced with its natural logarithm. In one of these FLO was replaced with its natural logarithm. The third variation included the natural logarithm of FLO with HOSPAC. Finally, a fourth added the square of BEDS to the equation.

Several approaches to each of these variations were tried; in some cases variables were omitted, in others they were transformed. A description of these approaches and some of the problems encountered is contained in the third section of this chapter. The second section, below, reviews the conceptual significance and methods of measurement of each of the independent variables and of the dependent variable.

VARIABLES

The variables used in the model were selected following a review of some of the available literature relating to hospital cost functions. The most commonly used variables are those related to scale and output, since most hospital cost functions have been estimated in order to adduce evidence of economies of scale. Other variables have been introduced to aid in isolating the effects of scale. These have included: role and status of the hospital, skill-mix of staff, wage levels, casemix and hospital location. This section will elaborate on the choice of variables by explaining the relevance of those chosen and the problems that led to exclusion of others.

Dependent Variables

The dependent variable chosen was average cost per case (HOSPAC in the regression equation). Other writers have used total cost (Fraser, 1970), or average cost per day (Cohen, 1963). Average cost per case was chosen for two reasons. First, the case, rather than the days of hospital stay, is a more realistic measure of hospital output. It is not an unambiguous measure of output -- since two hospitals each producing a "case" of similar type could produce vastly different results. Clearly the final product need not be identical. However, even given this ambiguity, the case is a superior measure to the days of hospital stay, for, as Feldstein (1968) says:

> "The possibility of a tradeoff between length of stay and cost per week is the most important reason for measuring output in terms of the number of cases treated. If increasing costs per week could decrease average cost per case, hospital costs should not be measured in a way that penalizes this solution." (p.24)

Thus, use of the case as a measure means that cases produced by two hospitals with widely different lengths of stay are considered identical.

It could be argued that longer length of stay (normally associated with higher case costs) is an indicator (or indeed a prerequisite) of higher quality. The clear implication is that the two cases referred to above are a very different product and therefore cannot be compared in a standard economic analysis. In fact, the issue of product heterogeneity has received considerable attention in the literature. No one has resolved the question adequately and it is probably so complex that it defies solution. Quality of care is only one aspect of product heterogeneity, others being casemix, case severity, patient age, quality of amenities, existence of parallel functions such as teaching and research and so on. Writers and researchers in the hospital field have tried to account for all of these in their attempts to differentiate and measure hospital production. Of all aspects of product differentiation, however, quality of care is probably the most elusive. Some writers have tried to use service intensity or volume of ancillary services per case as one measure of quality (Jeffers, 1974). However, it would be hard to find a health-professional who agrees that more laboratory or x-ray tests are always better than fewer or that the number of such tests always correlates more strongly with quality of care than with other elements in a hospital's objective function. Complex "health status indices" have been devised (see, for example, Patrick et.al (1973), Torrance et.al. (1972), and Chiang (1965), but none has been successfully applied to the question of quality of care.

As other works have done (Feldstein, 1968), this analysis ducks the issue of quality by suggesting that in most cases, the burden of proof of higher quality should fall on the institution which routinely produces higher cost cases, whether as a result of longer lengths of stay or of some other factor. In a system such as Manitoba's which is publicly funded, it can be argued that quality differences, where not actually illusory, are not justifiable, i.e., that are not valued by the public qua taxpayer, and hence should be given no weight in comparing hospital cases.

Some exceptions to this general rule will, of course, arise, but these can usually be dealt with by proxy. For example, it might generally be thought that quality of case would (or should) be higher in teaching hospitals. A dummy variable for teaching can then be used to represent quality of care along with a number of other teaching-related characteristics.

Thus, the evidence supporting the use of the case as a basic measure of hospital output is condsiderable. Adjustments to this basic measure are possible. For example, Cohen (1963) adjusted his measure of output to account for wage differentials among hospitals and to account for variations in special types of cases and in services provided.[1]

Adjustment for service intensity was discussed earlier and rejected on the grounds that service intensity, like length of stay, is

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[1] Cohen's analysis was based on patient days. However, the same adjustments are possible with a case-based measure of output.

a variable that is available for manipulation by management to achieve efficient hospital production. Wage rates, however, represent a different question.

The decision not to adjust cases or case costs for interhospital variations in wage rates was taken because Manitoba represents essentially a single labour market with few if any regional differences. Virtually all hospitals in the province are budget facilities and bargaining takes place among large groups of employees on the one hand and an umbrella organization, Manitoba Health Organizations Inc., bargaining on behalf of rural hospitals. Wages thus tend to be equalized for staff of equal training and experience, at least in rural areas. Differences in wage bills should therefore be reflected in higher productivity (according to orthodox economic theory) and adjustment for wage differences would distort rather than remedy distortions.[1] Accordingly, no adjustment is made for wage differences among rural hospitals.

Regional wage differentials (i.e., wage differentials that exist due to geographic rather than productivity or seniority differences) could exist between rural Manitoba and Winnipeg. However, these are likely to be compounded by so many other differences between a rural and urban hospital case that the simplest approach is simply to specify

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[1] In practice, of course, hospitals with long-tenured staff may tend to have wages which reflect institutional rather than productivity considerations. The use of long-tenured staff would then represent an inefficiency, although not one that could easily be remedied.

an urban location as a cost determinant and use a dummy variable to represent it.

The second significant aspect of the dependent variable is that average cost is used. The cost curve specified is an average cost curve and not a total cost curve. This convention follows Feldstein and is made to improve the chances of avoiding two important regression problems: multicollinearity among the independent variables and heteroscedasticity in one or more of these variables.[1] Feldstein argues that use of a total cost curve obliges one to use numbers of cases for each casetype independent variable; obviously correlation will exist since a hospital with large numbers of one type of case is likely to have large numbers of other types. Using average cost as the dependent variable requires that case proportions be used; the degree of multicollinearity among these can be expected to be somewhat less. Heteroscedasticity can be expected in a total cost model since larger total costs usually indicate larger hospitals. The variance in costs among larger hospitals can normally be expected to be greater than the variance in cost among smaller hospitals.

A final note is required on the practical definition of average cost per case. Because we are concerned with inpatient care only, outpatient costs are excluded from the total cost used to derive average cost. This exclusion is important, but in practice it is not easy to make. The Manitoba Health Services Commission defines outpatient costs

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[1] Despite this precaution both problems were encountered in original specifications of the model. Their resolution is described later in this chapter.

according to accounting conventions which may not, of course, reflect the actual resource split between inpatient and outpatient services. Nevertheless, because outpatient care usually accounts for a small proportion of a hospital's budget, the degree of distortion introduced by accepting the accounting convention is not likely to be excessive.

A second potential distortion is removed by eliminating capital charges from total costs. In Manitoba, capital charges refer to rent paid for the use of facilities, interest on long-term debt and/or depreciation on plant and equipment. Interest and depreciation predominate overwhelmingly. Because inflation in the last twenty years has brought about a rapid increase in building costs, inclusion of capital charges would overstate actual costs of newer hospitals. A third potential distortion is avoided by excluding costs directly related to education and research and identified as such in hospital budgets. While such costs can (and often indirectly do) influence the type of care received by patients and costs of that care, they are more appropriately viewed as expenditures which benefit the entire health system and not only the hospital in which they occur.

Finally, the expression "a case" must be given practical significance. A case refers to an episode of hospital care provided to a patient aged 28 days or more. An episode of care begins with an admission, includes observation or treatment designed to determine the patient's health status or affect it, and ends with a discharge (sometimes called a separation) or a death. Newborns are excluded; the cost of their care is deemed to be part of the cost of the mother's case.

Independent Variables

(1) The Casemix Variables. Inclusion of casemix in models seeking to explain hospital costs is one of the easiest ways of accounting for one aspect of the multi-product nature of the hospital firm. Casemix is, after all, readily defined by physicians and there are good *a priori* reasons to believe that costs differ among casetypes. For example, a cancer patient lingering thirty days or longer in an acute care hospital or a person undergoing expensive heart surgery is likely to incur greater costs than a woman giving normal delivery or a young industrial worker recovering from a simple leg fracture.

Most writers in this field have tried to make some allowance for this type of product heterogeneity. Carr and Feldstein (1967) concentrated on facilities (e.g., a laboratory) available in hospitals. This approach has the merit of incorporating differences in case severity as well as diagnostic differences. However, as discussed earlier, the availability (and utilization) of facilities may also reflect management discretion and thus not be related only to hospital product. Martin Feldstein, in the classic study of hospital costs, used case proportions, e.g., the casemix approach which is adopted here. Feldstein pioneered this approach and found, not surprisingly, that casemix accounted for 27 per cent of cost variation among 177 British hospitals, when only nine casetypes were used. When 28 casetypes were used, the explanatory power increased to 32 per cent.

Feldstein's approach to product heterogeneity is, of course, subject to some criticism. Migue and Belanger (1973) make the point that there is no guarantee that the casemix specification adopted will account for hospital product heterogeneity. Clearly casemix specification affords no possibility of accounting for severity or anomalies associated with a given case. Among potential casemix specifications there are some that will be better than others, even if none adequately accounts for product heterogeneity. Presumably the more disaggregate the specification the more likely it is to capture the full effects of casemix variation on cost.

Feldstein's specification was one in which costs were assumed to vary linearly with the casemix proportions. Thus, even if his level of disaggregation and specification of case types is accepted, it could be argued that a logarithm or polynomial specification would be superior. Feldstein recognizes this himself and admits that the linear relationship was arbitrarily assumed.

However, in a policy framework, Feldstein's linear casemix proportion specification has two major points in its favour. The first is simplicity. Investigating dozens or perhaps hundreds of potential variables and subjecting them to pre-tests or sophisticated ranking procedures can be both difficult and time-consuming. Moreover, in a province such as Manitoba there is not a great deal of variation in service capability among hospitals: that is to say, there are not several categories of service capability into which a number of hospitals could be classed. Rural hospitals differ from urban hospitals in service capability and rural hospitals themselves may be divided into perhaps two groups. Second, the relatively small number of hospitals in Manitoba limits the number of variables that can be introduced into the analysis.

The potentially large number of casemix variables that could be introduced into the analysis suggest one of the approaches used by Evans and Walker. Either a large number of casemix variables could be reduced by factor analysis or indices of complexity or specialization developed using the information theoretic devices explained by Evans and Walker (1972). Either of these approaches presents an enormous computational task. As will be shown subsequently in this chapter, however, the first approach was tried. When it failed to show that casemix had much influence on Manitoba hospital costs, it was decided not to pursue the second approach.

Consequently, Feldstein's casemix proportions approach was adopted and the casetypes used were similar, although not identical to Feldstein's. Eleven casetypes were chosen: they are medically meaningful in the same sense as Feldstein's and they represent a number which is computationally easy to handle. They were identified by the following symbols:

INFPAR	Infective and Parasitic Diseases
OBS	Obstetric cases
TREM	Trauma and Emergency
MALNEO	Malignant Neoplasms
CIRC	Diseases of the Circulatory System
RESP	Diseases of the Respiratory System
NEURPSY	Neurological and Psychiatric Disorders
GASENT	Gastro-enterological Disorders
GENUR	Genito-urinary Disorders

In addition, surgical cases were separated from other cases and divided into two groups on the basis of their complexity. These groups were:

SPESURG "Special" Surgery (i.e., more complex surgery) and

SURG Other Surgery

Finally, there was a residual category. In a regression analysis containing only casemix variables, the residual would serve as a benchmark against which the impact of other casetypes is measured. In fact, its cost is represented by the intercept parameter.

Cases for 80 Manitoba hospitals were classified into these groupings using the International Classification of Diseases (8th Revision). Appendix I details the classification according to ICD code numbers.

(2) Urban Hospitals. A major division among Manitoba hospitals which accounts for variation in intensity of care and complexity of services available is that between urban and rural hospitals. Some of these potential differences can be appreciated by noting that:

(i) An average case in an urban hospital cost $1,414 in 1977 compared to $979 in a rural facility.[1]

(ii) Urban hospitals average 453 beds compared to 31 for rural hospitals.[2]

(iii) Rural hospitals handle proportionately three times as many trauma and emergency cases while urban hospitals handle proportionately four times as many "special" surgery cases.[3]

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[1] Manitoba Health Services Commission. HS-1 Hospital Return 1977.

[2] Manitoba Health Services Commission. ibid.

[3] Manitoba Health Services Commission. Derived from hospital Admission/Separation forms.

Difference in casemix is one reason urban hospitals may be expected to offer a different hospital inpatient product than rural hospitals do. However, even for similar casetypes, the urban case can be different because of the availability of a wider range of diagnostic and therapeutic services. It is, of course, possible that an "urban case" may accomplish no more than a "rural case" of similar type towards improving the patient's health and that such a case could be treated for less cost in a rural hospital. However, the significance of transfers from rural areas and the acknowledged greater complexity of urban cases argue for inclusion of dummy variables to describe urban location.

None of the authors reviewed during the course of this study used a dichotomous variable (or any other technique) to identify urban hospitals in their analyses. Feldstein was content to use casemix to describe product differences. Other writers have concentrated on service availability. For example, Berry (1974) used dichotomous variables for forty services (e.g., pharmacy, occupational therapy, etc.) as substitutes for both casemix and other hospital descriptors. In some of his earlier work (1967) he grouped hospitals according to the number and type of facilities. Edgar Francisco (1969) used a similar approach. Both these writers had far more degrees of freedom available to them. Given this, as well as the rather unique distribution of hospital facilities in Manitoba, it was felt that the URBAN variable could cover product differences attributable to a large number of possible effects.

Urban hospitals include all Winnipeg hospitals and Brandon General Hospital.

(3) Teaching Hospitals. Within the class of urban hospitals in Manitoba, there are two hospitals for which it is possible to argue on a priori grounds that even higher than "normal" urban hospital costs can be traced to even greater concentrations of resources. These are the province's two teaching hospitals: the Health Sciences Centre and St. Boniface Hospital. The fact that most complicated cases are referred to these hospitals as well as affiliation with facilities for instruction and research, using the hospitals' patients for these purposes,argues for higher costs per case. These costs may not necessarily always be associated with higher quality of care (although they undoubtedly are in many cases) but they do not represent, in their entirety, expenditures which could be viewed as part of a managerial discretion budget. Consequently, they, too, should be accounted for in a model seeking to explain hospital costs.

In one sense, a use of a dichotomous variable to describe the existence of Teaching and Research facilities is an extension of the URBAN variable discussed earlier. It is an attempt to include the effect of a number of variables on hospital costs. These include the presence of facilities for training a variety of health care professionals as well as the existence of a number of Berry's "service centres", e.g., Radiation Treatment for Cancer. In a relatively non-complex hospital system, such as Manitoba's, it is possible to describe the existence of this range of facilities using a single variable.

Cohen (1969) treated "affiliation with a medical school" as a proxy for quality of care. It was treated in the same manner as accreditation, e.g., as a dichotomous variable associated with quality.

In the present context it should be taken more as representing an agglomeration of service and ancillary features as well as the capability of providing special kinds of care. In this context Fort Churchill General Hospital is treated as a teaching hospital, since its entire medical program is provided by staff, and residents of the University of Manitoba School of Medicine.

(4) Extended Care Units. One of the major concerns of federal and provincial health policy papers that appeared in the early 1970s was that the hospital system was structured in such a manner as to provide incentives to use costly acute care when less intensive types of care would have been available. Manitoba's White Paper referred to estimates that as many as thirty per cent of patients in acute hospitals were needlessly occupying beds. Transfer of these patients to nursing homes or extended treatment hospitals (if available) would be more efficient, e.g., the total cost of caring for the patient would decline.

That total costs would decline in a system which efficiently transferred patients from acute to extended care has not been established. True, average costs in acute facilities are higher than those in extended care facilities; however, extended care patients in acute facilities place less-than-average demand on a hospital's resources. One conclusion which can be made, however, is that acute care becomes less costly when hospital stays are shortened by moving a patient to an extended treatment facility. Further, on *a priori* grounds, it would be expected that an acute hospital which is affiliated with or administratively linked to an extended facility would have an easier time transferring acute patients and would thus be able to reduce average acute costs in this way. This was Norris' (1971) principal finding in his study of Baltimore hospitals. Patients accepted into a Baltimore extended treatment facility had experienced, on average, 55 days of previous acute care hospitalization if they were admitted from outside hospitals, as opposed to only 31 days for those admitted from the affiliated hospital.

Consequently, one of the determinants of average cost in the present analysis will be the presence of a linked extended care facility. This will be represented by the dichotomous variable:

1 if the hospital has a linked facility; 0 otherwise.

(5) Adjusted Length of Stay. Some writers have found that the single most important determinant of the cost of an individual case is the patient's length of stay (Lave and Leinhardt, 1976). Length of stay is dependent on a large number of other variables relating to the patient's demographic characteristics (age, sex, marital status, etc.), the characteristics of the hospital (such as occupancy rate), the patient's health status and diagnosis, and the preferences of the attending physician.

Length of stay (unadjusted) is not included in the present model. However, length of stay can be adjusted to capture, in a single measure, the effects of differences in the age-mixes of patients served by different hospitals. (Casemix differentiation has been used to capture the effects of diagnosis differences.) The adjustment procedure makes use of the fact that different age groups have different average lengths of stay.

First, a standard formula was used to adjust the number of cases in each hospital, h, for the age and sex distribution of its patients. The formula is:

$$K^* = \sum_{i=1}^{n} \frac{Ki\ (Pi,m)\ (Ph)}{(Pm)\ (Pi,h)}$$

where: K* = the adjusted number of cases

Ki = the actual number of cases served; patients in age/sex cohort i

Pi,m = total cases of Manitoba in age/sex cohort i

Ph = the number of cases in hospital h

Pm = total cases in Manitoba

Pi,h = the number of cases in age/sex cohort i in hospital h

Thus, if a hospital had more than a proportionate share of elderly cases, the adjustment formula would reduce the number of cases served to this group. Because the elderly are relatively bigger users of hospital care, this would tend to reduce the adjusted number of cases, K*, below the actual number, K.

The same formula can be used to derive the adjusted number of days of care, D*. The adjusted average length of stay is then simply:

$$ALS^* = \frac{D^*}{K^*}$$

This average length of stay has been adjusted for the influence of age and sex; that is, the effects of age and sex in ALS have been netted out. However, what is required as a proxy for age distribution is an ALS* out of which the effects of all other factors <u>except</u> age and sex have been netted. This can be done if three quantities are known:

ALS, ALS* and the provincial average length of stay $\overline{ALS}$:

Clearly, if ALS* is ALS adjusted for age and sex, then the factor which would adjust ALS* for <u>all</u> differences other than age and sex is = $\frac{\overline{ALS}}{ALS^*}$ since, once all differences are accounted for, totally adjusted average length of stay in each hospital will be identical with the provincial average. Therefore, length of stay adjusted for all factors other than age and sex is:

$$ALS^{**} = \frac{ALS \times \overline{ALS}}{ALS^*}$$

The beauty of this measure is that it: 1) varies uniquely with the age and sex distribution of patients; and 2) is expressed through a phenomenon (ALS) which has significant influence on average care costs. A serious problem with this measure could arise only if ALS (or individual lengths of stay, LOS) were not correlated with age and sex.

Some studies have found very little relationship between age/sex cohort and LOS. Lave and Leinhardt (1976) found virtually no effect of age on LOS in a large Pittsburgh teaching hospital, once diagnostic, therapeutic and hospital characteristics were accounted for. Walker and Evans (1972) obtained similar results using British Columbia data.

However, it was clear from the ALS adjustment exercise undertaken that age and sex did, in fact, have a great deal to do with length of stay in Manitoba hospitals. The variation in adjusted ALS's and the extent of the differences between adjusted and actual ALS's all suggested a strong relationship with age. Whether this relationship would persist once diagnostic variables were introduced into the relationship was an important question. However, the test of the relationship could await the calculation of the model's parameters. A weak relationship would indicate that age had little effect on LOS and consequently on costs. On the other hand a strong relationship would confirm both effects. In either case, the validity of ALS** as a proxy for age distribution is the same.

The method has one further advantage. It provides an indication of the differences in age/sex composition of hospital casemix equivalent to that provided by a very fine breakdown into age/sex classes. The ALS**'s calculated for this work were based on five year intervals, that is, 34 separate age/sex cohorts. The proliferation of dummy variables that are avoided is clear.

(6) Beds. There are two ways in which the effects of hospital size on average cost may be assessed. One is to use output, e.g., cases, as an independent variable. The second is to use scale or capacity. In the case of hospitals the best measure of the latter is either "rated beds", or "beds set up". In this study "beds set up" was the measure used. Almost invariably "beds set up" was greater than "rated beds" and thus reflected more closely the capacity available to hospital decision-makers.

There are several arguments which favour using capacity as a scale measure rather than output. The first relates to what has been called the "regression fallacy". The tendency of output to increase more rapidly than capacity (i.e., occupancy rate increases with capacity) coupled with the fact that conventional accounting does not increase depreciation when output increases tends to bias measured costs downward at larger outputs. Use of capacity as a scale measure also avoids the possibility of a simultaneous equations bias; that is, the reverse dependency of output on average cost.

These are the reasons given by Feldstein (1968) for using capacity as an output measure. Neither of them appears to be very compelling. The first type of bias is eliminated when capital costs are excluded from the analysis as they are in this study. The second is also unlikely if, as is believed, hospital administrators and other decision-makers know very little about average or marginal cost behaviour under varying output conditions.

A stronger reason for using capacity is that output (cases) can vary considerably in a plant of the same size. The notion of economies of scale or scale effects refers, in fact, to changes in production capability that are only possible in the long run. Some not inconsiderable variation in output can be due to short run factors.

This leads directly to the major reason for using number of beds as a scale measure. For policy analysis purposes interest is focussed on both long run and short run cost behaviour. With one set of data, then, output must be broken down into two measures: one which relates strictly to short term variations in output, and the other strictly to long term variations. Clearly, capacity measures are appropriate for the latter.

One other capacity measure other than number of beds is available. That is average daily census (ADC), (see Carr and Feldstein, 1967, Berry 1974). It has been argued that the number of beds set up is not representative of the hospital's average capacity, over a year, to handle patients. This is because the hospital's rating is planned to achieve a low probability that a patient will be turned away. That probability is determined by the number of beds, the ADC and the variance of daily census. It can be shown that the coefficient of variation of daily census declines as capacity (as measured by beds set up) increases. That is, larger hospitals can sustain higher occupancy rates than smaller hospitals at the same probability of being full. Thus, it is argued, average daily census represents an "efficient" scale at which a hospital can operate. Using beds instead biases the magnitude of possible economies or diseconomies of scale since the range of bed sizes is less than the range of ADC's in any given sample.

The problem with this reasoning is that while ADC may represent the maximum "efficient" use of available capacity, measured ADC does not necessarily correspond to a "desirable" occupancy rate. There are no criteria regarding an appropriate probability of a hospital being full: this would vary depending on the proximity of other hospitals. Second, hospitals have some degree of latitude in planning admissions and discharges; the more such latitude is available, the less will be the difference between maximum "efficient" ADC and beds set up. To take account of the numerous factors which determine an "appropriate" occupancy rate is beyond the scope of this work. Finally, for the capacity range in which Manitoba hospitals cluster, e.g., 18 to 40 beds, the difference between capacity as measured by rated beds or by ADC is unlikely to be very great.

Thus, the capacity measure employed in the analysis is beds set up. It was also considered desirable to test for any curvature in the capacity average cost relationship. Therefore, in some specifications of the model, the square of beds was also introduced.

(7) Caseflow. With long term variations in potential output measured by number of beds, the degree to which available beds are utilized becomes the appropriate measure of short term output variations. Following the convention established by Feldstein (1968) this work uses caseflow as a measure of short term variation. Caseflow is defined simply as:

$$\frac{\text{The number of adult and child cases served during 1977}}{\text{The number of beds set up in the hospital}}$$

Caseflow appears to be a very appropriate measure of short term output variation. However, caseflow is, itself, the product of two underlying variables: 1) the hospital's occupancy rate; and 2) the average length of stay. Caseflow, as a measure, has the advantage of embodying both of these in a single quantity. However, if either of them is significant as a policy variable, the use of caseflow masks their effects. For the purpose of the present exercise it was appropriate to view overall utilization of hospital plant as a single measure and provide separate treatment for length of stay and occupancy rate in individual policy applications.[1]

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[1] Feldstein showed that, among his sample of British hospitals, length of stay was by far the most important aspect of caseflow from a cost determining perspective. This agrees with the importance of LOS as a determinant of cost per case as adduced by Lave and Leinhardt (1976). However, the standard deviation of occupancy rate in Feldstein's hospitals was only 4.94 around a mean of 81.7 per cent. The standard deviation of Manitoba hospitals' occupancy rates in 1977 was 17.00 around a mean of 61.7 per cent. Thus, with considerably more variation in occupancy rates in Manitoba, average cost could be more strongly influenced by occupancy than was the case for Feldstein's data.

(8) Variables Excluded. The variables which are included in this analysis and have been discussed above are the most important of those affecting average cost per case. However, other variables have entered discussions, and even specifications, of the determinants of average hospital costs.

Berry (1974) has summarized the relationship between costs and significant determinants as follows:

$$C = f(O, Q, M, P, E)$$

where: C = some specification of hospital cost;
O = some specification of output;
Q = some specification of quality;
M = some specification of the available mix of services;
P = factor prices;
E = efficiency.

Of the items in this loosely defined relationship, the only one that has been included in the present analysis in recognizable form is output. Some of the others have been discussed extensively and/or specified in proxy form. Quality of care has been excluded because of both the difficulty of measuring it and problems of determining which of its dimensions are relevant in a publicly funded system. The amenity aspects of quality are certainly irrelevant to a publicly funded system. Other possible measures such as physicians' time spent with the patient or number of tests ordered can represent overservicing as well as superior care and there is no a priori basis for distinguishing between the two. Finally, "hard" measures of quality such as hospital deaths or post-surgical infection rates may have little meaning considered apart from the severity of cases, the latter being another variable which is extremely difficult to operationalize.

As discussed earlier, an approach which would classify hospitals according to the mix of available services was rejected in favour of classification according to casemix, location and role.[1] Factor prices were neglected because the most important prices (labour wages) are negotiated on a province-wide basis with any differences presumably reflecting productivity.

Efficiency is the one cost determinant which has neither been included in the model's specification nor discussed extensively. In order to place efficiency in the context of the present analysis, it is worth defining what, precisely, is meant by efficiency in a hospital.

Mark Pauly (1970) defined four conditions which are necessary for static efficiency. They are:

1) Technical Efficiency. Regardless of input-combination used, output must be maximized.

2) Appropriate Inputs. The combination of inputs chosen reflects the relative factor prices.

3) Industry Cost Minimized. Plants should be of optimum scale.

4) Mix of services is optimal. Within the industry there is equality of marginal rates of substitution and marginal rates of transformation among all commodities and services. This equality must also hold true between health care or hospital commodities and other goods

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[1] One study (Thompson et.al., 1975) determined that a very limited specification of casemix could account for a great deal of variation in "special services" cost. This study's casemix variables included only nine per cent of cases in 18 Connecticut hospitals. However, this 9 per cent accounted for 85 per cent of variation in inter-hospital "special services" charges. The study's findings are weakened by the limited sample, and, more particularly, by the lack of any explicit or implicit conceptual economic model.

and services in the economy.[1]

It has been accepted, prior to undertaking this analysis, that the conditions described in 4) above do not hold. In fact, imperfect markets, inability of consumers or producers to evaluate at the margin and failure of other necessary conditions for optimality have been posited as incentives for other kinds of inefficiency (Berki, 1972).

The third condition, optimal scale, is not the subject of this investigation, although scale has potentially important policy implications. The same imperfections in the market for hospital services that lead to sub-optimal mixes of goods and services can generate sub-optimal scale. In any case, the model described above incorporates a scale measure; thus, to the extent that efficiency is related to scale, this type of efficiency has been included.

The efficiency that Berry referred to in his model is described by the first two conditions. Feldstein (1968) has referred to the efficiency described in the first condition as "productivity" and to that described in the second as "input efficiency".

The relationship of these two types of efficiency to the model described earlier is interesting. Assume that the independent variables

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[1] If 4) does not hold, it may be considered desirable as a matter of policy, to tolerate technical inefficiency or inefficient scale. Suppose, for example, that society is willing to tolerate overproduction of hospital services rather than risk underproduction in a situation where the market does not allocate production optimally. Suppose also that there is a distortion in the market for capital used in the production of hospital services such that the production function used has too much capital relative to labour. If society considers that it is desirable to encourage employment in this sector to offset the impact of distorted prices, a "second-best" solution may be to tolerate inefficient operation or scale.

included in the model are all beyond the influence of management.[1] Assume further that they are all properly specified and that they are the <u>only</u> variables not subject to management influence.

Consider next three types of average cost per case. ACCh is the average cost per case for hospital h. $ACC\bar{h}$ is the average of average cost per case for all hospitals. Finally, $\widehat{ACCh}$ is the average cost estimated by regression of ACCh against all the variables included in the model.

The difference between ACCh and $ACC\bar{h}$ is determined by the variables in the model (assumed to be beyond management control) and the two types of efficiency (by definition, subject to management control). The difference between $\widehat{ACCh}$ and $ACC\bar{h}$ is that portion of the total difference beyond the control of management. Thus, the difference between $\widehat{ACCh}$ and ACCh represents the portion the total difference attributable to relative inefficiency (if $ACCh > \widehat{ACCh}$) or to relative efficiency (if $ACCh < \widehat{ACCh}$).

In fact, some of the variables in the model may be amenable to management influence. The degree of amenability is discussed in Chapter 5. However, the most important variables have not been included;[2] consequently, the difference between $\widehat{ACCh}$ and ACCh may be viewed as being a measure of relative hospital efficiency.

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[1] The possibility that some of these variables are not beyond management influence is discussed in Chapter 5.

[2] The most important variables amenable to managerial discretion would probably be measured by ratios; e.g., ratios of various types of inputs to outputs or to other inputs.

Some of the less important variables which may not be subject to management influence have not been included. While it may have been possible to devise measures for some of them, it would be difficult. In most cases it is impossible to determine how the characteristic would affect costs. Degree of remoteness of location is one variable that possibly could have been measured. Others, such as hospital age and physical characteristics could also have some impact on costs.

Table 3-1 below indicates the range, mean and standard deviation and coefficient of variation of all variables included in the analysis. For most variables the range of variation is considerable. For example, average costs per case vary from $425 to $2,638, a more than sixfold variation. Caseflow varies from 7.75 to 51.37, a nearly sevenfold difference. The extent of variation means that for most variables, if significant relationships with HOSPAC exist, they should be uncovered in the analysis.

Table 3-2 points out differences among various groups of hospitals. For example, while average cost per case over all Manitoba hospitals was $1,017, it was $1,415 for urban hospitals and $979 for rural hospitals. Small rural hospitals were more costly at $1,120 per case.

The independent variables vary substantially among groups as well. Surgery makes up 48 per cent of the caseload of urban hospitals but only 15 per cent of rural hospital caseloads. For rural hospitals under 30 beds the proportion is only eight per cent. On the other hand rural hospitals handle more medical cases. Combining the groups MALNEO, CIRC, RESP, and NEURPSY, the percentages are 20, 40, and 44 for urban,

TABLE 3-1

DESCRIPTIVE STATISTICS: ORIGINAL VARIABLES AND MAJOR TRANSFORMATIONS

80 MANITOBA ACUTE CARE HOSPITALS, 1977

Variable	Mean	Standard Deviation	Coefficient of Variation	Minimum	Maximum
HOSPAC ($)	1,017.20	443.44	.44	425.43	2,638.10
LOGCOST ($)	6.8482	.38041	.06	6.0531	7.8778
INFPAR	.0505	.0309	.61	.0037	.1695
OBS	.0862	.0497	.58	.0000	.2312
TREM	.0580	.0253	.44	.0169	.1829
MALNEO	.0193	.0138	.72	.0000	.0800
CIRC	.1219	.0470	.39	.0311	.2930
RESP	.1733	.0744	.43	.0055	.3357
NEURPSY	.0695	.0346	.50	.0081	.2136
GASENT	.0782	.0268	.34	.0000	.1686
GENUR	.0395	.0158	.40	.0000	.0972
SPESURG	.0457	.0485	1.06	.0000	.1665
SURG	.1307	.1130	.86	.0000	.4536
URBAN	.0875	.2844	3.25	.0000	1.0000
TEACH	.0375	.1912	5.10	.0000	1.0000
EXTCU	.0750	.2650	3.53	.0000	1.0000
ADJLOS	10.8640	2.0552	.19	6.8618	16.9690
BEDS	67.7120	165.0900	2.44	7.0000	1304.0000
BEDSSQ	31500.0000	193480.0000	6.14	49.0000	1.7×10^6
FLO	28.0340	9.6528	.34	7.7500	51.3700
FLOSQ	877.9000	568.8000	.65	60.0630	2638.9000

Source: Calculated from figures supplied by Manitoba Health Services Commission from Hospital HS-1 returns (financial and statistical data) and Hospital Admission/Separation forms.

TABLE 3-2

VARIABLE MEANS FOR DIFFERENT HOSPITAL GROUPINGS

80 MANITOBA ACUTE CARE HOSPITALS, 1977

Variable	All Hospitals n = 80	Teaching n = 3	Urban n = 7	Rural n = 73	Small Rural Beds 20 n = 34
HOSPAC ($)	1,017.20	1,919.78	1,415.23	979.03	1,120.16
LOGCOST($)	6.8482	7.5577	7.2253	6.8120	6.9365
INFPAR	.0505	.0234	.0164	.0538	.0546
OBS	.0862	.1726	.1378	.0812	.0692
TREM	.0580	.0447	.0279	.0609	.0646
MALNEO	.0193	.0153	.0152	.0197	.0217
CIRC	.1219	.0684	.0783	.1260	.1441
RESP	.1733	.0755	.0562	.1845	.1930
NEURPSY	.0695	.0632	.0473	.0716	.0762
GASENT	.0782	.0410	.0333	.0825	.0894
GENUR	.0395	.0242	.0187	.0415	.0422
SPESURG	.0457	.1128	.1430	.0364	.0196
SURG	.1307	.2741	.3376	.1109	.0612
ADJLOS	10.86	8.31	9.42	11.00	12.00
BEDS	67.71	633.33	453.43	30.72	14.03
FLO	28.03	27.81	33.09	27.06	23.41

Source: See Table 3-1.

rural, and small rural hospitals, respectively. Urban hospitals are much larger; they have higher caseflows (with the exception of teaching facilities) and their patients are, on average, younger.

DATA AND ANALYSIS

Data were obtained from the Manitoba Health Services Commission (M.H.S.C.) which is the governmental funding agency for all "budget" hospitals in the province. "Budget" hospitals are those which are funded almost entirely by M.H.S.C. and therefore are subject to M.H.S.C. budget review. Other types of hospitals in the province are federal and (until recently) private. These hospitals are funded largely from other sources but may be subject to M.H.S.C. budget review to establish per diem charges for patients for whom M.H.S.C. is financially responsible.

Data came from two principal sources within M.H.S.C. Most information came from the annual forms filled out by hospitals indicating operating characteristics, some output statistics and financial data. These forms were, until recently, required by Statistics Canada for analysis and prepration of annual hospital data publications. The forms themselves were called "HS-1".

Other data (length of stay by age) and casemix groupings came from the internal data bank maintained by M.H.S.C. These records are based on admission/separation forms prepared by the hospitals for each patient admitted.

During the period for which the data are collected, M.H.S.C. changed its fiscal year. M.H.S.C.'s fiscal year had always corresponded to the calendar year. In 1977, however, the fiscal year was extended through to March 31, 1978 so that future fiscal years would correspond with those of the Manitoba government. Consequently, financial data related to a 15 month period while casemix and length of stay data related to a 12 month period. Therefore, for this analysis the financial (and some operating) data were scaled by a factor of 12/15.

Most of the data analysis was done on the University of Manitoba's IBM 370 computer using the SHAZAM software package (Version 2.4). This program was used to develop the regression analysis and estimate the parameters that were eventually used. Some supplementary analysis (e.g., the calculation of casetype costs and marginal costs) was done using a small desk computer, the Olivetti P652.

During the course of analysis the model evolved through several specifications. These were necessitated by several technical problems with the data. In order of severity, these problems were:

1) implausibility of casetype costs;
2) multicollinearity;
3) heteroscedasticity;
4) poor fit

The fit of the equation was the least serious of the problems encountered. In fact, most specification gave good F values and (when all variables were included) good R^2 values. Some variables turned out to have less significance than might have been expected on _a priori_ grounds, but generally the model's statistical behaviour was good.

The other three problems were addressed in reverse order of severity since the casetype problem could not be resolved until the standard issues of heteroscedasticity and multicollinearity had been addressed.

Two approaches were used in dealing with the model's heteroscedasticity. The tests used to detect heteroscedasticity and the approaches used in correcting for it are discussed in detail in Appendix II. Standard weighting procedures were not employed; instead a technique was employed which divided the sample into quartiles based on OLS estimates of the dependent variable and then weighted each quartile inversely to the standard deviation of its associated residuals. This approach proved less than satisfactory; a logarithmic transformation of the variables provided both a better fit for the equation and eliminated the heteroscedasticity.

Multicollinearity was a more persistent problem. The degree of multicollinearity in the data and the several approaches to accommodate it are discussed in Appendix III. The approach finally adopted was the Principal Components Method -- a special case of factor analysis.

Some problems associated with plausibility of the parameters are discussed in Appendix IV. The results were improved by omitting two of the casemix variables, GASENT and GENUR. Thus, the results of the regressions finally used for policy simulations may have understated, by four or five per cent, the impact of casemix; the gain in plausibility of results was an acceptable pay-off.

The best results were obtained from an equation which also omitted URBAN, TEACH, EXTCU and ADJLOS as explanatory variables. As Chapter 5's discussion shows, this results in a loss of only 2.3 per cent in the explanatory power of the model.

During the course of the analysis, more than thirty sets of regressions were run, not including those done merely to test for multicollinearity or heteroscedasticity or to test the appropriateness of the principal components technique. Only two are discussed in detail in Chapter 4. The parameters of the other regressions and their statistical tests are shown in Appendix V.

The methodological issues associated with explaining and/or predicting hospital costs have not been resolved in the twenty odd years that this subject has attracted study. This analysis has attempted to come to grips with some of them, but cannot purport to have resolved them. In its present form, this model is suitable for policy purposes. It would, however, require considerable refinement before it could make a major contribution to a theory of hospital cost behaviour.

CHAPTER 4

RESULTS AND POLICY APPLICATIONS

The model was estimated using several specifications and forms. Only the best results are reported in this chapter; others are summarized in Appendix V. The variables included in the best fitting specifications explain a large part of hospital cost variation, but not all (about 80 per cent) with caseflow being by far the single most important determinant of cost. The 20 per cent unexplained variation and the overwhelming importance of caseflow suggest that, contrary to the opinions of many hospital administrators, higher than average hospital costs are the result of overutilization (or improper utilization) of hospital resources, including manpower, and underutilization of hospital capacity (or conversely, maintenance of excess capacity in the system).

Surprisingly, casemix was not a significant major determinant of average case cost. The correlation between the casemix variables alone and average cost was .266 which is significant at the five per cent level. However, when introduced into a model that already includes caseflow and scale values (beds), the entire array of casemix variables, expressed as principal components, increased the R^2 from .69 to only .77. Clearly this points to correlation between casemix and other variables and the direction of causation may be difficult to predict. However, the size of the R^2 of casemix alone with costs implies that factors other than casemix determine variation in flow.

Of the more than thirty specifications of the model, two were selected for their acceptable parameters and good fit for further analysis.[1] Both of these specifications included the natural logarithms of average cost and caseflow; both excluded two casetypes (genitourinary and gastroenterology). One included only caseflow, beds and beds squared among the non-casemix variables while the second also included the urban, teaching and extended care dummies as well as adjusted length of stay. None of these four variables, either singly or in any combination, contributed significantly to the explanation of average cost variation, but they were included for estimating purposes. (The F statistic on their incremental explanation of variance was only 1.90.)

Tables 4-1 and 4-2 indicate the regression coefficients and tests of significance for both of these specifications. In the case of the casemix variables, the coefficients and t-statistics have been transformed back from the principal components.

Several observations about the results are in order.

First, the independent variables explain about three-quarters of the variation in the dependent variables. The overall relationship is highly significant with total F's of 40.83 in the twelve variable case and 26.55 in the sixteen variable case.

Second, most of the coefficients are significant. There is some concern with MALNEO and INFPAR among the casemix variables. Among the other variables BEDS and BEDSSQ are significant in the twelve variable

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[1] See Regressions #31 and #32, Appendix V.

TABLE 4-1

REGRESSION PARAMETERS AND TESTS OF SIGNIFICANCE

LOGCOST AND 16 INDEPENDENT VARIABLES

	Estimated Coefficient	T-ratio
INTERCEPT	9.5354	26.365
LOGFLO	- .85957	-11.811
BEDS	.00060612	.794
BEDSSQ	.0000004211	- .827
URBAN	.20685	1.191
TEACH	.35154	2.214
EXTCU	.054469	.553
ADJLOS	.018867	1.120
INFPAR	- .085456	- .345
OBS	- .49382	3.002
TREM	-2.5661	- 5.867
MALNEO	.50268	.689
CIRC	.67697	3.368
RESP	- .086006	- .909
NEURPSY	-1.2865	- 3.632
SURG	.25340	4.919
SPESURG	.57396	4.938
R^2	.7932	
Adjusted R^2	.7632	
F on all regressors	26.549	
Number of Principal Components Used	3	
Cumulative Percentage of Eigenvalues	69.6%	

Source: See Regression #31, Appendix V.

TABLE 4-2

REGRESSION PARAMETERS AND TESTS OF SIGNIFICANCE

LOGCOST AND 12 INDEPENDENT VARIABLES

	Estimated Coefficient	T-ratio
INTERCEPT	9.9427	45.427
LOGFLO	- .92949	-14.287
BEDS	.0014498	2.8505
BEDSSQ	- .00000072521	- 1.8319
INFPAR	- .23191	- .915
OBS	- .50491	- 2.996
TREM	-2.5014	- 5.583
MALNEO	.95872	1.281
CIRC	.71938	3.494
RESP	- .13425	- 1.386
NEURPSY	-1.0803	- 2.994
SURG	.24807	4.701
SPESURG	.56612	4.756
R^2	.7704	
Adjusted R^2	.7516	
F on all regressors	40.831	
Number of Principal Components Used	3	
Cumulative Percentage of Eigenvalues	69.6%	

Source: See Regression #30, Appendix V.

case. However, they lose their significance when the three dummy variables and ADJLOS are added, suggesting that these variables correlate with BEDS and, in fact, have considerable explanatory power independent of BEDS and BEDSSQ. The relatively miniscule size of the BEDS and BEDSSQ coefficients and their lack of significance when the dummy variables are added is additional evidence that hospital economies of scale are not terribly important. In fact, the coefficients of this analysis imply a cost curve in the shape of a shallow inverted U, a finding in common with Ingbar and Taylor (1968).

Third, the casemix coefficients, even where significant, do not exercise a great deal of influence on cost, at least relative to caseflow, which explains the greatest part of cost variation. For example, on a regression of casemix variables on the log of average costs, the total R^2 was only 0.19 (see Regression #27, Appendix V).

The coefficients of the casemix variables indicate a wide variance in average casetype costs (a subject which will be discussed in further detail). However, within the range of empirical variation of casemix proportions, the effect on average cost is slight. For example, a doubling of the proportion of expensive MALNEO cases in the average Manitoba hospital raises average costs by less than $10 per case. Doubling the proportion of expensive SPESURG cases results in an increase in average costs of less than $25 per case. On the other hand, a mere ten per cent increase in caseflow reduces average costs by more than $80, or almost ten per cent of the average cost in the average

Manitoba hospital.[1] Thus, while casemix could potentially exert a considerable effect on average costs (for example, if hospitals were to specialize completely in one casetype) over the range of variation now experienced in Manitoba, their importance is secondary.

The difficulty experienced in previous studies (National Health and Welfare, 1977) in obtaining coefficients for casemix variables which correspond with a reasonable a priori notions of their magnitude is again revealed here. The relative positioning of the coefficients appears to make a priori sense. It would be expected that INFPAR, OBS, and TREM would have lower than average costs, and in both Tables 4-1 and 4-2 they have negative signs. Correspondingly, MALNEO, CIRC and the surgical cases would be expected to have higher than average costs and their positive signs confirm this. However, the large size of the coefficients, especially in the case of MALNEO and TREM, suggests that multicollinearity is not the only problem afflicting attempts to measure the influence of casemix on costs. It may well be that Feldstein's British hospitals could show a more or less linear relationship between casemix proportions and costs. In Manitoba hospitals, however, it is

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[1] The behaviour of cost with respect to caseflow will be used, in a later section of this chapter, to derive a type of dynamic average cost curve which incorporates characteristics of both long and short run average cost curves. This curve will be used to demonstrate the cost behaviour of hospitals as they expand, and contains significant implications for hospital services planning.

likely that the relationship is more complex.[1]

The degree of variation in average casetype costs can be shown directly by calculating the average casetype costs for any Manitoba hospital. All that is required is that the non-casemix variables be plugged into the regression equation and added to the coefficient for each casetype. For each casetype, this yields the average cost that would obtain in a given hospital if all cases were of that type. For example, if the sum $V = \sum K_i N_i = 6.80$ where the Ki are the co-efficients and the Ni are the non-casemix variables, and the coefficient for MALNEO is .50, then the casetype cost for MALNEO is the anti-logarithm of 6.80 + .50 or $1,480.

The variation in casetype costs is made clear in Table 4-3 which shows casetype costs for the average Manitoba hospital for each of the two regressions. In general, the casetype costs are plausible, which gives some confidence in the results. There are no negative casetype costs, a result which has occurred in earlier analyses. The results of the 16-variable case are more plausible than those of the 12-variable case. MALNEO is a little high, although not totally implausible.

Casetype costs are an interesting output of this exercise and on their plausibility rests much of the confidence with which the model can be viewed. Their economic significance, however, lies merely in

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[1] Regressions employing non-linear variants of the casemix variables were attempted. These variations included squaring the variables, taking square roots, and using logarithmic and exponential transformations. None of these transformations produced results which were more meaningful than those being reported here. (See Regression #28, Appendix V.)

the fact that they give rise to variations in cost due to variations in casemix, a factor which must be accounted for in determining relative hospital efficiency or in developing an understanding of cost behaviour that can be applied to policy formulation. This model cannot, for example, be used to determine if individual hospitals have comparative advantage in producing certain types of cases.[1]

TABLE 4-3

CASETYPE COSTS FOR AVERAGE MANITOBA HOSPITAL

	12 Independent Variables	16 Independent Variables
INFPAR	$ 818.32	$ 957.27
OBS	622.82	636.33
TREM	84.59	80.11
MALNEO	2,691.58	1,723.69
CIRC	2,118.67	2,051.88
RESP	902.27	956.75
NEURPSY	348.23	288.02
SURG	1,322.44	1,343.38
SPESURG	1,817.62	1,851.04
RESIDUAL	1,031.91	1,042.67

[1] This is because casetype costs will not vary with proportion of cases. Their variance with respect to the non-casemix variables is identical; in other words, if a non-casemix variable causes overall average cost to increase by $100, then each casetype will increase by $100. To determine unique variation of any single casemix variable would require that a model be specified with casetype cost as the dependent variable. Casetype cost would then have to be estimated using some other procedure, for example, the disease costing techniques of Lay and Babson (1975).

Apart from acting as checks on the model, the casetype costs are, of course, by-products of a process that explains the variation in hospital average costs. The casemix parameters estimated by the regressions are part of the equation that provides the regression estimates of average cost or, in the terminology used here, the expected costs. If the expected average cost of a given hospital is greater than its actual average cost, then relative to other hospitals, that hospital is either providing care more efficiently or using a more appropriate combination of factors.[1] Thus, the ratio of actual to expected average cost is an indicator of relative efficiency. It is an indicator which can provide a useful perspective for policy and budget management. Table 4-4 shows this ratio (which Feldstein has called a Costliness Index) for all Manitoba hospitals.

In Table 4-4 the 80 Manitoba hospitals are identified by a code number which assures confidentiality. The first costliness index, C^1, excludes caseflow from the regression specification of expected cost. This is done by calculating expected cost for each hospital using that hospital's value for all variables except caseflow, for which the average caseflow for all Manitoba hospitals was used. Thus C^1 shows the ratio of actual average costs to expected costs with caseflow held constant. The rationale for developing this statistic is that most variables treated in this study are not amenable or are only slightly amenable to management influence. On the other hand, caseflow may be influenced either by hospital management or by systems rationalization.

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[1] See Chapter 3 for a discussion of the relationship of productivity, factor combinations, and expected cost.

TABLE 4-4

COSTLINESS RANKING OF MANITOBA HOSPITALS

Hospital Number	Costliness Index C^1	Costliness Index C^2	Hospital Number	Costliness Index C^1	Costliness Index C^2
59	.5630	.8604	65	.9986	.8294
26	.5819	.9793	79	1.0006	1.1355
49	.6339	1.0212	19	1.0097	.8038
2	.6400	.8930	24	1.0152	1.0017
61	.6807	.9114	3	1.0226	1.0932
15	.6927	.9797	44	1.0233	1.0507
37	.7074	.9176	64	1.0340	1.0250
42	.7114	.8793	22	1.0345	.6512
58	.7132	.9188	7	1.0387	1.0150
38	.7276	.8142	1	1.0808	.8742
12	.7441	1.0472	76	1.0816	1.1204
52	.7519	.8770	16	1.0926	1.8334
33	.7524	1.1182	56	1.0976	.9555
80	.7807	.9420	51	1.1192	1.0354
32	.7690	.8251	36	1.1459	.6640
66	.7840	1.1178	46	1.1541	.9844
10	.7863	.9258	71	1.1616	1.2373
62	.7999	.7972	45	1.1873	1.4591
40	.8041	.7681	72	1.1981	.6854
9	.8141	.8063	78	1.2132	.7761
48	.8211	.9316	67	1.2267	1.1158
35	.8243	.9836	70	1.2310	1.2561
53	.8246	1.0047	69	1.3408	.9828
11	.8253	1.0852	68	1.3468	.6740
25	.8412	1.0215	41	1.4069	.8650
47	.8418	.8036	6	1.4420	1.6986
29	.8427	.9061	8	1.4921	1.1258
17	.8619	.9471	63	1.5763	.7820
74	.8729	.9036	21	1.5931	.9937
55	.8763	1.1039	39	1.6320	1.1248
14	.8811	.7507	60	1.6535	1.2597
77	.8963	.8145	31	1.7050	.8703
27	.9043	.7431	34	1.9207	1.0014
73	.9201	1.0790	28	1.9238	1.7086
75	.9241	1.0037	54	1.9275	.6383
24	.9290	.7751	13	2.1641	1.4327
20	.9366	.9260	57	2.7303	2.0583
43	.9737	1.0810	23	2.9787	1.3423
18	.9739	.8486	30	3.3950	2.7210
50	.9825	.9316	5	4.0475	1.5866

[1] See page 97.

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[1] Based on regressions of 16 independent variables on the natural logarithm of average cost per case. Expected average costs are transformed back from log form and become denominator of ratio: $\frac{\text{Actual Cost}}{\text{Expected Cost}}$.

C^1 is the ratio using expected cost derived from the regression formula with CASEFLO held constant at the Manitoba average. Thus it describes the costliness index obtained if caseflow were not included in the regression.

C^2 is the index for Actual Expected where Expected incorporates CASEFLO in the equation.

In either case, the index can be compared to a benchmark of 1.0000 which represents the cost of a hypothetical "average" hospital sharing all characteristics for which the index number is given. Thus the number .7500 means that average cost per case is 75 per cent of the average cost per case of its hypothetical counterpart.

Hence, variation of casemix is not included in adjusting costs to what would be expected, given those factors beyond management's control.

Using C^1 as a guide to the costliness of individual hospitals, the table shows that 41 hospitals have costs that are lower than would be expected, given their casemix, size and orientation. Another 39 have costs higher than what would be expected. The range of costliness is from .5630 to 4.0495, the standard deviation of the costliness index is .4128 and its unweighted mean is .9702. This compares with an unweighted mean of 1.0000, standard deviation of .4359, and range of .4182 to 2.5935 for a hypothetical costliness index using the unweighted average cost of all hospitals as the denominator or "expected cost".

C^2 is a costliness index which shows the ratio of actual average cost to estimated average cost, including individual parameters for caseflow. Because caseflow is such a significant determinant of average cost (compared to the other variables) the range of C^2 is less than that of C^1. Forty-three hospitals have $C^2 < 1.0000$ and 37 have $C^2 > 1.0000$. The range of C^2 is from .6383 to 2.7210, its unweighted mean is 1.0428 and its standard deviation is .3569.[1]

The value of measures, such as C^1 and C^2 in policy application lies in their use as benchmarks for measuring or enforcing budgetary policy. The mechanics and theoretical considerations underlying such application are discussed in the subsequent section on policy.

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[1] It may appear unusual that C^2's standard deviation is not smaller since caseflow explains such a large proportion of average cost variation. However, the indices are based on estimated cost transformed back from their logarithmic values.

The technique of costliness measures is well known and rather straightforward. This section has been meant to demonstrate that various costliness indices can be developed, depending on the requirements of policymakers. By way of further elaboration, costliness indices could be developed which incorporated other variables which could have policy significance, e.g., location of the hospital, age and structural aspects, or special caseload characteristics. Costliness indices could be applied to specific elements of hospital cost such as nursing costs, or administrative costs. Finally, costliness indices could be supplemented by productivity indices as discussed in Chapter 3 in order to determine more closely the sources of possible inefficiency. In the section on policy application, supplementary analyses are further discussed. Given some of the problems of developing the indices themselves -- problems which would be expected to have equal or greater significance in the development of supplementary measures -- it is also possible that simpler measures could be used to highlight the costliness comparisons.

It has long been a near-axiom in the hospital industry that because of high fixed, and especially quasi-fixed, costs that marginal costs of a hospital case were substantially lower than average costs. The positive regression coefficient for BEDS in the present exercise suggests that this is not the case for long run marginal costs. However, the large negative coefficient for caseflow suggests strongly that short run marginal costs are, indeed, well below average costs. Thus, additions to capacity may not result in lower costs, but more intensive utilization of existing capacity certainly does.

Given this clear indication of both long and short run marginal costs relative to average costs, the calculation of marginal costs is probably no more than a dramatization of these differences. Nevertheless, such dramatization may be useful to policy makers in that it further points out the costs of maintaining excess capacity.

Marginal costs were estimated for each hospital's overall caseload and for each casetype. In addition, marginal costs were estimated for significant groupings of hospitals, e.g., urban hospitals, rural hospitals, hospitals of 35-44 beds, etc.

There are two approaches that can be used in estimating marginal costs. The first regesses total costs against number of cases of each casetype along with other variables such as caseflow that are considered relevant. The coefficients of the casetype variables then become the marginal costs. This is essentially the approach used by Feldstein (1968), and his results were satisfactory. However, this approach was rejected here because of the problems with multicollinearity and heteroscedasticity discussed in the previous chapter. It was believed that if such problems were significant in a regression which used casetype proportions they would be of even greater significance where actual cases and total costs were specified.

Consequently, the second approach was used. This involved use of the parameters of the two regressions selected as most plausible. A computer program was written which simply added the marginal case to the variables for any given hospital, calculated the average cost, compared it with the hospital's original estimated average cost, and thereby calculated the marginal cost of that case.

For example, the predicted average of hospital number 09 was $922.33. The predicted average cost of hospital number 09 with one more case and with no change in case proportions or other parameters of the equation was $921.36, yielding a marginal cost of $62.66. If the type of case (e.g., INFPAR) is specified, marginal casetype costs for each case can be calculated.

The results of this exercise, as calculated for the average Manitoba hospital, are displayed in Table 4-5. The results for selected individual hospitals and groupings of hospitals were calculated but are not included here. The hospital's overall marginal cost (independent of casetype) are certainly plausible.[1] Otherwise, however, the results are disappointing.

For example, the variance among the marginal casetype costs is plainly unrealistic, especially since several have large negative marginal costs. In the 16-variable case, the overall marginal cost of $126 (compared to an estimated average cost of $899, i.e., marginal cost about 14 per cent of average cost) is highly plausible. However, it would be expected that the variance of the casetype costs around this mean would be more or less proportional to the variance of casetype costs around the estimated average cost. In fact, the variance of the marginal costs is greater even in absolute terms than that of the casetype costs.

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[1] This "overall marginal cost" was calculated by simply assuming that the marginal case had no influence on casetype proportions.

TABLE 4-5

MARGINAL COSTS OF HOSPITAL CASES: AVERAGE MANITOBA HOSPITAL

Casetype	12 Independent Variables	16 Independent Variables
No Specific Casetype	$ 63.50	$ 126.02
INFPAR	- 24.21	182.68
OBS	- 270.29	- 184.15
TREM	-2,068.82	-2,044.44
MALNEO	1,049.43	711.13
CIRC	833.55	867.76
RESP	63.83	182.18
NEURPSY	- 794.22	- 895.98
SURG	408.53	487.13
SPESURG	695.33	775.19
RESIDUAL	2,314.40	936.16

Except for the "average" or undifferentiated case, then, the model clearly fails to provide believable marginal costs. It appears that its specification is either insufficiently discrete or rigorous to permit their calculation. This particular failure of the model may also be due to the relatively small contribution made to overall cost variation among hospitals by casemix.

In effect, this failure cancels any possibility of using the model for policy applications that relate to shifting of casemix, unless the more rigorous specification can be developed. It does not, however, limit its use for applications which are indifferent as to casemix.

The calculation of marginal costs or at least the implication drawn by the relationship between caseflow and average cost should be susceptible to testing of two related hypotheses. First, it seems likely that marginal costs would decline as caseflow increases, up to some point of optimum utilization and then should begin rising until they approach, or even exceed, average cost. This hypothesis can only be rigorously tested by inclusion in the regression estimate of a term which includes the square of caseflow as a variable. Such a formulation was made and the results are discussed below. A corollary of this hypothesis, though, is that marginal costs in the logarithmic formulations described in detail should, beyond some point, be greater the larger the caseflow, or, at the very least should be a greater proportion of average costs as caseflow increases.

From the display shown in Table 4-6 it appears that the standard textbook marginal cost curve has not been estimated. There appears to be no relationship between caseflow and the marginal cost/average cost ratio. It appears as if marginal cost continues to decline along with average cost. In fact, the coefficient of correlation of caseflow and the MC/AC ratio is .0133 which is not significant at the ten per cent level.

The regression which included both caseflow and caseflow squared explains, in part, why this is the case. The parameter estimated for caseflow squared is significant (t = 3.50) and positive, while that for caseflow remains negative. This relationship implies the standard textbook U-shaped marginal cost curve with respect to caseflow. However, using the regression parameters obtained, average cost does not reach

TABLE 4-6

RELATIONSHIP OF CASEFLOW TO ESTIMATED MARGINAL COST AND ESTIMATED MC/AC RATIO: MANITOBA HOSPITALS, 1977

Hospital Number	Caseflow	Marginal Cost ($)	Marginal Cost ÷ Average Cost	Hospital Number	Caseflow	Marginal Cost ($)	Marginal Cost ÷ Average Cost
54	7.75	351.44	.1309	11	21.90	86.38	.0893
5	9.43	228.78	.1375	27	22.31	134.76	.1243
23	11.09	259.30	.1343	65	22.59	136.79	.1310
63	12.33	233.83	.1333	4	22.91	145.20	.1256
68	12.53	239.45	.1252	46	23.30	176.84	.1918
31	12.82	219.51	.1342	14	23.37	175.48	.1320
34	13.14	157.16	.1179	56	23.86	143.40	.1470
21	14.64	213.44	.1246	18	23.88	120.11	.1259
36	14.86	197.04	.1385	28	24.42	124.32	.1132
41	15.92	183.08	.1303	77	25.08	69.62	.0777
21	16.00	252.29	.1684	67	25.11	452.69	.2410
22	16.36	209.87	.1380	51	25.61	125.79	.1348
78	16.67	234.44	.1346	50	26.35	105.49	.1360
39	18.18	91.77	.0813	47	26.56	103.52	.1149
69	19.53	129.87	.1183	40	26.58	118.10	.1197
57	20.18	99.52	.1082	7	27.29	71.75	.0804
8	20.20	136.17	.1231	24	27.60	111.04	.1227
60	20.43	141.71	.1302	20	27.66	85.25	.0856
19	21.50	160.20	.1434	9	27.72	62.66	.0679
30	21.67	84.11	.1126	64	27.75	118.52	.1240

TABLE 4-6 (continued)

RELATIONSHIP OF CASEFLOW TO ESTIMATED MARGINAL COST AND ESTIMATED MC/AC RATIO: MANITOBA HOSPITALS, 1977

Hospital Number	Caseflow	Marginal Cost ($)	Marginal Cost ÷ Average Cost	Hospital Number	Caseflow	Marginal Cost ($)	Marginal Cost ÷ Average Cost
62	27.93	95.93	.0976	6	33.92	89.26	.1616
70	28.70	97.76	.1219	35	34.43	90.89	.1447
44	28.94	98.34	.1155	25	35.14	84.57	.1046
74	29.18	72.40	.0876	53	35.28	77.68	.1033
76	29.21	71.35	.0996	45	35.63	44.60	.0719
71	30.17	89.24	.1412	42	35.87	92.86	.1313
3	30.30	69.85	.0864	80	35.95	34.83	.0408
32	30.43	70.10	.0840	66	37.21	174.53	.2232
29	30.50	244.80	.1716	58	37.34	321.98	.3009
75	30.86	79.66	.1195	37	37.94	83.64	.1208
17	31.28	79.32	.1148	11	38.55	112.18	.1058
43	31.66	150.24	.1656	61	39.37	71.65	.1181
38	31.95	76.56	.1048	21	41.30	47.18	.0818
13	32.12	59.27	.1298	12	41.72	57.81	.0953
79	32.48	262.62	.2320	15	41.96	41.50	.0759
55	33.22	96.21	.1477	33	44.45	92.49	.1559
48	32.47	93.34	.1043	59	45.52	53.22	.1076
52	33.53	81.07	.1300	49	48.82	99.15	.1705
73	33.74	182.96	.1504	16	51.18	92.65	.2027
10	33.90	264.74	.1372	26	51.37	35.05	.0709

its minimum until caseflow equals 113, and marginal cost does not reach its minimum until caseflow equals 57. Both of these caseflows are greater than any experienced in Manitoba in 1977. Thus, the part of the marginal curve depicted by the study hospitals is the falling part and it appears that the curve is falling shallowly at a declining rate.

How realistic is this type of depiction, that is, one in which short run average costs do not begin to rise until each bed provides 113 cases? This is equivalent to a situation where occupancy is 100 per cent and average length of stay is 3.23 days. Probably not very realistic, since beyond the maximum caseflow achieved by Manitoba hospitals in 1977, the regression curve becomes, in terms of the theory itself, defined with much less confidence, and may, in fact, be subject to discontinuities that are not even hinted at in the model.

In any case, the marginal cost curve appears to have so little curvature that there is no harm done in using the specification of the model which neglects the square of caseflow. The explanatory power of the regression is not improved by it and the estimates of the casetype costs are less plausible when it is included. And finally, it does not change the major conclusion of this study, that is, that caseflow is the dominant determinant of costs in Manitoba hospitals and that, relative to caseflow, other factors (such as casemix) to which have been ascribed considerable importance are not very meaningfully associated with cost.

In fact, the dramatic effect of caseflow on average costs supports the "sawtooth" average variable cost hypothesis, that is, that average costs decline as flow increases, and then increase discontinuously as new capacity is added. The regression model used in this study would, of course, permit costs to decline continuously as simulated caseflow increased from 40 to 50 cases per bed and beyond into such unrealistic domains as 70 or 80 cases.

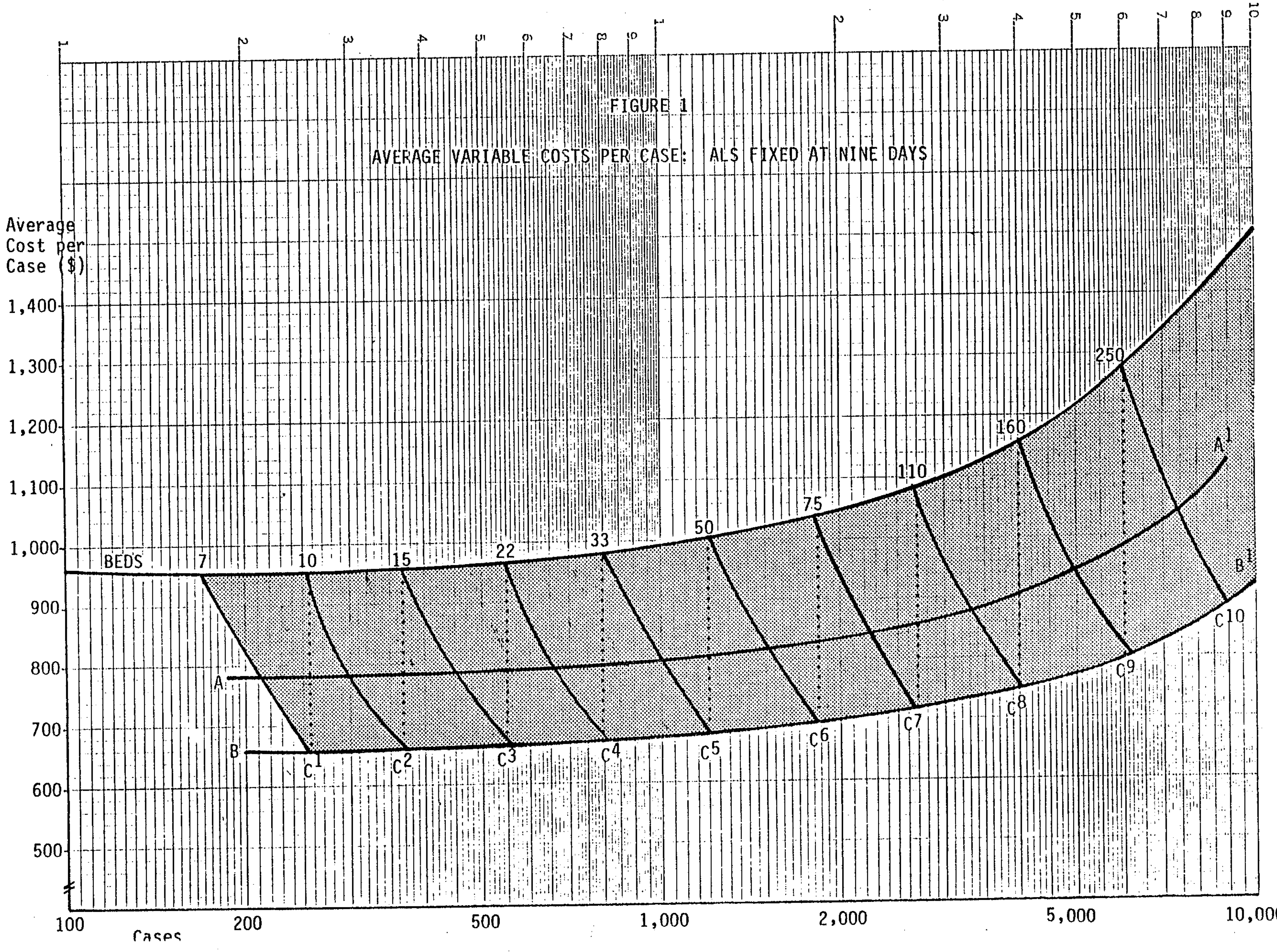
The "sawtooth" curve appears when the parameters are applied to the model and working rules are used to specify the limits to which caseflow can rise or fall before capacity is added or deleted and the amount of capacity added or deleted as each trip point is touched. Figure 1 is one member of a family of "sawtooth" average variable cost curves. It is obtained by assuming that a hospital will never fall below 60 per cent occupancy and that if occupancy increases to 90 per cent, enough new capacity is added to reduce occupancy to 60 per cent at the same caseload. A constant length of stay of nine days is assumed.

Figure 1 shows ten continuous sections of the cost curve, labelled C^1 through C^{10} separated by the discontinuities. As the regression parameter for capacity (beds) is positive, the continuous sections occur at progressively higher costs as capacity increases. Each section represents a different capacity, i.e., C^1 represents costs for a seven bed hospital, C^2 for a ten bed hospital, and so on. The sensitivity of average costs to capacity utilization is clearly shown. As cases increase from 800 to 1,200, for example, curve C^5, 33 beds, costs decline from $980 to $680 per case -- over thirty per cent. However, if new capacity must be added, average costs jump back to $1,000.

Of course, the curve in Figure 1 cannot properly be called an AVC curve since it is only a representation of a family of curves. If

FIGURE 1

AVERAGE VARIABLE COSTS PER CASE: ALS FIXED AT NINE DAYS



it had begun, say, by showing costs for a five or an eight bed hospital, a slightly different curve would have resulted. Actually, the combination of regression coefficients and casemix proportions used to derive the curve in Figure 1 yields a cost "surface", like the shaded area in Figures 1 and 2 which rises slightly as it moves from left to right. Alternatively, we could view it as a single continuous curve at a fixed occupancy, say, 75 per cent, with deviations on either side for changes in occupancy, such as the line AA^1.

With this interpretation, it may be tempting to say that the "sawtooth" curve of Figure 1 is a trivial representation of what is actually a well-known phenomenon. Of course costs per case may rise, fall, or stay constant (in this case, rise) as cases increase. For any given caseload, costs will be higher or lower depending on the extent of capacity utilization. In a theoretical sense, the depiction of these phenomena in the "sawtooth" form of Figure 1 may indeed be trivial. In terms of the conventional theory, the solid lines C^1 through C^{10} are merely a series of short run average cost curves with only the declining section represented because the regression model does not permit specification of the rising section. Assuming the maximum possible occupancy is 90 per cent and costs continue to fall to that point, curve BB^1 in Figure 1 is the long run average cost (or envelope) curve. The "sawtooth" curve, then, is merely a combination of the long and short run average cost curves and has no unique theoretical significance.

However, for policy purposes, such a curve, (or any other curve of the same family) is not trivial. For a policy maker anxious to control hospital costs, it may be very important to know how average costs

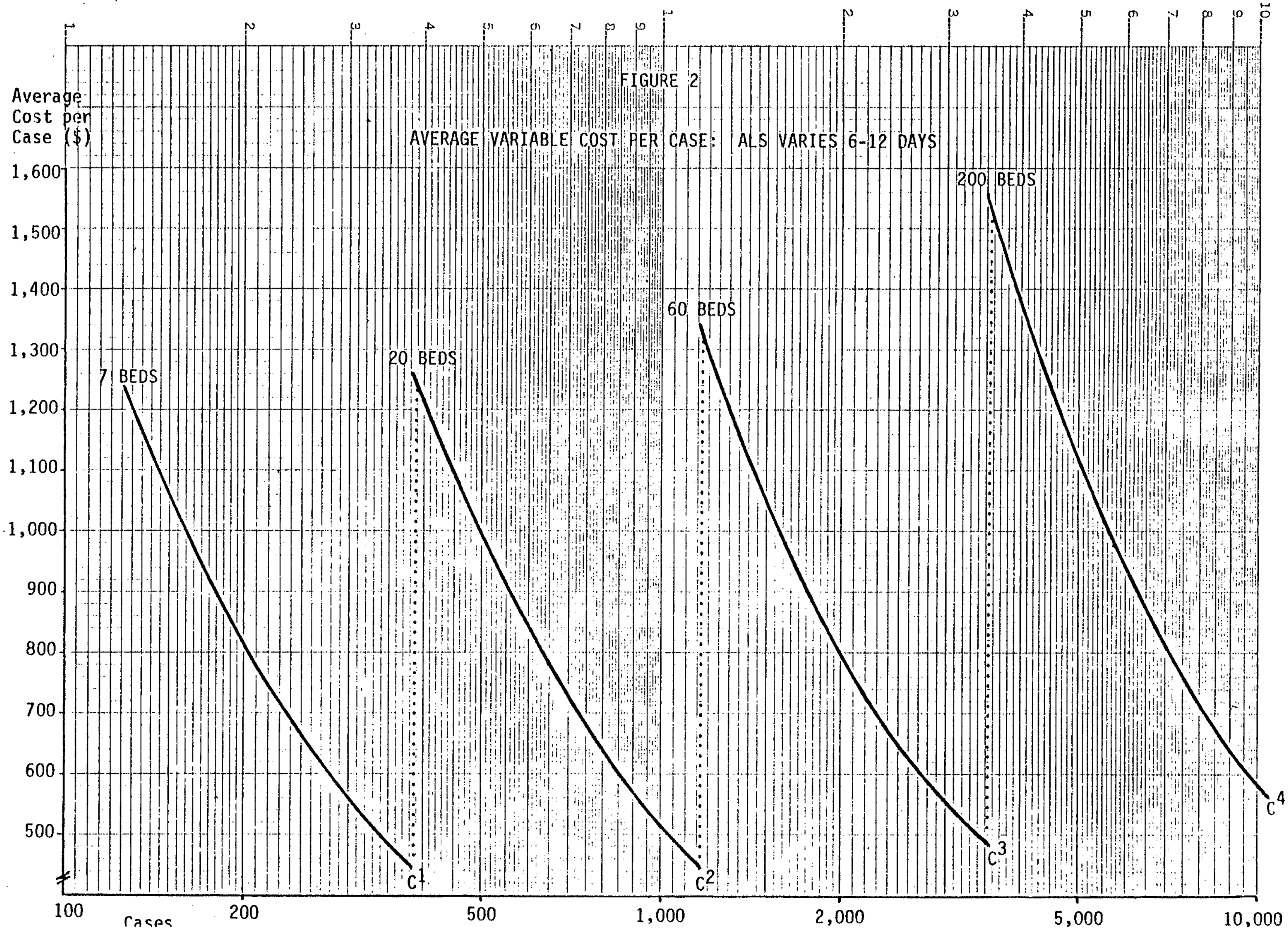


FIGURE 2

AVERAGE VARIABLE COST PER CASE: ALS VARIES 6-12 DAYS behave as capacity utilization increases or decreases or when a change in capacity is contemplated. The curve in Figure 1 provides a good representation of this behaviour.

The shape of the curve will also vary depending on the occupancy rates chosen as parameters and on the average length of stay. And, of course, it will vary with casemix. For Figure 1 an average casemix for all Manitoba hospitals was used. For policy applications, individual casemixes would be required.

Given the regression parameters used in this analysis, increasing the maximum occupancy permitted would lower the lowest point on the solid line sections of the curve, while decreasing the minimum would raise the highest points. Increasing the constant average length of stay will raise the entire curve, while decreasing it will lower the curve.

A more interesting parameter change, and one which would cause the model to correspond more closely with reality, would be to allow the ALS to vary as well as the occupancy rate. This has the effect of increasing the curvature as shown in Figure 2. The curvature is increased because at low occupancy rates, average length of stay is relatively high, reducing caseflow to less than it was in the fixed ALS case. At high occupancy rates, ALS is lower and consequently caseflow is even higher than at high occupancy rates in the fixed ALS case. This pattern more realistically describes the behaviour of hospitals which are willing to let patients stay longer when there is no pressure on beds (e.g., at low occupancy rates) but urge advanced discharges if this can be done safely when there is pressure.

The curve in Figure 2 was constructed on the assumption that occupancy rates are allowed to vary between 60 and 90 per cent (as before) but that ALS also decreases linearly from 12 days at 60 per cent occupancy to six days at 90 per cent. The wide range is not necessarily the most realistic, but it has the advantage of demonstrating more clearly, in an example, the effects of varying ALS. Clearly, the assumption of linear decrease is not essential to the analysis either, but merely the most convenient for the calculations.

With both ALS and occupancy varying, the range of caseflow is increased considerably. In Figure 1 caseflow ranged from 24 to 36 cases per bed per year. In Figure 2 the range is from 18 to 55 cases and so the range of average costs at each capacity is greater. The discontinuities are correspondingly larger as is the difference in capacity sizes. For example, a 200 bed hospital can have an average variable cost per case ranging from $560 to $1,560.

It should be made clear that the discontinuities in Figures 1 and 2 are not due to the need to incur new capital costs to increase capacity. Capital costs would be in addition to the new costs shown in the charts. The discontinuities are due to the fact that in the hospital industry a large proportion of non-capital costs are quasi-fixed. They represent a minimum of staff, equipment, etc. required to maintain that capacity.

The figures (1 and 2) do tend to indicate diseconomies of scale. However, we agree with Feldstein and other writers who, having found either economies or diseconomies, downplay their significance because of either insignificant parameters or low (i.e., near zero) values of parameters. For example, in Figures 1 and 2, although the parameters for both beds and beds squared were significant (C = 2.8505 and -1.8317 respectively) they were not large (BEDS = .001498; BEDSSQ = .00000072521).

Their significance becomes even less when we admit the four previously omitted variables into the analysis. Here the coefficients lose their significance (BEDS = .774, BEDSSQ = -.827) while three of the four previously omitted variables become relatively significant. T values: URBAN 1.10; TEACH 2.21; and ADJLOS 1.12. The result is a much flatter longrun cost curve (see Figures 1a and 2a). Costs still increase with caseload and bed capacity, but the increase is much less marked and indeed, for policy purposes is not significant. On a case-mix and role adjusted basis it is really not much (if any) more or less costly to treat a case in a small hospital than in a large one.

This lack of significance of hospital size/caseload suggests that for a large variety of unspecialized cases, small hospitals may be just as effective as large -- and provide care closer to the user. Capacity and long term costs are not important to the costliness of a hospital. However, short term costs are; and given this, hospital consolidation may still be an economic decision. The reason is that larger hsopitals tend to operate closer to the low point of their short run average cost curves. This may be due largely to the fact that larger hospitals can utilize a greater part of their capacity on average. Moreover, even if larger facilities are not better utilized -- consolidation can still produce cost saving, if it can lead to better utilization in the future.

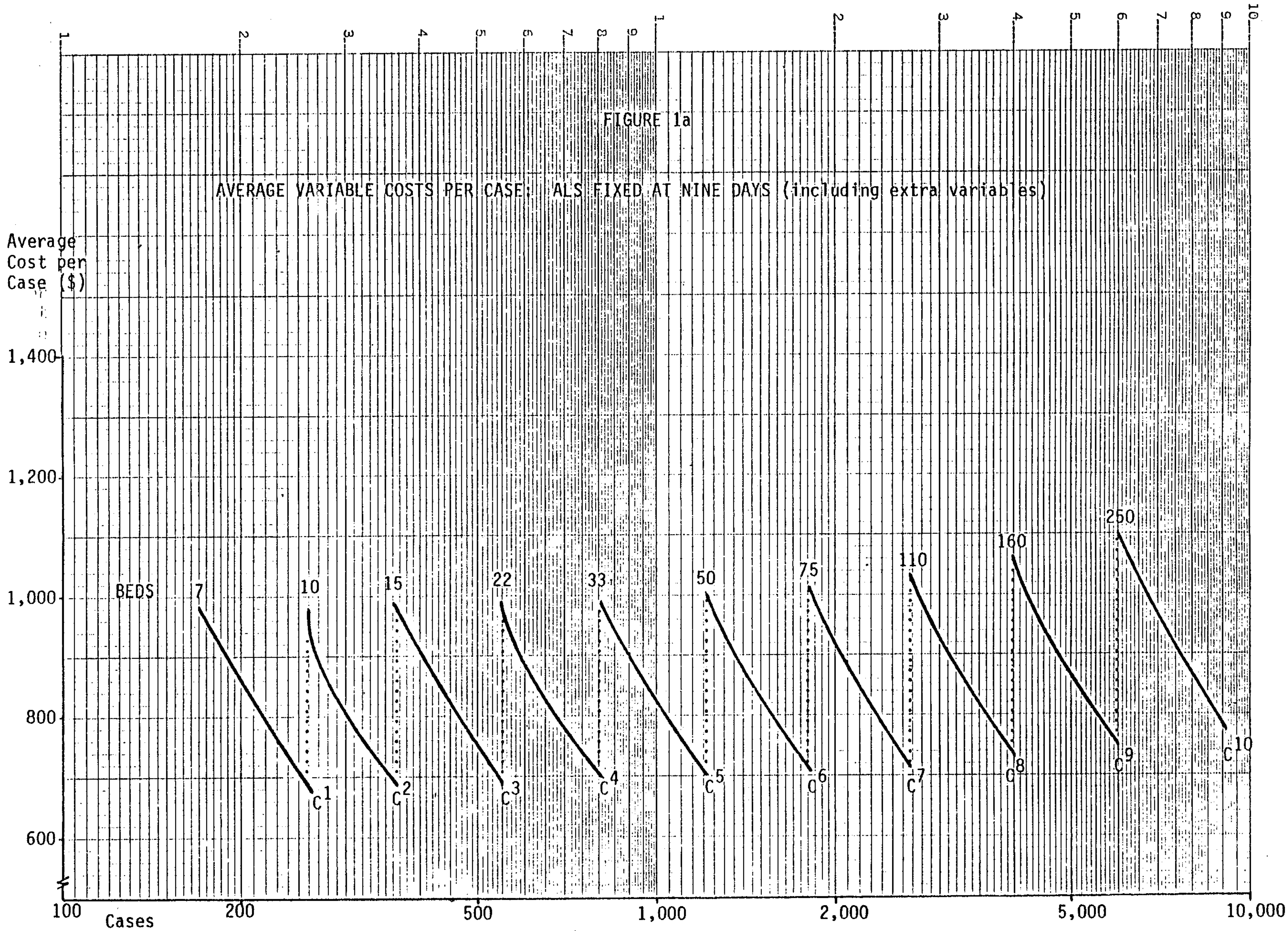
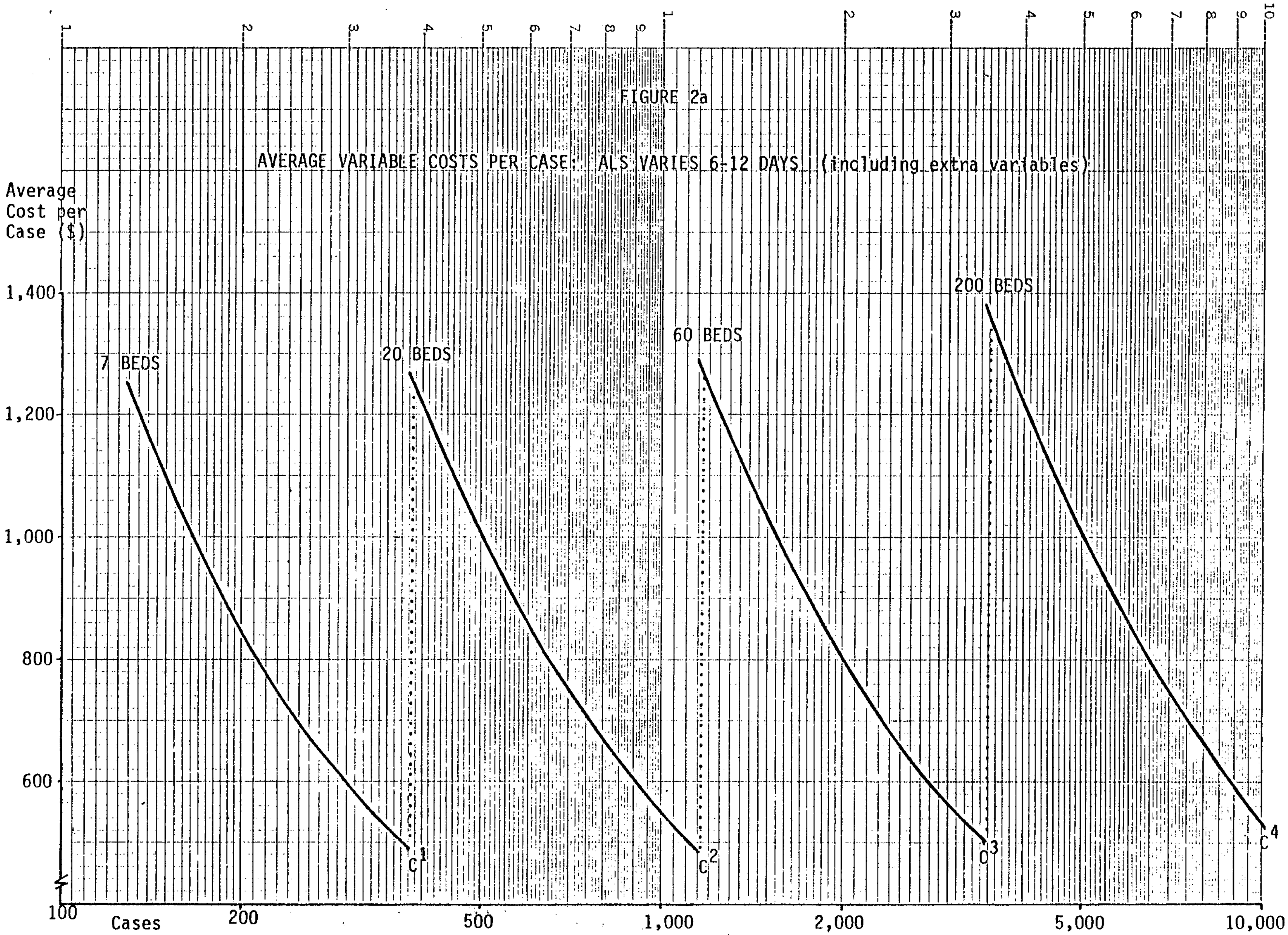


FIGURE 1a

AVERAGE VARIABLE COSTS PER CASE: ALS FIXED AT NINE DAYS (including extra variables)

FIGURE 2a

AVERAGE VARIABLE COSTS PER CASE: ALS VARIES 6-12 DAYS (including extra variables)



While the average cost behaviour of the average Manitoba hospital with the average Manitoba casemix is perhaps of the most interest, other groups of hospitals may be of interest as well; for example, urban hospitals, teaching hospitals, and rural hospitals. It may also be interesting from a theoretical perspective to examine any of these groups with different casemixes: i.e., what would it be like if the rural hospitals had fewer "nursing home" type casemixes; what would it be like if teaching hospitals passed over virtually their entire surgical load to urban non-teaching hospitals? Finally, since Figures 1/2 and 1a/2a keep casemix constant -- what is the effect of changing casemix as the hospital size grows -- a phenomenon which is highly likely?

Figure 3 shows a hypothetical set of average variable cost curves for urban hospitals, assuming the parameters of the 16 variable regression and an ALS which varies from eight days at 60 per cent occupancy to twelve days at 90 per cent occupancy. As expected, costs per case are higher than those of the average Manitoba hospital. However, since all other parameters are the same, the curves are similar. Costs rise dramatically when capacity is added and fall steadily as it is absorbed by an increasing caseload. Interestingly, the envelope to the curves rises first, then falls as the BEDSSQ variable takes on importance in determining the location of the curve. This aspect of the model, however, is of secondary importance since the significance of scale (as previously discussed) is not anywhere near that of capacity utilization.

For rural hospitals (Figure 4), average costs are lower, and

FIGURE 3

AVERAGE VARIABLE COSTS PER CASE: ALS VARIES 8-12 DAYS, URBAN HOSPITALS

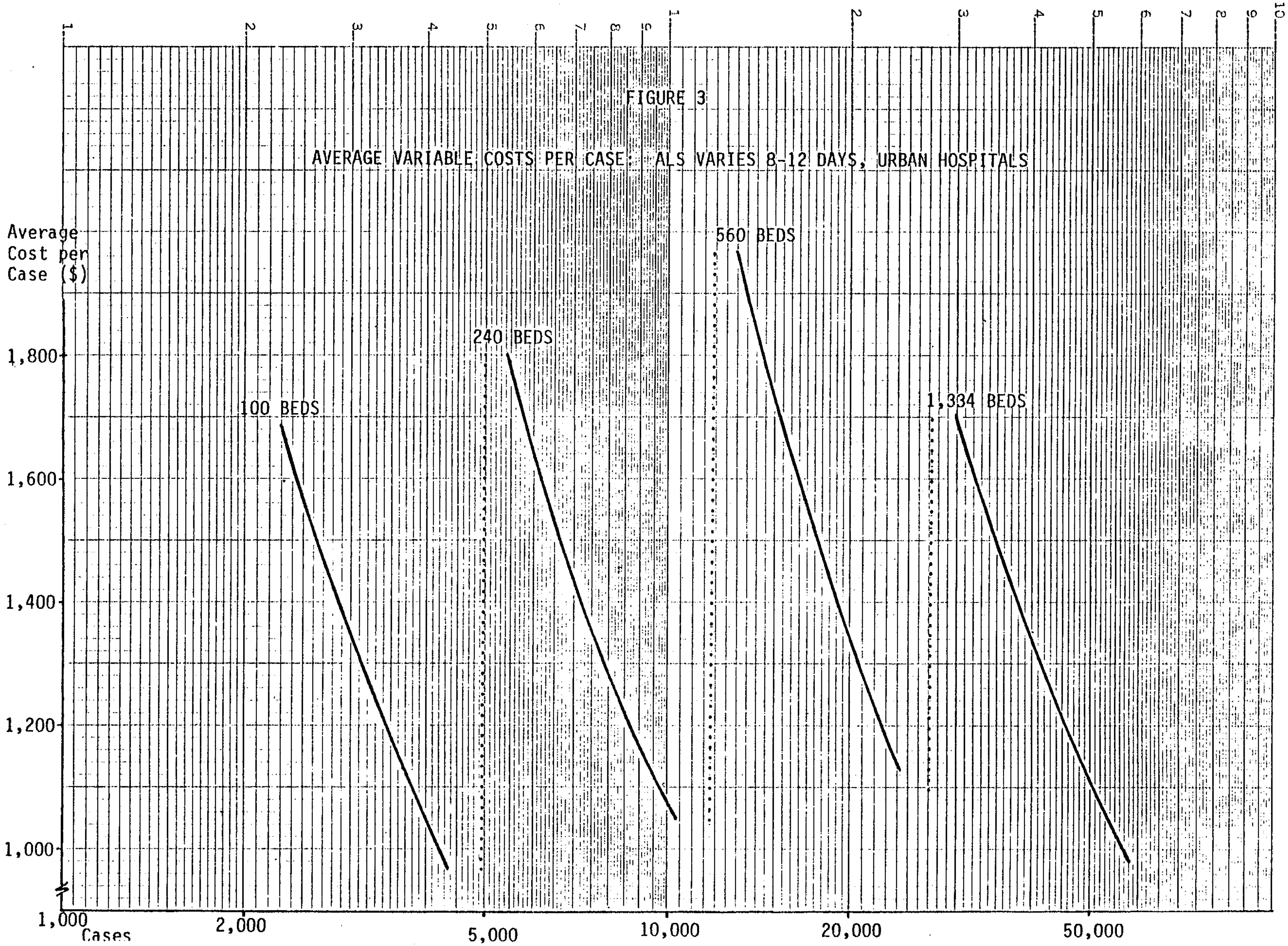
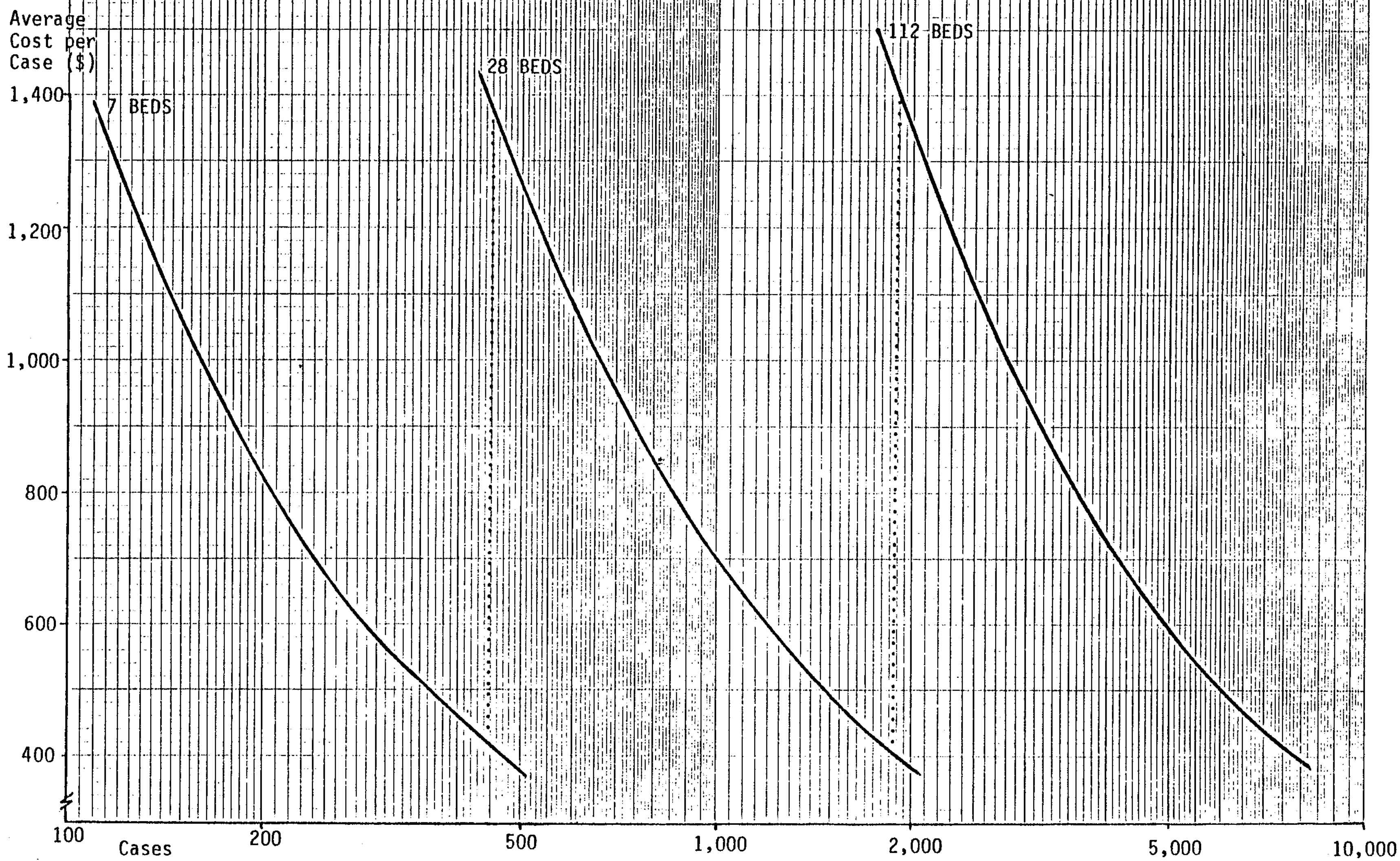


FIGURE 4

AVERAGE VARIABLE COSTS PER CASE: ALS VARIES 4-12 DAYS, RURAL HOSPITALS



again, the same general shape of curves obtained.

Potential policy applications are significant. For example, one would be able to judge more accurately the effect on expenditures of changes in utilization brought on by changes in population, changes in methods of delivering health care (i.e., making substitute services available) or administrative closure or addition of beds. One would be able to estimate the fiscal effects of hospital district amalgamation, closure of certain facilities, and caseload transfer. It would even be possible to develop a cost minimization model of hospital network location subject to constraints of availability, safety, maximum acceptable private transportation cost, etc.

Some typical policy applications are discussed below.

The policy issue of whether or not to require small hospitals to transfer long-term patients from active to chronic care cannot be entirely satisfactorily resolved using this model. An estimate was attempted using the parameters for 18-22 bed rural hospitals. It was assumed that all malignant neoplasm cases and circulatory cases would be transferred to nursing home care, and beds closed in these hospitals to the point that the same average caseflow of 30.5 cases per bed would be maintained. Average size of these hospitals would fall from 19.3 beds to 16.5 beds. Average cost per case would fall from $754 to $650 per case, representing a saving over present costs of nearly one million dollars over all fifteen Manitoba hospitals in that size category. That this degree of cost savings could be achievable is not surprising since malignancies and circulatory ailments are high cost cases. However, even if nursing homes could provide convalescent care for these cases at less cost than the small rural hospitals, the savings indicated by use of this model are overstated. One cannot simply transfer hospital cases to a nursing home without initial hospitalization for evaluation, diagnosis, preparation of treatment plan and, sometimes, intensive care. These functions occur in the early days of a hospital stay and these days are normally more costly than the convalescent days. The transfer to nursing homes could more realistically occur only once they had been completed. Hence, to estimate the effect on costs of realistic transfer of convalescent patients requires that length of stay for each casetype be explicitly included in the model.

A more realistic problem involving rationalization of care provided in small rural hospitals is the economics of hospital consolidation. In this case, the model provides some clues as to the likely cost outcome of decisions to consolidate.

There are literally dozens of situations where this type of transfer could take place. In some cases it would, of course, be risky to apply a receiving hospital's cost parameters to cases from another hospital because historically the two have served different "severity" of case or provided different "intensity" of care. For example, transferring the caseload of a small rural hospital to the Health Sciences' Centre would not necessarily mean that the Health Sciences' Centre's marginal case costs would be relevant. However, among rural hospitals, to assume similarity of intensity or severity is reasonable.

Several groups of hospitals were selected as having particular relevance to analysis of desirability of consolidation and a method to determine the approach of consolidation was developed. In order to demonstrate the approach, an example is given using hospitals numbers 19, 24, and 68. These three hospitals are all located in very close proximity to each other. In fact, they are so close that caseload transfer and closure of one facility is technically (if not politically) feasible. The relevant operating data for each of the hospitals are shown below:

	Hospital 19	Hospital 24	Hospital 68	Total
Actual 1977 AC ($)	898.00	906.00	1,289.00	
Beds	16	10	19	
Caseflow	21.50	27.60	12.53	
ALS	11.83	9.77	11.44	
Occupancy Rate (%)	72.63	75.99	41.16	
Estimated Average Cost	1,116.89	904.77	1,912.18	
Costliness Index (2)	1.0097	1.0152	1.3468	
Marginal Cost	160.20	111.04	239.46	
Total Cost (Actual) ($)	308,912	250,056	306,872	865,840
Total Cost Estimate ($)	384,210	249,717	455,233	1,089,160

At least one, and possibly two, of these hospitals is underutilized. Hospital 68 is almost assuredly underutilized. Hospital 19 has a reasonably high occupancy rate, but this is due, in part, to its high average length of stay. Its caseflow is well below the average for this type of hospital (about 30 cases per bed per year). These considerations of underutilization are independent of the rate of utilization among the population served by the hospital. The organization of health care services in rural areas is such that hospital utilization rates in excess of 250 cases per 1,000 persons per year are not unusual -- as compared with 100 to 110 for urban areas.

Consequently, it might be argued that one hospital should be closed to save its high average costs and its caseload distributed among the other two, where costs would be incurred at the margin. But which hospital should be closed, and how should the caseload be distributed among the remaining hospitals? The regression analysis provides a framework for these decisions, the objective being to maximize the total reduction in the cost of providing services.

Option 1. Close the hospital with the highest average and marginal costs (#68) and divert three-quarters of its caseload to #19 and one-quarter to #24. Assume that for every five percentage points of increase in occupancy, average length of stay decreases by one-half day to a minimum of 9.5 days.

Hospital #19 will take 178 of #68's cases, and #24 will take 60. Average length of stay at #19 will be 10.08 days and occupancy will rise to 90.11 per cent. Caseflow will be 32.62, total cases 522, and casemix will be:

INFPAR	.0326	MALNEO	.0211	NEURPSY	.0785
OBS	.0441	CIRC	.1571	SURG	.0805
TREM	.0498	RESP	.1609	SPESURG	.0115

Hospital #24 will take 60 cases. Its occupancy will be 83.25 per cent, and ALS will be 9.04. Caseflow will be 33.60, total cases 336, and casemix:

INFPAR	.0297	MALNEO	.0268	NEURPSY	.0595
OBS	.0804	CIRC	.1012	SURG	.0952
TREM	.0625	RESP	.1696	SPESURG	.1369

It is possible that occupancy rates of this magnitude cannot be maintained in a small hospital over a long period of time. In fact, applying a Poisson probability distribution to admissions and a negative exponential curve to average length of stay suggests that hospitals of this size should have an occupancy rate of no more than 60 to 70 per cent to have less than a five per cent probability that a patient will be turned away. This probably understates the desirable occupancy rate, since length of stay can be manipulated (for example, Ste.Anne Hospital has an average length of stay of only 5.1 days) and some caseload can be planned thus eliminating part of the stochastic element. Nevertheless, it is conceivable that in order to effect this type of consolidation, new beds would need to be added to one or both of the remaining hospitals, thus inducing new capital costs.

Applying the regression formula to the two new hospitals, the new estimated total cost for serving the 1977 caseload is $677,000. This represents a substantial saving over the $1,089,000 estimated for service by the three hospitals.

The effect of the possible requirement to add new beds to the two remaining hospitals is uncertain. If occupancy rates no greater than 60 per cent are desired and the same average lengths of stay are maintained, then consolidation would require that eight beds be added to #19 and four beds to #24. If the hospitals could manage at an occupancy rate of 75 per cent, then only four beds need to be added to #19 and one to #24. The additional capital cost is made up of the present value of undepreciated capital services that could be obtained by leaving #68 in service. This may be modified by any ability of the other hospitals to add beds without adding plant. Finally, the lower caseflow of the larger hospitals would act to increase operating costs, thus reducing the value of the savings calculated above.

Option 2. Close the smallest hospital (#24) and distribute 75 per cent of its cases to #68 and 25 per cent to #19. The same assumption about the relationship between changing ALS and occupancy rate apply.

The new operating data for hospitals #19 and #68 are shown below:

	#19	#68
BEDS	16	19
CASES	413	445
ALS	11.18	9.48
OCC.RATE	79.09	60.80
CASEFLOW	25.81	23.42
INFPAR	.0281	.0404
OBS	.0582	.0562

	#19	#68
TREM	.0557	.0517
MALNEO	.0169	.0292
CIRC	.1429	.1281
RESP	.1525	.1775
NEURPSY	.0581	.0831
SURG	.0969	.0764
SPESURG	.0339	.0854

The effect on average cost is to produce a per case cost of $959.26 in #19 and $1,087.06 in #68. Total cost, therefore, is $880,000 and the resultant savings are somewhat less than for Option 1. Transferring all of #24's cases to #68 makes only a slight difference, yielding a total cost of $877,000. Capital cost implications would be much less likely if hospital #24 were to be closed.

Option 3. Close hospital #19 and transfer all its cases to #68. Clearly, costs at #24 would remain at their present level. The new data for #68 would be:

BEDS	19	INFPAR	.0344	RESP	.1632
CASES	582	OBS	.0412	NEURPSY	.0825
ALS	8.49	TREM	.0498	SURG	.0773
OCCUPANCY	70.98	MALNEO	.0223	SPESURG	.0120
CASEFLOW	30.63	CIRC	.1581		

The new average cost for #68 is $850 and the new total cost for all cases is $744,000. While this represents a greater total cost than that of Option 1, it is unlikely to have any of the capital cost implications and consequently could turn out to be the most appropriate option.

It appears that within rather wide limits, the distribution of cases from a closed hospital among the two remaining in service does not have a major effect on the potential cost savings. What appears to be most significant is that elimination of cases at one service centre enables underutilized nearby centres to serve these cases at their marginal cost which, according to the present analysis, is somewhere in the neighbourhood of 12 to 15 per cent of average costs. The relatively small impact of distribution is fortunate, since it would be difficult to specify or control that distribution. It depends on local and regional ties and the influence of individual physicians. The latter variable is particularly subject to considerable fluctuation over, say, a five to ten year period.

The same approach applied to other groups of geographically close hospitals suggested that consolidation could be productive of significant savings. For example, hospitals #47, #77, and #14 required $1.6 million in public funding of operating costs. The model suggests that 12 per cent of costs could be saved by consolidation. Similarly, 22 per cent of the $1.1 million in operating costs of hospitals #23, #56, and #69 could be saved by consolidation.

Unfortunately, despite the cost advantages of consolidation (both intuitive and as suggested by this application of the model) it is unlikely that it could be undertaken on any significant scale. The argument usually mustered against closure or change in role of a small local hospital is that it brings about a reduction in quality of care to the local populace. The disadvantage of less immediate accessibility is apparent, and the additional private costs of transport over longer distances, while probably not significant to the individual compared to the overall costs of hospitalization, nonetheless represent a reduction in welfare caused by changes in public expenditure patterns. This, the affected individuals resist, naturally enough, through the political system which, in a small province, is highly responsive to this type of manipulation. Behind the concerns of reduced quality or access also lie such intangibles as community pride and less intangible factors such as the importance of even a small hospital to the community's economic base and labour market. The arguments in favour of consolidation appear much more abstract to those affected, e.g., that public expenditures on health care should be made both efficiently and equitably and that many individuals live in other communities even further removed from acute hospital care facilities.

Thus, as a tool to reduce expenditures with minimal impact on availability and quality of care, consolidation is probably infeasible for political reasons. Even faced with major demands for restraint, the political system will normally opt for across-the-board restraint, a move which is likely to have adverse effects on efficiency, equity and quality of care, but which is more saleable in that "everybody bears his share of the burden".

An application of the model which may be more politically saleable is to use the findings to develop targets for efficiency of individual hospitals and to assist hospitals in developing management programs to meet these targets within some realistic time period. Among the independent variables of the cost equation, some can be manipulated by management and others cannot. The excluded variables, by definition, account for the differences in actual and estimated average cost per case. Thus, the costliness index C^2 shown in Table 4-4 indicates the degree to which each hospital exceeds or falls below its expected cost and thus offers a measure of either productivity or degree of inappropriate factor utilization or both.[1] A number of approaches may be

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[1] While this analysis does not separate costliness into productivity and input efficiency components, there are relatively straightforward techniques which do. M.Feldstein (1968) found that 71 per cent of costliness variation among 177 British hospitals was due to productivity differences and only 18 per cent due to inappropriate input combinations. In Manitoba it is possible, particularly given the current budget system of hospital finance, that inefficient input combinations are built into many hospitals and perpetuated over the years. However, such could also be the case for productivity aspects as well.

used to identify important areas for management consideration.

First, the variables which are included in the model and which may be subject to management influence to achieve economies are: 1) caseflow; 2) adjusted length of stay; and 3) some of the casemix variables. Low caseflow is associated with underutilization of the hospital plant and quasi-fixed factors, therefore, as shown in the previous section, it is also associated with high unit costs. Normally, if management could exercise control over caseflow (through transferring convalescent cases or by attracting new cases) the result would not necessarily produce savings for the overall system. Attracting new cases would reduce average costs but increase total costs. Transfer of convalescent cases would transfer at least some of their costs elsewhere. Alternatively, closure of beds would increase caseflow but would not necessarily reduce either plant or quasi-fixed costs. The reduction of these costs in the short run could only be accomplished through consolidation as described above. In the longer run, however, it may be possible to close beds <u>and</u> to eliminate their associated quasi-fixed costs, thereby reducing the average cost of a hospital case.

Adjusted length of stay, as described earlier, reflects the average age of patients served by the hospital during the year and, according to the model, is associated with higher average costs (about $17 per case for each day's increase over the provincial average adjusted length of stay). This is not a significant item in the overall cost picture and is not entirely amenable to management influence. In some cases it is possible that a high proportion of elderly patients contributes to higher costs because of greater length of stay and this length of stay could be reduced by transfer of convalescent patients. The present model does not permit the extent of this pehnomenon to be identified. A multi-equation model, incorporating length of stay and patient age classifications for various casetypes would probably be required.

Similar comments pertain to the influence of some of the casemix variables. For example, rural hospitals which are underutilized tend to be characterized by a large proportion of cases in the circulatory or respiratory categories. The former has a positive parameter. For the average Manitoba hospital, an increase of one percentage point in the proportion of circulatory cases has the effect of increasing average case cost by more than six dollars per case, i.e., it increases the average hospital's total operating costs by nearly $12,000. These cases are also often associated with long convalescent stays, and it may be within the power of management to reduce them by judicious use of other health care resources.

The scope for management to increase efficiency by managing the age or casemix of hospital patients is admittedly small. Management of caseflow may not always be possible, and where it is, quasi-fixed costs may not always respond to management except possibly in the longer run. However, in cases where a response is possible, the efficiency gains could be quite substantial. Comparing the costliness index figures C^1 and C^2 in Table 4-4 gives some idea of the possibilities.

C^1 shows the ratio of expected average cost to actual average cost assuming each hospital's caseflow is equal to the provincial average and all other variables take on their empirical values. C^2 is the same ratio with casemix included as a variable. Thus, the difference between the values on C^1 and C^2 indicates the extent to which differences in caseflow account for differences in average cost. For example, hospital #41 has average costs which are 41 per cent higher than expected for its size, type, casemix, and age of patients. However, when its low caseflow is accounted for, its actual costs are actually less than expected by about 14 per cent. If quasi-fixed costs could be eliminated along with beds removed to increase caseflow, about 40 per cent of the hospital's costs could be eliminated.

The effect of caseflow is equally apparent in the opposite direction. Average cost at hospital #26 is 42 per cent below what would be expeected, given its size, type, casemix, and patient age. This is entirely due to its very rapid case turnover, however, since, when actual caseflow is included in the equation, average cost is almost exactly what would be expected.

Given the small magnitude of benefits achievable by manipulating patient mix and the less than certain outcomes of manipulating caseflow, however, to concentrate on factors not included in the model's specification may be more fruitful. Here, the costliness index C^2 represents only a measure of the distance the hospital is from its target -- which may be set at 1.0000 for convenience's sake, or even less than 1.0000 given that this has already been achieved by many hospitals. Unity, after all, represents only an average, and efficiency, in the present context, is measured as deviation from the average.

Once the target has been set, an examination of productivity and factor combination configurations underlying the deviation must be undertaken. This particular model offers no concrete clues, but the methodology may. For example, it may be possible to derive costliness indices based on nursing costs, on supply costs, and so on to identify the elements of cost which most contribute to the deviation. Alternatively, simpler methodologies may be more appropriate. One possibility is the construction of indiçes which indicate factor utilization relative to some average.

It should always be remembered that when assessing costliness indices that they are relative. Regardless of the relative contributions of productivity and input efficiency to costliness, a low costliness number reflects a situation that is desirable in a relative, but not necessarily absolute sense. Costliness relates actual costs to an "average" which may not in itself be desirable. It should not be overlooked, too, that even where a hospital produces cases efficiently it may still be producing many unnecessary, or at least avoidable, cases. Technically efficient production represents only two aspects of Pauly's tetralogy of economic efficiency.

Policy applications of this model should not be restricted by limiting consideration to present utilization and hospital characteristics. The model offers significant planning potential. For example, the consolidation exercises discussed earlier could be made to relate to a scenario which could be set for five or ten years into the future. Such approaches offer the possibility of more efficient use of existing hospital plant and greater timeliness of decisions to add to capacity.

Health care planners generally have good, if sometimes merely intuitive, understanding of the variables affecting hospital utilization and how those variables are likely to behave in the future. If it is known that a certain suburban area of the City of Winnipeg will undergo considerable growth in the next ten years, and the likely demographic composition of the new population is also known, then, the model permits an estimate of expected costs of providing hospital service under different assumptions. One such assumption might be the construction of a new hospital. Another would be addition to existing hospitals.

In rural areas, changes in the population and age mix of hospital users can also be studied for their impact on utilization and costs. Here, too, alternative means of meeting expected utilization can be studied and appropriate steps taken. Even if such an approach does no more than enable medium and long term prediction of costs, it provides a useful budget planning and management tool.

CHAPTER 5

CONCLUSIONS

The primary purpose of this analysis was to show that overall costs in the hospital sector can be and are influenced by government planning, funding, and review policies, and by the environment in which care is delivered, e.g., age distribution of population, casemix, etc. The secondary purpose was to explore some of the problems in econometric methodology used in hospital cost analysis.

The influence of government policy (or, in some cases, lack thereof) on overall hospital costs is quite apparent from the nature of the relationships between average costs and some of the variables used in the analysis, particularly caseflow. The failure of these principal variables to explain more than eighty per cent of total costs may be due in part to the specification of the model. However, it is almost certainly also due to factors not specifically included in the analysis, notably efficiency and factor combinations. The wide range in costliness of different hospitals attests to the importance of these excluded factors.

The wide range of costliness indices also suggests that, whatever the objective function of hospitals, it is not one which consistently leads to cost minimization. The variation in average cast costs, even once the most likely determinants (apart from efficiency) are accounted for attests to this. The results also do not accord systematically with the thesis that hospitals seek to maximize output. There is wide variation in caseflow among hospitals of similar size; a variation which would not be expected if hospitals attempted to maximize output.

We cannot say conclusively that hospitals do not attempt to maximize "quality of care" at a given level of output, since explicit measures of quality were not undertaken. However, even if quality is not a maximand it almost certainly is a constraint in a hospital's objective function.

The behaviour of hospital costs accords quite well with Berki's theory that hospitals have multiple and competing objectives which are "satisficed", subject to a maximum acceptable operating deficit and capital budget constraints. Hospitals, by and large, do not appear to produce optimum output; for the most part they are underutilized. Moreover, the remaining variation in costs suggests that "prices" are higher than they would be if hospitals were net revenue or output maximizers. The system of reimbursing hospitals has elements of bilateral monopoly that can perpetuate inefficiences. Since bargaining between the monopolists (the hospital) and the monopsonist (government) is still to a large degree determined by historical factors and incrementalism still plays a role in determining hospital budgets, the inefficiencies that may be engendered by the hospital's behavioural characteristics are compounded.

The evidence shown in this analysis indicates that such objectives likely play a significant role in hospital budgeting. While prospective budgeting as is practised in Manitoba is almost certainly a superior alternative to cost-based or charge-based reimbursement, it, too, leaves considerable room for discretionary spending. Even ever-tightening restraint since 1976 appears to have left considerable discretion in the system. This is not surprising either, since the hospital has some limited freedom to alter both quantity and quality of care provided.

The results of this analysis are clearly consistent with market failure on several fronts on the one hand, and the failure of government policy to compensate for market failure on the other. The absence of such Pareto optimum conditions as perfect competition, free entry, competitive availability of information, absence of technical externalities and consumer ability to evaluate utility points to a significant, and probably greater than average, degree of market failure. The wide ranges in degree of plant utilization and in costs of care indicate that government policy has not yet made up for the market failure.

Yet it has long been recognized that government is usually an imperfect vehicle for rectifying these complex deviations from market optimality (Fraser, 1970). As the difficulties encountered in the present analysis (and other similar analyses) attest, the cost of appropriate information to government is very high. The possibility of designing an output-oriented reimbursement system which is efficient, equitable, and understandable to the affected public is remote. Systems such as those proposed by Ro and Auster (1969), Lave et.al.(1973), Dowling (1974), and Walker (1974) suffer from deficiencies in one or more of these desirable qualities, and it is not yet clear that the gains made by such systems would outweigh the administrative costs and difficulties.

The policy measures recommended as an outcome of the present analysis are not so ambitious. They are not formally or rigorously related to output, but rather to individual hospitals and the expected economic impact of key variables on them. They are not definitive, but are, in most cases, merely experimental. However, they have the virtue of relative administrative simplicity and, at least, a move towards equity.

The differences in caseflow and their impact on costs, which are the hallmark of this analysis, are certainly a function of, and amenable to, application of government policy. If government policy were to focus on planning facility capacity and availability for anticipated caseflow, the effect on hospital costs could be substantial over a period of several years. Thus, the signal importance of this variable is more eloquent of the possibilities of future government policy than of present failures.

Environment, by which term is meant the demographic structure of the population and its associated illness patterns, also has had an effect on the costs of providing care, although not as much as might have been expected. When the model was specified as a function of case-mix only, our particular specification of casemix accounted for about 19 per cent of variation only (see Regression #28, Appendix V) compared to 47 per cent when caseflow was the only independent variable (see Regression #25, Appendix V). Moreover, there is considerable multicollinearity between casemix and other variables including FLO, BEDS, and ADJLOS. Consequently, it is possible that casemix variables account for substantially less than 19 per cent of cost variation.

In the version of the model finally adopted, casemix was represented by three principal components accounting for 75 per cent of variation in the original specification. These components accounted for .145 per cent of average case cost variation when only casemix variables were considered, and some eight per cent when all other variables were included. Clearly the specification of casemix using principal components allowed some casemix influence to be attributed to other factors; but not likely more than three or four per cent of the overall variance.

The age and sex distribution of the various hospital populations also did not influence costs to the degree anticipated. The ADJLOS variable explained only 5.3 per cent of average cost variation when it alone was regressed against the log of HOSPAC (see Regression #15, Appendix V) and only 0.3 per cent when it was fitted into a complete model. BEDS and BEDSSQ added 12.0 per cent and 9.9 per cent when added to complete models -- values which approximated their simple regression R^2's. However, if the models included the other environmental hospital variables (URBAN, TEACH, EXTCU) the effect of BEDS and BEDSSQ was substantially reduced. In fact, in a model where caseflow alone accounted for 47 per cent of variance, all other variables added only 32 per cent (see Regression #23, Appendix V). Multicollinearity means that the actual contributions could be somewhat greater or somewhat less, but the relative positions are not likely to change.

Moreover, the parameters associated with most of the "environmental" variables were so small that they did not produce large changes in costs over the range of variable variations among Manitoba hospitals.

Certainly BEDS, ADJLOS and EXTCU were smaller than expected.

Despite the problems involved in estimating the model, the significance of caseflow in virtually all specifications is sufficient to impress on planners the importance of this variable. Nevertheless, it does not obscure the fact that the model would benefit from refinement.

One refinement would be to break the effect of caseflow out into those of occupancy rate and those of length of stay. This could further elucidate on the possibilities of consolidation or the value of long term reduction in hospital size and staffing. However, this type of analysis begs for the development of a simultaneous model that explains length of stay (a function of patient age, casemix, hospital type, etc.) as well as costs. Caseflow might also be endogenously determined. Such a model would quite possibly be an improvement over the present model, both in terms of explaining cost variation and developing policy. However, given some of the severe problems experienced in the present analysis, it is beyond the scope of this work.

Specification of a system of equations is unlikely to solve all the problems associated with cost estimation. The issue of product heterogeneity, here addressed using casemix and some hospital role dummies variables, and elsewhere by using hospital service mix, is far from resolved, although Evans' approach has been the most promising to date. Models with a certain degree of multicollinearity or weak parameters may be usable for some policy purposes, but they are less useful as contributors to our understanding of how hospital costs are influenced.

This work has taken one approach to multicollinearity, but only partly resolved the problem. While it is not likely that different approaches to specification of the heterogenous product could reduce multicollinearity substantially, some improvement may be possible. However, intuitively it seems unlikely that multicollinearity can be eliminated entirely without the use of principal components or the Evans information theoretic approach, both of which sacrifice some explanatory power.

Yet work towards superior specification of hospital product should also proceed for other reasons. One is that plausibility of casemix or similar variables would be improved. Another is that a better fit of the data may be achieved.[1]

In order to experiment with different specifications is would be desirable to have a much larger sample. Using all of Canada's acute care hospitals as a sampling frame introduces some new difficulties. Provincial reimbursement systems, while fundamentally similar, have, no doubt, their individual peculiarities and subleties. For example, differences in factor prices are likely to be significant across regions. Nevertheless, these problems can be overcome and the larger

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[1] Feldstein's work should caution anyone who thinks that a less aggregate casemix structure would drastically improve data fit. His nine case model yielded R^2 = .275 while his 28 case model had R^2 = .32. The improvement was statistically significant but not intuitively important, especially considering the greater computational difficulties associated with larger casemix specifications. On the other hand, the information theoretic technique of Evans and Walker (see Chapter 2) shows considerable promise. This, however, does not mean that Feldstein's inference was wrong; it could merely have been a result of his particular data.

frame would permit more detailed experimentation.

A larger number of hospitals would also permit grouping of hospitals into more homogeneous categories for economic analysis (Berry, 1973). In the present case, Manitoba's urban hospitals are so different from the rural facilities that they should, properly, be analyzed separately. Use of dichotomous variables is really only a compromise since they shift the intercept of the explanatory equation, but not the structure of its hyperplane. Only inclusion of a much larger group of hospitals would permit separate analyses for more homogeneous groups.

Incorporating all Canadian hospitals into the analysis runs the risk of obscuring some provincial peculiarities and losing some relevance for provincial policy purposes. This is probably a risk that can be accepted, given the similar policy problems faced by each Canadian province. A better specified and functioning Canadian model could supplement less reliable provincial models (which would, however, be more sensitive to provincial peculiarities) in policy development.

APPENDIX I

ALLOCATION OF IDC DISEASE CLASSIFICATIONS INTO CASE TYPES

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ALLOCATION OF IDC DISEASE CLASSIFICATIONS INTO CASE TYPES

NON-SURGICAL (DIAGNOSTIC CODES)

Infectious and Parasitic	001-136
Obstetric and Newborn	630-678, 760-779
Trauma and Emergency	800-999
Malignant Neoplasms	140-209
Circulatory Disorders	390-458, 746-747, 782
Respiratory Disorders	212, 231, 460-519, 748, 783
Neurological/Psychiatric Disorders	225,238.1-238.9, 290-358, 740-743, 780-781, 790-791, 794
Gastro-enterological Disorders	211, 230, 527-577, 750-751, 784-785
Genito-urinary Disorders	214.1, 217-223, 233-237, 580-629, 752-753, 786, 789
Residual	All codes except those listed above

SURGICAL (SURGICAL CODES)

SPECIAL SURGERY	0.10-03.5, 03.9-04.6, 04.8, 05.0, 05.1, 05.9, 07.1, 07.3-07.9, 08.0-08.9, 09.2-09.4, 09.9, 10.3, 11.0-11.3, 11.5-12.1, 12.3-12.6, 12.8-13.9, 16.5, 17.5, 17.6, 18.1-19.9, 22.0-22.9, 24.2-24.5, 25.0-26.0, 26.3-26.9, 30.0-32.4, 33.1-36.3, 39.4, 39.5, 41.1, 41.2, 41.9, 43.1-43.7, 46.4, 47.3, 47.4, 50.2, 52.1-52.3, 54.2-54.6, 56.3, 61.3-61.5, 65.4, 65.5, 68.3, 68.4, 71.2, 71.4, 71.5, 74.5, 74.6, 75.1, 75.2, 75.4, 76.8, 80.0, 80.1, 81.0-81.3, 81.6, 81.9, 82.3-82.5, 84.0-84.2, 84.4, 84.6, 85.6, 85.7, 86.5, 87.9, 88.0-88.5, 90.4-90.5, 96.6, 99.3-99.6.
OTHER SURGERY:	All other surgery codes except those listed for special surgery.

APPENDIX II

HETEROSCEDASTICITY IN THE DATA

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HETEROSCEDASTICITY IN THE DATA

Heteroscedasticity occurs when the error terms in the regression model cannot be assumed to have the same variance. In effect, when heteroscedasticity occurs, the confidence with which the parameters of the model may be accepted is overestimated where the error variance is relatively larger.

There are several ways of testing for heteroscedasticity in the data. One is to perform separate Spearman rank-correlation tests with the error residuals of a regression analysis and each independent variable. Should the rank relationship be non-random, heteroscedasticity is indicated. The Goldfield and Quandt test performs two separate simple regressions between each independent variable and the residuals, one regression for independent values below their medium and one for those above. Significant differences in the regression parameters indicate heteroscedasticity (see Koutsoyiannis, 1973).

Feldstein (1968) adopts an approach which tests for heteroscedasticity using the dependent variable. The ordinary least squares (OLS) estimates of the dependent variable are ranked from lowest to highest and divided into quantities. Each estimate is associated with its residual. Then separate variances are calculated for the residuals in each quartile. The variance of all residuals is also calculated. Then the variances of the four quartiles are tested for significant differences which, if found to exist, indicate heteroscedasticity.

The test used here is the general likelihood ratio test of the equality of several variances (Mood, 1950). The formula for the test is:

$$\lambda = \frac{\prod_{q=1}^{4} (\hat{\sigma}_{uq})^{\bar{n}_q}}{(\hat{\sigma}_u)^{n}}$$

where $\hat{\sigma}_{uq}$ = the standard deviation in the residuals in quartile q

$\bar{n}_q$ = the number of observations in quantile q

$\hat{\sigma}_u$ = the standard deviation of the entire sample

n = the number of observations in the entire sample

The expression $-2 \ln \lambda$ is distributed as χ^2 with three degrees of freedom.

The general likelihood ratio test was applied to the results of an early estimate of the parameters.[1] This estimate had yielded an R^2 of .67, $F = 12.57$ and significant t values for most variables. The test, however, indicated substantial heteroscedasticity. The expression $-2 \ln \lambda$ was equal to 24.46 with $\chi^2_{.005} = 12.84$.

The normal procedure in dealing with heteroscedasticity is to weight each observation (all variables) by the standard deviation of its error estimate. Since, in practice the standard devisions are unknown, the equivalent transformation is to divide each of the terms in the normal equation by X_i^2 where Xi is the variable that is causing the heteroscedasticity, e.g., Xi is systematically associated with the error variance (see Wonnacott, 1970).

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[1] See Regression #6, Appendix V.

However, the general likelihood ratio test does not indicate which of the independent variables is causing the heteroscedasticity. It does provide an approach for weighting for heteroscedasticity. However, it was felt that a check in the relationship between the residuals and at least some of the independent variables was merited before applying the technique.

The general likelihood ratio test showed that high values of the residual were associated with high values of the predicted dependent variable (HOSPAC). This lends plausibility to the hypothesis that independent variables which are highly correlated with HOSPAC are heteroscedastic.

There are no _a priori_ grounds for believing that any of the casemix variables are correlated with the error variances. The casemix variables are all expressed as proportions and were expressed that way primarily to avoid problems of heteroscedasticity. Moreover, none correlates with HOSPAC more than $|.26|$ and most correlation coefficients are less than $|.10|$.

The independent variable most strongly correlated with HOSPAC was FLO (R = -.61). The Spearman rank correlation test was applied to the relationship between FLO and the residuals. The coefficient of correlation was only -.19, which is not significantly different from zero at the five per cent level. The same test was performed on rural and urban hospitals separately. The coefficients were -.27 (rural) and .96 (urban). These results suggest that heteroscedasticity results from an interaction of the independent variables and is not traceable to a single variable. Where it may be traceable (as in the case of the dichotomous URBAN variable) there are an insignificant number of hospitals involved. Hence it would be inappropriate to weight each observation for heteroscedasticity that is most pronounced in urban hospitals. On the other hand, it would be extremely difficult to determine appropriate weights to counter heteroscedasticity caused by the interaction of a number of variables. In practice it would be complex, but perhaps possible; in theory it would not be appropriate. Thus Feldstein's weighting approach appears to be as appropriate as any to deal with heteroscedasticity.

This is the method of normalized weighting. Four weights are calculated and applied to each of the quartiles. The weights are calculated using the error variances of each quartile according to the formula:

$$Wq = \frac{1}{\hat{\sigma}uq} \div \frac{1}{4} \sum_{q=1}^{4} \frac{1}{\hat{\sigma}uq}$$

where: Wq = the normalized weighting for the observations in quartile q.

Thus, the observations in each previously assigned quartile were weighted by the following normalized weights (so-called because their average is unity):

q_1 = 1.19117

q_2 = 1.30379

q_3 = .991985

q_4 = .513048

The analysis using the full set of variables was repeated, this time with each quartile transformed as previously.[1] The new λ was equal to: .0705 with

$$-2 \ln\lambda = 5.3039 \qquad X^2_{.10} \ (3d.f.) = 6.25$$

Thus, some heteroscedasticity remained, but it was not statistically significant at the ten per cent level. If this probability was considered inadequate, it is possible to repeat the entire procedure. After a second iteration it is unlikely that the X^2 test would reveal significant differences in variances, even at the fifty per cent level.

In fact, further weighting of the data for heteroscedasticity was not done. The first analysis with transformed data showed other problems, including implausibility of some of the parameters (casetype costs) and persistent multicollinearity. In order to address these problems, a logarithmic specification of a radically transformed model was adopted. This is described in the succeeding subsections. Of interest here, however, is that that these transformations had the fortunate effect of eliminating virtually all traces of heteroscedasticity. In the model specification which was finally adopted the expression $-2 \ln\lambda$ was equal to 2.9656 with $X^2_{-.25}$ (3d.f.) = 4.11. [2]

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[1] See Regression #13 i), Appendix V.

[2] See Regression #24, Appendix V.

APPENDIX III

MULTICOLLINEARITY IN THE DATA

APPENDIX III

MULTICOLLINEARITY IN THE DATA

Multicollinearity in the model was a much more difficult and persistent problem than heteroscedasticity. The most serious multicollinearity occurred among the casemix variables and it was this that occupied most of the attention devoted to the multicollinearity problem. In addition, some multicollinearity was observed between the urban and teaching dichotomous variables and some of the casemix variables.

Specification of a model including a sizeable number of casemix variables can be expected to present problems of multicollinear relationships. If actual case numbers had been used in the specification, the appropriate procedure would have been to estimate total costs rather than average costs. This type of specification is open to both significant heteroscedasticity (since higher total costs will be associated with greater error variance as well as larger hospitals with more of all types of cases) and milticollinearity, since a hospital with more of one type of case is likely to have more of all the others.

If casemix is estimated using proportions, as was done in the present analysis, heteroscedasticity due to casemix specification is likely to be slight, if present at all. However, multicollinearity is not eliminated. There are reasons for believing that multicollinearity among the casemix proportions will be less significant than it is among the actual case numbers. Nevertheless, it is easily conceivable that hospitals with a high proportion of surgery might have a low proportion of general medicine cases. In fact, the comparison of urban and rural cases shown earlier demonstrates this point.

Surprisingly, Feldstein (1968) found little evidence of multicollinearity in his casemix proportions. Using a nine proportion casemix specification he found that only 17 of 36 correlations were statistically significant at the five per cent level, and many that were significant were still not highly correlated.

On the other hand, the Department of National Health and Welfare (1976) attempting a similar exercise with 1972 Manitoba data found multicollinearity to be so severe that they were forced to drop eight of eleven casemix variables and give up nearly half the observations, thereby losing the substantial base of their information.

The original specification of the present analysis included a twelve proportion casemix (eleven specifics, one residual) in an attempt to introduce a more medically meaningful specification. Collinearity showed up among many of the variables, both casemix and non-casemix, as is evident in Table 3-3. Focusing on the interrelationships among the casemix variables, 36 of 55 correlations are significant at the five per cent level and 24 of 55 at the one per cent level. Nine correlations exceed .50.

This substantial degree of multicollinearity is matched by the collinear relationships among the non-casemix variables. Of 15 correlations, nine or 60 per cent were significant at the five per cent level, seven (47 per cent) at the one per cent level, and four (27 per cent) exceeded .50. Again, this degree of collinearity is not un-

TABLE 3-3

SIMPLE CORRELATION COEFFICIENT[1] MATRIX ON HOSPITAL VARIABLES

	URBAN	TEACH	EXTCU	BEDS	FLO	ADJLOS	INFPAR	OBS	TREM	MALNEO	CIRC	RESP	NEURPSY	GASENT	GENUR	SPESURG	SURG
HOSPAC	.28	.40	.11	.31	-.61	.16	-.17	.08	.02	-.02	-.09	.06	.13	-.26	-.07	-.03	-.04
URBAN		.40	.42	.73	.16	-.22	-.34	.32	-.37	-.09	-.29	-.49	-.20	-.52	-.41	.62	.69
TEACH			.44	.68	.00	-.25	-.17	.35	-.10	-.06	-.23	-.26	-.04	-.27	-.20	.27	.25
EXTCU				.55	.24	-.20	-.18	.15	-.18	-.06	-.20	-.26	-.16	-.31	-.16	.35	.41
BEDS					.12	-.26	-.21	.25	-.26	.01	-.29	-.37	-.08	-.44	-.33	.44	.52
FLO						-.58	-.07	.37	-.05	-.22	-.40	-.31	-.23	-.13	-.13	.41	.45
ADJLOS							.02	-.50	-.10	.40	.72	.14	.15	.28	.22	-.31	-.39
INFPAR								-.23	.17	-.26	.11	.50	-.02	.11	.02	-.55	-.51
OBS									.06	-.23	-.52	-.49	-.14	-.26	-.23	.39	.41
TREM										-.09	-.23	.32	.23	.31	.24	-.48	-.51
MALNEO											.29	-.15	.17	.02	.07	-.02	-.04
CIRC												.13	.11	.33	.24	-.38	-.40
RESP													-.09	.19	.27	-.67	-.73
NEURPSY														.21	.26	-.28	-.29
GASENT															.47	-.48	-.48
GENUR																-.45	-.46
SPESURG																	.83
SURG																	

[1] If r > ± .22 correlation is significant at 5% level. If r > ± .29 correlation is significant at 1% level.

Source: Calculated from data supplied by the Manitoba Health Services Commission.

expected. Teaching hospitals tend to be urban hospitals and both urban and teaching hospitals tend to be large. Also, large urban hospitals tend to have a younger patient age profile since in Manitoba, the Winnipeg population is significantly younger than that of the rest of the province. However, multicollinearity among the non-casemix variables was not considered serious, since parameter estimates generally accorded with a priori beliefs, even though some had large standard errors. For policy related purposes, such estimates are acceptable (see Koutsoyiannis, 1973) and moreover, removal of some of these variables did little harm to overall results while improving the reliability of other estimates.

The least serious multicollinearity was that between the casemix and non-casemix variables. Here 39 out of 66 had correlation coefficients significantly different from zero at the five per cent level; 27 at the one per cent level. Only six were greater than .50. Some multicollinearity among these variables is to be expected. Large urban and teaching hospitals tend to have more surgical and obstetrical cases and fewer medical cases. Some of this collinearity can be reduced by reducing the collinearity among the non-casemix variables or by removing some of them. Removing collinearity among the casemix variables would also affect these relationships.

Collinearity among the casemix variables was no doubt in part responsible for the difficulty in interpreting the initial regression.[1]

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[1] See Regression #1, Appendix V.

Four of the casemix coefficients would have implied negative case costs for that casetype (casetype costs). Only four of eleven casemix coefficients were significantly different from zero. When only casemix variables were run against average case cost, again four of the eleven coefficients were significant and five would have yielded negative case type costs.[2] Thus, casemix proportion multicollinearity was considered the most serious multicollinearity in the model.

Once the original data had been transformed in order to reduce their heteroscedasticity, a systematic analysis was made of multicollinearity among the casemix variables. Various solutions to the problem of multicollinearity were tried and one, the principal components method, adopted. The analysis of multicollinearity was then extended to the non-casemix variables.

Table 3-4 shows the simple correlation coefficients among all the variables once the data had been transformed to reduce heteroscedasticity. Comparison of Table 3-4 with Table 3-3 shows that the pattern of correlation has changed but the overall degree has not. Among the casemix variables 29 of 55 (53 per cent) correlate significantly at the five per cent level; 27 of 55 (49 per cent) at the one per cent level, and eight exceed 50 per cent.

One test of whether or not multicollinearity is harmful to the model is whether or not the simple correlation coefficients are greater than the overall R^2 (Klein, 1970). The R^2 of the transformed HOSPAC and casemix variables was .245. On this basis 27 of 55 casemix correlations in the matrix in Table 3-4 pose "serious" multicollinearity

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[1] See Regression #5 c), Appendix V.

TABLE 3-4

SIMPLE CORRELATION COEFFICIENT MATRIX ON HOSPITAL VARIABLES

TRANSFORMED TO REDUCE HETEROSCEDASTICITY

	URBAN	TEACH	EXTCU	BEDS	FLO	ADJLOS	INFPAR	OBS	TREM	MALNEO	CIRC	RESP	NEURPSY	GASENT	GENUR	SPESURG	SURG
HOSPAC	.13	.06	.06	.11	-.02	.34	-.09	.19	-.08	.25	.30	-.13	.17	.05	.10	.21	.26
URBAN		.26	.25	.64	-.04	-.27	-.31	.14	-.39	-.18	-.29	-.46	-.27	-.41	-.36	.41	.47
TEACH			.20	.60	-.20	-.37	-.21	.01	-.25	-.15	-.28	-.31	-.18	-.32	-.27	.04	.01
EXTCU				.38	.20	-.05	-.11	.11	-.08	-.09	-.09	-.10	-.13	-.13	-.01	.33	.29
BEDS					.05	-.28	-.18	.16	-.28	-.13	-.31	-.33	-.19	-.35	-.28	.32	.42
FLO						.56	.37	.57	.53	.20	.32	.42	.33	.54	.48	.51	.45
ADJLOS							.36	.22	.41	.56	.87	.44	.49	.71	.63	.18	.19
INFPAR								.07	.36	-.07	.34	.63	.15	.32	.24	-.30	-.24
OBS									.26	.10	-.01	-.09	.17	.19	.16	.42	.48
TREM										.22	.27	.53	.47	.66	.51	-.16	-.13
MALNEO											.43	.07	.38	.37	.38	.14	.12
CIRC												.41	.44	.60	.58	-.06	-.06
RESP													.08	.50	.51	-.31	-.34
NEURPSY														.50	.41	-.01	.02
GASENT															.68	-.04	-.02
GENUR																-.07	-.06
SPESURG																	.81
SURG																	

problems.

Another test that can be used to indicate multicollinearity is the Farrar-Glauber test (Koutsoyiannis, 1973). The first step is a χ^2 test on the "standardized correlation determinant". The standardized correlation is simply a determinant consisting of all the simple correlation coefficients in the regression in the form:

$$\begin{matrix} rx_1, x_1; & rx_1, x_2 & \cdots\cdots\cdots & rx_1, xk \\ rx_2, x_1; & rx_2, x_2 & \cdots\cdots\cdots & rx_2, xk \\ \cdots\cdots & \cdots\cdots & \cdots\cdots\cdots & \cdots\cdots \\ \cdots\cdots & \cdots\cdots & \cdots\cdots\cdots & \cdots\cdots \\ rxk, x_1, & rxk, x_2 & \cdots\cdots\cdots & rxk, xk \end{matrix}$$

In the case of perfect multicollinearity all r's are equal to one and the value of the determinant is equal to zero. In the case of perfect orthoganality, only the diagonals are equal to unity; all other r's are equal to zero. Thus, the determinant is equal to one.

The quantity

$$- \quad n-1-\frac{1}{6}\ (2k + 5) \quad \ln D$$

where: n = number of observations;

k = number of regressors; and

D = the value of the standardized determinant

is distributed as χ^2 with $\frac{1}{2}k\ (k - 1)$ degrees of freedom (Koutsoyiannis).

The standardized correlation determinant of the casemix variables was found to be .01.

Thus, the test for the presence of multicollinearity is:

$$\chi^2 = -\left[80 - 1 - \frac{1}{6}(22 + 5)\right] \times \ln .01$$

$$= 343.085$$

$$\chi^2_{.025} \quad (df = \tfrac{1}{2}(11)(10) = 55) = 77.4$$

Thus, the assumption of orthoganality of these data can be easily rejected.

Once serious multicollinearity in the data has been shown to exist, the Farrar-Glauber test proceeds to identify those variables which are responsible for the multicollinearity. This is done by calculating an F value for each variable, using the formula:

$$Fi - \frac{R^2 i \,/\, (k - 1)}{(1 - R^2 i) \,/\, (n - k)}$$

$$i = 1 \ldots k$$

where: k = the number of explanatory variables

n = the number of observations

$R^2 i$ = the coefficient of multiple correlation among the regressors.[1]

The degrees of freedom are k - 1 (where k equals the number of casemix regressors) for the numerator and n - k (where n = the number of observations) for the denominator. This formula is nothing more than the standard F-test dressed up in a different form, and it shows the significance of the regression of each regressor in all other regressors.

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[1] See Regression #8, Appendix V for R^2's among regressors.

Then, as Table 3-5 shows, all variables indicated some multicollinearity when the F-test was applied. The most serious multicollinearity was associated with RESP, GASENT and the surgical casemixes.

TABLE 3-5

F-VALUES FOR INDIVIDUAL CASEMIX VARIABLES: FARRAR-GLAUBER TEST

	F-Value
INFPAR	7.35
OBS	5.07
TREM	13.29
MALNEO	3.46
CIRC	9.72
RESP	15.42
NEURPSY	6.64
GASENT	14.02
GENUR	10.10
SPESURG	16.32
SURG	15.05
F.05	1.98
F.01	2.60

A final step in the identification of multicollinearity is to calculate the partial correlation coefficients of each pair of individual independent variables and the associated t-values. This test shows the relationship between each pair stripped of the influence of all other casemix variables. Table 3-6 shows the partial correlation matrix and indicates significant relationships.

TABLE 3-6

PARTIAL CORRELATION COEFFICIENTS: CASEMIX VARIABLES

	OBS	TREM	MALNEO	CIRC	RESP	NEURPSY	GASENT	GENUR	SPESURG	SURG
INFPAR	.27*	-.05	-.19	.20*	.53**	.15	-.01	-.22*	.05	-.19
OBS		.30**	-.02	-.11	-.26*	-.06	.01	.15	.25*	.14
TREM			.01	-.34**	.39**	.39**	.40**	.05	-.08	-.06
MALNEO				.24*	.00	.17	.03	.12	.00	.07
CIRC					.13	.26*	.33**	.26*	-.01	.04
RESP						-.41**	.07	.30**	-.12	.07
NEURPSY							.10	.08	.01	-.03
GASENT								.26*	.07	.01
GENUR									.02	.06
SPESURG										.72**
SURG										

* r^2 is significantly different from zero at 5% level.

** r^2 is significantly different from zero at 1% level.

The variables with the most serious multicollinearity are: TREM, RESP, GASENT, GENUR, SPESURG and SURG. An examination of the partial correlation coefficients and their associated t-values reveals that:

TREM is significantly correlated with OBS, CIRC, RESP, GASENT, GENUR, SPESURG and SURG.

RESP is significantly correlated with INFPAR, OBS, TREM, NEURPSY and GENUR.

GASENT is significantly correlated with INFPAR, TREM, CIRC and GENUR.

GENUR is significantly correlated with INFPAR, CIRC, RESP and GASENT.

SPESURG is significantly correlated with SURG.

SURG is significantly correlated with OBS and SPESURG.

Less serious, but still significant multicollinearity occurs amony other variables. Of the 55 partial correlation coefficients, 19 are indicative of statistically significant multicollinearity. Thus, the pattern of multicollinearity is not confined to a few variables and, indeed, is pervasive. This implies: a) that it may be possible to remove several casemix variables without seriously affecting the estimates; or b) that principal components may be used in the regression instead of the original casemix variables.

The first possibility can be examined using a method based on Frische's confluence test (Koutsoyiannis, 1973). This test runs simple linear regressions on each of the variables separately and ranks these simple regressions according to the most plausible results. Plausibility is determined by *a priori* and statistical (R^2, t) criteria. For the present analysis they were ranked from the highest R^2 and t-values to the lowest. (Rank correlation among the two statistics was perfect.) The ranking was as follows:

1. CIRC
2. SURG
3. MALNEO
4. SPESURG
5. OBS
6. NEURPSY
7. RESP
8. GENUR
9. INFPAR
10. TREM
11. GASENT[1]

Then successive regressions were run entering the variables successively in the order shown above. Each new regression is done to determine if the new variable is useful (e.g., it adds to R^2 without adversely affecting previous coefficients); superfluous (e.g., it neither adds significantly to R^2 nor affects previous coefficients) or detrimental (e.g., it has a considerable effect on the signs and values of previously estimated coefficients).[2]

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[1] See Regression #7, Appendix V.

[2] See Regression #9, Appendix V.

Of the eleven casemix variables only four (CIRC, SURG, RESP, and GASENT) could be classified as useful by this analysis. Another five are quite clearly superfluous (MALNEO, OBS, NEURPSY, GENUR, and INFPAR) while two (TREM and SPESURG) were detrimental. SPESURG because of its exceedingly high correlation with SURG, could be combined with the latter: it was also believed that TREM might improve if the superfluous variables were excluded from the model.

Despite the substantial multicollinearity, the regression of variables transformed to reduce heteroscedasticity showed results which were superior to those of the earlier models. Standard errors were smaller and coefficients appeared more plausible. Only one implied casetype cost was negative; that of GASENT. All other parameters yielded casetype costs in the highly plausible range of \$161 - \$2,320. The higher casetype costs occurred where expected: CIRC, \$2,320; MALNEO, \$2,032; and the lower costs casetypes were also those that would be expected: RESP, \$609; INFPAR, \$1,641. SPESURG appeared to be too low at \$539, but its correlation with SURG could explain its implausibility and its large standard error (\$1,859).[1]

The analysis was performed again, eliminating the superfluous variables and combining SURG and SPESURG. The results, however, were not as good as had been hoped. The overall R^2 was .2126; slightly less than the .245 obtained with all variables. Four of the six parameters were significant at the five per cent level. However, TREM remained

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[1] See Regression #9 k), Appendix V.

detrimental and highly unstable. All variables but one showed plausible coefficients yielding case type costs ranging from $301 (RESP) to $2,445 (CIRC). GASENT remained negative.[1]

The reduction in the number of variables thus did not improve the results significantly. Moreover, it largely failed to deal with the problem of multicollinearity. The Farrar-Glauber χ^2 was 52.8 with $\chi^2_{.025} = 27.5$. All variables except the new combined SURG showed some multicollinearity, and each variable was collinear with all others.

Thus, the usual solutions to problems of multicollinearity were not available. Elimination of some variables had failed to reduce it to an acceptable level. High standard errors and a negative case type cost made the model unfit even for forecasting purposes. Mixed estimation methods are not available to this analysis. Although some work has been done in this area, definitive conclusions about the value of these coefficients have not been made. Thus, prior information cannot be incorporated into the model. It might be possible to enlarge the sample by using 1976 and/or 1978 data. This, however, would not likely reduce substantially the multicollinearity since there are no a priori grounds for believing the proportions would change.

Consequently, the Principal Components method was used to estimate casemix parameters. This method transforms the original correlated variables into a new set of uncorrelated principal components which are linear combinations of the original variables.

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[1] See Regression #10, Appendix V.

$$Pi = \sum_{j=1}^{k} aijXj$$

where: Pi is the i^{th} principal component;

aij is the "loading" or coefficient applied to the original variable;

Xj is the original variable;

k is the number of variables.

Up to k principal components can be calculated for each observation. Principal components can be extracted for all observations. They must, however, satisfy two conditions: first that they are orthoganal, and second, the first principal component accounts for the maximum possible variation in the original variables, the second accounts for the maximum remaining variation, and so on. Components can be extracted using the actual variables, their deviations from their means or their standardized variables.

Principal components analysis also provides an indication of the degree of multicollinearity in the original variables. If, for example, there were no multicollinearity in the original casemix variables each principal component would account for $\frac{1}{11}$ or nine per cent of the total variation. Actually, the first three components accounted for 69 per cent of the variation as opposed to 27 per cent that would have been expected if there were no multicollinearity.[1] For five components the comparison is 83 per cent versus 45 per cent. Thus, most of the variation in sample average case costs which is due to casemix may be

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[1] See Regression #11, Appendix V.

explained by only three or four casemix variables.

One technique that has been used to compute OLS regressions where the data are collinear is to substitute the most meaningful principal components for the variables that are collinear. These components do not, in themselves, have any economic interpretation but, given the limitations on the use of existing casemix data, are equally appropriate (Pidot, 1969). The non-casemix variables, especially those more significant or with a well documented economic interpretation can be entered into the analysis in ordinary form. This technique produced somewhat better results among the coefficients and enabled the retention of all but two of the original casemix variables, at the cost, of course, of some reduction in R^2.

Three tests were employed to determine the number of principal components to leave in the analysis. Kaiser's criteria (Koutsoyiannis, 1973) is that all principal components whose latent vectors (eigenvalues) are greater than one should be included. On this basis three components accounting for 69 per cent of casemix variation would be retained. Cattell's Scree test (Whitla, 1968) suggests that five principal components be retained. This simple test plots the eigenvalues of the components on rectangular co-ordinates and retains all those which are not approximately linear.

Bartlett's criterion is the most sophisticated statistical test (Kendall & Stuart, 1966). This criterion tests the statistical similarity of excluded components by the formula:

$$\chi^2 = n \ln \left\{ \left[(\lambda r + 1)(\lambda r + 2) \ldots (\lambda k) \right]^{-1} \left(\frac{\lambda r + 1 + \ldots \lambda k}{k - r} \right)^{k+r} \right\}$$

where: r is the number of components included;

k is the total number of components;

X_i is the eigenvalue of the i^{th} component ($i > r$)

n is the number of observations.

This criterion suggested retaining only one principal component. This (Bartlett's criterion's sophistication notwithstanding) violates the other two criteria. Consequently, separate OLS regressions were run on three, four and five components.[1]

On three components the regression yielded R^2 = .145 and significant parameters for all the original casemix variables except two (TREM and OBS). All coefficients yielded positive casetype costs in a range of $186 (INFPAR) to $2,714 (MALNEO). The overall regression was significant with F = 4.308 [F.05 (df 3,76) = 2.74; Fs1 (df 3,76) = 4.11] .

On four components the regression yielded R^2 = .162 and significant values in five of the original casemix variables. Casetype costs were all reasonably plausible and the F-ratio was 3.622 [F.01 (df 4,75) = 3.60] . The loss of significance of individual coefficients was worrisome. The addition of the fourth component did not improve R^2 significantly. [F = 1.50 F.05 (df 1,76) = 3.98] .

On five components, the regression yielded R^2 = .189 and significant parameters for five original casemix variables. Most implied casetype costs were plausible but TREM was negative (- 345). The F-ratio was 3.45 [F.01 (df 5,74) = 3.27] . R^2 was signifi-

[1] See Regression #11, Appendix V.

cantly greater than the R^2 derived from the three-component case.

However, the significance of the coefficients and the plausibility of the casetype costs argued in favour of retaining only three principal components for further work.

Multicollinearity persisted when the non-casemix variables were entered into the equation and a new regression run. The existence of multicollinearity is shown in the partial correlation matrix of the retained variables shown in Table 3-7. The decision was made at this point to accept this degree of multicollinearity and bear it in mind in interpreting the model's parameters. The number of non-casemix variables, it was later found, could be reduced by half without impairing the fit of the data.

TABLE 3-7

PARTIAL CORRELATION COEFFICIENTS:

PRINCIPAL COMPONENTS OF CASEMIX AND NON-CASEMIX VARIABLES

	TEACH	EXTCU	BEDS	FLO	ADJLOS	FIRST COMP.	SECOND COMP.	THIRD COMP.
URBAN	-.23*	-.04	.52**	-.01	.19	-.31**	.10	.03
TEACHING		.03	.57**	-.10	-.13	.04	-.03	-.04
EXTCU			.19	.20	.04	-.16	.05	-.06
BEDS				.13	-.06	-.01	-.03	.01
FLO					.06	.52**	-.65**	.70**
ADJLOS						.63**	-.36**	-.23
FIRST COMP							.54**	-.23*
SECOND COMP								.42**

* r^2 is significant at the 5% level.
** r^2 is significant at the 1% level.

APPENDIX IV

PLAUSIBILITY OF THE PARAMETERS

APPENDIX IV

PLAUSIBILITY OF THE PARAMETERS

Even accepting the multicollinearity among the non-casemix variables, some problems remained with the model. First, the R^2 was poor -- only .39.[1] For four of the six non-casemix variables the standard errors were larger than the parameter estimates. Only FLO and ADJLOS had significant parameters. Finally, the introduction of the non-casemix variables had affected the plausibility of the casemix parameters. Six of the eleven were significant, but some of the implied casetype costs were no longer believable. For example, the highest was OBS at $1,644, while CIRC was only $493, and MALNEO only $45. Apart from the figures themselves, the ordering of these costs should be reversed.

This situation led to several respecifications of the model. These included: 1) specifying BEDS as a series of dummy variables;[2] 2) specifying HOSPAC and some of the dependent variables in non-linear form, e.g., logarithmic, exponential; 3) squaring the BEDS and FLO variables; 4) specifying a different model for hospitals under twenty beds; 5) reverting to the original (unweighted) observations.[3] Not

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[1] See Regression #13 i), Appendix V.

[2] BEDS less than 20, BEDS 20-49, BEDS 50-119, BEDS 120-299, BEDS 300+. See Regression #14, Appendix V.

[3] See Regressions #15-#32, Appendix V.

all the respecifications are reported here.

Replacement of BEDS, URBAN, TEACH and EXTCU by a series of dummies resulted in some improvement in R^2 (to .4530).[1] Three of the five BEDS dummies had significant parameters as did all but three of the casemix variables. However, the specification resulted in some unlikely relationships among the casetype costs. All were positive but MALNEO and CIRC were less than half the cost of OBS. INFPAR, too, was more costly than either MALNEO or CIRC.

A specification which regressed HOSPAC against the log of FLO, the bed dummies and the principal components yielded a better R^2 (73) and an overall F of 21.03.[2] For all regressors but one (RESP) the parameters exceeded the standard errors, usually by a factor of at least two. However, casetype costs were even more implausible with two being negative (INFPAR and SPESURG). When only hospitals with twenty or more beds were included in the analysis the results were similar.[3]

Replacing the beds dummies with BEDS and BEDSSQ (the square of beds) also yielded significant parameters in all but one case. Again, however, casetype costs were implausible (e.g., SPESURG = $149; GENUR = $1,621).[4]

In a similar specification the log of HOSPAC was regressed

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1 See Regression #14, Appendix V.

2 See Regression #17 g), Appendix V.

3 See Regression #18, Appendix V.

4 See Regression #19, Appendix V.

against the log of FLO, the bed dummies and the principal components. Again the statistical results were good with all but two parameters exceeding their standard errors. R^2 was .78 and F was 28.15.[1] However, again implausibility of casetype costs was a problem, e.g., MALNEO = $6,796 but SPESURG = $314 for the mean hospital. Combining SURG and SPESURG did not improve the plausibility. Other reshuffling of variables and specification changes yielded approximately similar results. R^2 was as high as .84 with highly significant values for all parameters in a model which regressed the log of HOSPAC against the log of FLO, the bed dummy variables and the components. The casetype costs changed somewhat but the degree of implausibility was untouched.[2]

The approach finally adopted to the problem of implausible casetype costs was less than completely satisfactory. An experimental process was undertaken which omitted different casemix variables in turn. The best results obtained were those which are reported in Chapter 4. Two of the casemix variables, GASENT and GENUR were eliminated, or rather were eliminated as separate variables, and became part of the residual. Casemix continued to be represented by three principal components, now accounting for 75 per cent of variation in casemix. Thus, while the results of the regressions finally used for policy simulations may have understated -- by four or five per cent -- the impact of casemix, the gain in plausibility of results was an acceptable payoff.[3]

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[1] See Regression #23 g), Appendix V.

[2] See Regression #24, Appendix V.

[3] See Regressions #29, #30, Appendix V.

APPENDIX V

SUMMARY OF REGRESSION RESULTS

APPENDIX V

SUMMARY OF REGRESSION RESULTS

Literally hundreds of separate regression equations were estimated during the course of this work. Many, however, were run to undertake particular tests, to determine the order of entry of variables, or to enter variables one at a time to determine their impact. Not all these equations are summarized here; only those which imply a departure in approach, structure or variables included from the approaches used to derive previous equations are summarized here.

Each summary includes the equation's parameters (with t-values below in brackets), and the F-value and the R^2 for the entire equation. All parameters relate to original variables; but where principal components were used in the estimation, the casemix parameters have been translated back from the components. The use of principal components is indicated after the equation.

1. FIRST RUN ON ALL VARIABLES

```
HOSPAC  =  2610.9   -  30.47 FLO  +  268.74 URBAN
            (4.25)    (4.55)          (1.37)

        +  412.23 TEACH  +  92.55 EXTCU  +  .16 BEDS
            (1.68)           (.65)          (.43)

        +  31.91 ADJLOS  -  3689.7 INFPAR  +  763.44 OBS
           (1.25)            (-2.46)             (.83)

        -  905.13 TREM  -  5309.7 MALNEO  -  2687.9 CIRC
            (-.46)          (-1.91)           (-2.37)

        -  106.79 RESP  -  .12 RESP  -  3470 GASENT
            (-.13)         (-.90)        (-2.24)

        -  190.47 GENUR  -  620.23 SURG  -  1954.3 SPESURG
            (-.08)           (-.77)          (-1.41)
```

F = 13.31

R^2 = .7261

multicollinearity: severe

heteroscedasticity: severe

parameters: highly implausible

2. INCREMENTAL REGRESSIONS ON ORIGINAL VARIABLES

a) HOSPAC = 1806.1 - 28.14 FLO
(14.82) (-6.84)

F = 46.84
R^2 = .3752
multicollinearity: none
heteroscedasticity: not tested
parameters: plausible

b) HOSPAC = 1793.4 - 30.22 FLO + 1.05 BEDS
(16.774) (-8.32) (4.93)

F = 42.59 F on last regressor = 24.32
R^2 = .5252
multicollinearity: some
heteroscedasticity: not tested
parameters: plausible

c) HOSPAC = 1775.3 - 29.22 FLO + .57 BEDS + 594.97 TEACH
(17.10) (-8.25) (2.02) (2.45)

F = 32.35 F on last regressor = 6.02
R^2 = .5601
multicollinearity: some
heteroscedasticity: not tested
parameters: plausible

2.

d) $$\text{HOSPAC} = \underset{(17.85)}{1799.1} - \underset{(-8.74)}{30.06\ \text{FLO}} - \underset{(-.12)}{.04\ \text{BEDS}} + \underset{(2.93)}{697.11\ \text{TEACH}} + \underset{(2.53)}{432.04\ \text{URBAN}}$$

F = 27.50 F on last regressor = 6.39

R^2 = .5946

multicollinearity: some

heteroscedasticity: not tested

parameters: plausible

e) $$\text{HOSPAC} = \underset{(7.37)}{2264.8} - \underset{(-8.10)}{34.00\ \text{FLO}} - \underset{(-.16)}{.06\ \text{BEDS}} + \underset{(2.59)}{621.05\ \text{TEACH}} + \underset{(2.54)}{429.75\ \text{URBAN}} - \underset{(-1.60)}{32.34\ \text{ADJLOS}}$$

F = 22.98 F on last regressor = 2.57

R^2 = .6082

multicollinearity: some

heteroscedasticity: not tested

parameters: plausible

f) $$\text{HOSPAC} = \underset{(7.32)}{2273.6} - \underset{(-7.44)}{33.5\ \text{FLO}} - \underset{(-.14)}{.05\ \text{BEDS}} + \underset{(2.54)}{615.95\ \text{TEACH}} + \underset{(2.30)}{464.16\ \text{URBAN}} - \underset{(-1.62)}{32.99\ \text{ADJLOS}} - \underset{(-.32)}{144.95\ \text{SURG}}$$

F = 18.93 F on last regressor = .10

R^2 = .6088

multicollinearity: some

heteroscedasticity: not tested

parameters: all but SURG plausible

2.

g) HOSPAC = 2048 (6.24) - 34.29 FLO (-7.72) + .10 BEDS (.37) + 472.58 TEACH (1.89)

+ 200.25 URBAN (2.05) - 20.82 ADJLOS (-.99) - 268.60 SURG (-.59)

+ 1526 OBS (1.86)

F = 17.27 F on last regressor = 3.48

R^2 = .6268

multicollenearity: some

heteroscedasticity: not tested

parameters: casemix parameters implausible

h) HOSPAC = 2264.3 (6.39) - 34.20 FLO (-7.36) + .07 BEDS (.17) + 390.24 TEACH (1.50)

+ 429.4 URBAN (2.11) - 27.48 ADJLOS (-1.28) + 149.33 EXTCU (.98)

- 547.36 SURG (-.89) + 1499 OBS (1.81) - 416.54 SPESURG (-.33)

- 1904 INFPAR (-1.447)

F = 12.42 F on last regressors = 1.04

R^2 = .6429

multicollinearity: slight to moderate

heteroscedasticity: not tested

parameters: casemix parameters implausible

COMMENTS: Regression on original variables shows most effects due to caseflow and other hospital variables with casemix adding little explanatory power.

3. INCREMENTAL REGRESSIONS ON 'TEACH' AND ORIGINAL CASEMIX VARIABLES

a) HOSPAC = 1057.80 + 1036.2 TEACH - 450.5 (SURG + SPESURG)
(15.36) (4.19) (-1.48)

F = 8.83

F^2 = .1867

multicollinearity: some

heteroscedasticity: not tested

parameters: casemix not plausible

b) HOSPAC = 1060.9 + 1039.4 TEACH - 445.07 (SURG + SPESURG)
(10.98) (4.02) (-1.36)

- 48.10 OBS
(-.04)

F = 5.86 F on last regressor = .11

R^2 = .1867

multicollinearity: some

heteroscedasticity: not tested

parameters: (SURG + SPESURG) not plausible

c) HOSPAC = 1286.4 + 1020.9 TEACH - 671.29 (SURG + SPESURG)
(2.63) (4.01) (-1.25)

- 137.26 OBS - 1637.1 MALNEO - 624.3 CIRC
(-.10) (-.43) (-.47)

- 4388.6 INFPAR + 876.94 RESP
(-2.36) (.79)

F = 3.51 F on last regressors = 1.61

R^2 = .2547

multicollinearity: moderate

heteroscedasticity: not tested

parameters: casemix parameters implausible

COMMENTS: Casemix parameters do not estimate well, even with only one non-casemix parameter and appear to explain relatively little variance.

4. INCREMENTAL REGRESSIONS ON 'URBAN' AND ORIGINAL CASEMIX VARIABLES

a) HOSPAC = 1164.5 (15.45) + 932.01 URBAN (4.16) - 1297.3 (SURG + SPESURG) (-3.17)

F = 8.71
R^2 = .1845
multicollinearity: slight
heteroscedasticity: not tested
parameters: (SURG + SPESURG) is implausible

b) HOSPAC = 1471.6 (10.50) + 961.11 URBAN (4.45) - 1807.2 (SURG + SPESURG) (-4.08)

- 4355.1 INFPAR (-2.56)

F = 8.42 F on last regressor = 6.56
R^2 = .2494
multicollinearity: slight
heteroscedasticity: not tested
parameters: casemix parameters are implausible

c) HOSPAC = 2039 (8.53) + 798.11 URBAN (3.71) - 2187.6 (SURG + SPESURG) (-4.93)

- 5403.8 INFPAR (-3.25) - 5537.7 GASENT (-2.87)

F = 8.96 F on last regressor = 8.21
R^2 = .3235
multicollinearity: slight
heteroscedasticity: not tested
parameters: casemix parameters are implausible

COMMENTS: Somewhat better results on significance of casemix variables, but their parameters remain highly implausible.

5. INCREMENTAL REGRESSIONS ON ORIGINAL CASEMIX VARIABLES ONLY

a) HOSPAC = 1036.4 (13.70) − 108.74 (SURG + SPESURG) (−.34)

F = .11

R^2 = .0015

multicollinearity: none

heteroscedasticity: not tested

plausibility: fair

b) HOSPAC = 969.02 (9.43) − 253.87 (SURG + SPESURG) (−.71) + 1079 OBS (.97)

F = .52 F on last regressor = .94

R^2 = .0135

multicollinearity: some

heteroscedasticity: not tested

plausibility: poor

c) HOSPAC = 3712.2 (4.46) − 3031.7 (SURG + SPESURG) (−3.35) − 7966.4 INFPAR (−3.74)

− 448.54 OBS (−.33) − 4747.7 TREM (−1.61) − 6046.3 MALNEO (−1.47)

− 2626.3 CIRC (−1.57) − 1520.2 RESP (−1.20) + .001 NEURPSY (.57)

− 7379.2 GASENT (−3.27) − 4245.4 GENUR (−1.16)

F = 2.52 F on last regressor = 2.99

R^2 = .2676

multicollinearity: considerable

heteroscedasticity: not tested

parameters: largely implausible

COMMENTS: Casemix variables alone explain about 27 per cent of variance, but high correlation with non-casemix variables means that their residual importance is limited (see Regressions #3 and #4).

6. REGRESSION ON ORIGINAL NON-CASEMIX VARIABLES AND FIVE PRINCIPAL COMPONENTS OF CASEMIX VARIABLES

a) HOSPAC = 1640.6 (5.12) - 34.69 FLO (-7.81) + 332.08 URBAN (1.65) + 485.42 TEACH (2.03)

+ 125.91 EXTCU (.86) - .006 BEDS (-.02) + 16.22 ADJLOS (.66)

- 4.92 INFPAR* (-.26) + 2.63 OBS* (4.03) + 1.52 TREM* (3.13) - 22 MALNEO (-.85)

- 75 CIRC* (-4.45) + 2.75 RESP* (.17) + .10 NEURPSY* (.35)

- 20.23 GASENT* (-1.04) - 11.67 GENUR* (-.65) + 4.50 SURG* (.55)

+ 5.65 SPESURG* (.73)

SPC

$F = 12.56$

$R^2 = .67$

multicollinearity: none among casemix variables since PC used; some among non-casemix

heteroscedasticity: substantial

parameters: not tested

COMMENTS: The results of this regression were used to test for and adjust for heteroscedasticity in the data (see Appendix II). Regressions 7 to 14 describe operations on the transformed data.

* Proportions were normalized to mean zero and standard deviation unity.

7. REGRESSIONS ON INDIVIDUAL CASEMIX VARIABLES: TRANSFORMED DATA

a)	HOSPAC	=	941.81	-	541.20 INFPAR	R^2 = .0087
			(22.88)		(-.83)	
b)	HOSPAC	=	846.70	+	786.77 OBS	R^2 = .0373
			(18.55)		(1.74)	
c)	HOSPAC	=	949.17	-	612.34 TREM	R^2 = .0058
			(16.56)		(-.67)	
d)	HOSPAC	=	847.21	+	3401.8 MALNEO	R^2 = .0637
			(22.60)		(2.30)	
e)	HOSPAC	=	785.99	+	1036.7 CIRC	R^2 = .0898
			(15.18)		(2.77)	
f)	HOSPAC	=	971.37	-	337.71 RESP	R^2 = .0165
			(17.50)		(-1.14)	
g)	HOSPAC	=	853.15	+	886.24 NEURPSY	R^2 = .0282
			(18.07)		(1.50)	
h)	HOSPAC	=	890.43	+	299.68 GASENT	R^2 = .0026
			(15.25)		(.45)	
i)	HOSPAC	=	871.09	+	1084.7 GENUR	R^2 = .0105
			(16.36)		(.91)	
j)	HOSPAC	=	849.51	+	483.4 SURG	R^2 = .0663
			(23.44)		(2.35)	
k)	HOSPAC	=	870.41	+	933.10 SPESURG	R^2 = .0462
			(26.51)		(1.94)	

8. REGRESSIONS OF EACH TRANSFORMED CASEMIX VARIABLE ON ALL OTHER TRANSFORMED CASEMIX VARIABLES

a)	R^2	(INFPAR; all other casemix)	.5159
b)	R^2	(OBS; all other casemix)	.4235
c)	R^2	(TREM; all other casemix)	.6582
d)	R^2	(MALNEO; all other casemix)	.3343
e)	R^2	(CIRC; all other casemix)	.5848
f)	R^2	(RESP; all other casemix)	.6909
g)	R^2	(NEURPSY; all other casemix)	.4903
h)	R^2	(GASENT; all other casemix)	.6702
i)	R^2	(GENUR; all other casemix)	.5942
j)	R^2	(SURG; all other casemix)	.7029
k)	R^2	(SPESURG; all other casemix)	.6857

9. INCREMENTAL REGRESSIONS ON TRANSFORMED CASEMIX VARIABLES

a) HOSPAC = 785.99 + 1036.7 CIRC
(15.18) (2.77)

F = 7.70

R^2 = .0898

multicollinearity: none

heteroscedasticity: none

plausibility: good

b) HOSPAC = 710.09 + 1090.5 CIRC + 516.83 SURG.
(12.33) (3.02) (2.64)

F = 7.62 F on last regressor = 6.97

R^2 = .1653

multicollinearity: none

heteroscedasticity: none

plausibility: good

c) HOSPAC = 706.22 + 934.06 CIRC + 487.51 SURG + 1377.8 MALNEO
(12.20) (2.31) (2.45) (.87)

F = 5.32 F on last regressor = .76

R^2 = .1736

multicollinearity: some

heteroscedasticity: none

plausibility: good

COMMENT: Addition of MALNEO adds little to analysis.

9.

d) HOSPAC = 706.15 (12.12) + 936.30 CIRC (2.30) + 461.31 SURG (1.36) + 1365.5 MALNEO (.85) + 75.41 SPESURG (.10)

$F = 3.94$ F on last regressor = .01

$R^2 = .1737$

multicollinearity: some

heteroscedasticity: none

parameters: SPESURG unlikely

COMMENT: Addition of SPESURG is destabilizing.

e) HOSPAC = 688.62 (10.72) + 937.40 CIRC (2.30) + 401.25 SURG (1.14) + 1320.3 MALNEO (.82) + 44.26 SPESURG (.06) + 323.64 OBS (.66)

$F = 3.22$ F on last regressor = .43

$R^2 = .1785$

multicollinearity: some

heteroscedasticity: none

parameters: SPESURG unlikely

COMMENT: Addition of OBS has little effect on results.

f) HOSPAC = 689.79 (10:44) + 950.04 CIRC (2.18) + 401.30 SURG (1.13) + 1353.7 MALNEO (.81) + 39.11 SPESURG (.05) + 332:40 OBS (.66) - 56.74 NEURPSY (-.09)

$F = 2.64$ F on last regressor = .01

$R^2 = .1786$

multicollinearity: some

heteroscedasticity: none

parameters: SPESURG unlikely

COMMENT: Addition of NEURPSY has little effect on results.

9.

g) HOSPAC = 772.80 + 1336.9 CIRC + 284.4 SURG + 1210.9 MALNEO
(9.89) (2.82) (.81) (.74)

- 83.50 SPESURG + 450.32 OBS - 220.35 NEURPSY
(-.11) (.90) (-.34)

- 623.83 RESP
(-1.91)

F = 2.87 F on last regressor = 3.64

R^2 = .2181

multicollinearity: considerable

heteroscedasticity: none

parameters: SPESURG and RESP unlikely

COMMENT: Addition of RESP is significant.

h) HOSPAC = 771.43 + 1394.9 CIRC + 283.8 SURG
(9.80) (2.79) (.80)

+ 1324.3 MALNEO - 85.76 SPESURG + 486.5 OBS
(.79) (-.11) (.95)

- 168.22 NEURPSY - 566.46 RESP - 609.80 GENUR
(-.25) (-1.57) (-.38)

F = 2.50 F on last regressor = .15

R^2 = .2197

multicollinearity: considerable

heteroscedasticity: none

parameters: SPESURG, RESP and GENUR unlikely

COMMENT: Addition of GENUR has little effect on results.

9.

i) HOSPAC = 768.65 + 1472.6 CIRC + 294.93 SURG
(9.71) (2.85) (.83)

+ 1112.1 MALNEO - 181.62 SPESURG + 575.97 OBS
(.65) (-.22) (1.08)

- 107.45 NEURPSY - 408.33 RESP - 864.87 GENUR
(-.16) (.93) (-.53)

- 551.97 INFPAR
(-.63)

F = 2.25 F on last regressor = .40

R^2 = .2241

multicollinearity: considerable

heteroscedasticity: none

parameters: SPESURG, RESP and GENUR unlikely

COMMENT: Addition of INFPAR has little effect on results

9.

j) HOSPAC = 775.64 (9.75) + 1361.3 CIRC (2.56) + 286.3 SURG (.80)

+ 1213.2 MALNEO (.71) - 248.25 SPESURG (-.31) + 740.14 OBS (1.32)

+ 211.65 NEURPSY (.28) - 199.09 RESP (-.40) - 655.28 GENUR (-.39)

- 598.63 INFPAR (-.68) - 1199.7 TREM (-.93)

F = 2.10 F on last regressor = .86

R^2 = .2337

multicollinearity: considerable

heteroscedasticity: none

parameters: SPESURG, RESP, GENUR and TREM unlikely

COMMENT: Mildly de-stabilizing effect.

k) HOSPAC = 771.7 (9.69) + 1548.8 CIRC (2.76) + 308.31 SURG (.86)

+ 1261.10 MALNEO (.73) - 232.41 SPESURG (-.29) + 748.75 OBS (1.33)

+ 294.98 NEURPSY (.39) - 162.27 RESP (-.33) - 181.53 GENUR (-.11)

- 607.18 INFPAR (-.69) - 610.39 TREM (-.43) - 1114.0 GASENT (-1.03)

F = 2.01 F on last regressor = 1.06

R^2 = .2455

multicollinearity: considerable

heteroscedasticity: none

parameters: SPESURG, RESP, GENUR, TREM and GASENT unlikely

COMMENT: Slight and statistically insignificant effect.

10. BEST REGRESSION ON TRANSFORMED CASEMIX VARIABLES

a) $$\text{HOSPAC} = \underset{(10.64)}{799.73} + \underset{(3.50)}{1645.1}\ \text{CIRC} + \underset{(1.96)}{298.88}\ (\text{SURG} + \text{SPESURG})$$

$$- \underset{(-1.38)}{498.94}\ \text{RESP} + \underset{(.19)}{232.85}\ \text{TREM} - \underset{(-.90)}{905.36}\ \text{GASENT}$$

F = 4.00

R^2 = .2126

multicollinearity: considerable

heteroscedasticity: none

parameters: GASENT unlikely

11. REGRESSIONS ON PRINCIPAL COMPONENTS OF TRANSFORMED CASEMIX VARIABLE

a) HOSPAC = 805.81 - 619.51 INFPAR + 76.11 OBS - 149.42 TREM
(39.99) (-.2.23) (.35) (-.60)

+ 1907.9 MALNEO + 239.65 CIRC - 217.04 RESP
(2.70) (2.12) (-2.22)

+ 477.09 NEURPSY + 239.58 GASENT + 494.79 GENUR
(2.84) (1.67) (1.98)

+ 159.53 SURG + 390.61 SPESURG
(2.05) (2.30)

First three PC's used. Cum.% of Eigenvalues = 69.1

F = 4.31

R^2 = .1453

multicollinearity: none

heteroscedasticity: none

parameters: most are plausible

b) HOSPAC = 792.30 - 436.74 INFPAR - 73.67 OBS - 644.88 TREM
(40.12) (-1.38) (-.30) (-.135)

+ 2068.5 MALNEO + 442.59 CIRC - 99.26 RESP
(2.89) (2.20) (-.72)

+ 122.77 NEURPSY + 213.95 GASENT + 682.08 GENUR
(.37) (1.48) (2.33)

+ 219.97 SURG + 561.79 SPESURG
(2.39) (2.55)

First four PC's used. Cum.% of Eigenvalues = 77.0

F = 3.62 F on added PC = 1.48

R^2 = .1619

multicollinearity: none

heteroscedasticity: none

parameters: some loss in plausibility from 11 a) but most remain plausible.

11.

c) HOSPAC = 787.88 + 221.88 INFPAR - 22.87 OBS - 1133.10 TREM
(40.52) (.43) (-.09) (-2.01)

+ 1772.5 MALNEO + 678.16 CIRC - 231.86 RESP
(2.42) (2.73) (-1.45)

+ 687.91 NEURPSY + 14.09 GASENT - 87.05 GENUR
(1.41) (.07) (-.15)

+ 241.86 SURG + 521.26 SPESURG
(2.62) (2.38)

First five PC's used. Cum.% of Eigenvalues = 82.9

F = 3.46 F on added PC = 2.51

R^2 = .1894

multicollinearity: none

heteroscedasticity: none

parameters: TREM totally implausible.

12. REGRESSIONS ON INDIVIDUAL NON-CASEMIX VARIABLES (TRANSFORMED) AND CASEMIX PRINCIPAL COMPONENTS

a)	HOSPAC	=	905.85	+	133.99	URBAN	R^2 = .0178
			(35.94)		(1.19)		
b)	HOSPAC	=	911.52	+	143.11	TEACH	R^2 = .0042
			(36.71)		(.57)		
c)	HOSPAC	=	910.97	+	46.27	EXTCU	R^2 = .0032
			(36.10)		(.50)		
d)	HOSPAC	=	899.65	+	.27	BEDS	R^2 = .0124
			(31.66)		(.99)		
e)	HOSPAC	=	920.75	-	.22	FLO	R^2 = .0002
			(17.05)		(-.13)		
f)	HOSPAC	=	688.93	-	20.99	ADJLOS	R^2 = .1156
			(9.28)		(3.19)		
g)	HOSPAC	=	914.27	+	67.2	(FIRST COMPONENT)	R^2 = .0048
			(37.54)		(.61)		
h)	HOSPAC	=	914.27	-	409.82	(SECOND COMPONENT)	R^2 = .1103
			(39.71)		(-3.11)		
i)	HOSPAC	=	914.27	-	303.16	(THIRD COMPONENT)	R^2 = .0303
			(38.04)		(-1.56)		

13. INCREMENTAL REGRESSIONS ON TRANSFORMED NON-CASEMIX VARIABLES AND PRINCIPAL COMPONENTS OF TRANSFORMED CASEMIX VARIABLES

a) HOSPAC = 688.93 (9.20) + 20.99 ADJLOS (3.19)

$$\text{HOSPAC} = \underset{(9.20)}{688.93} + \underset{(3.19)}{20.99}\ \text{ADJLOS}$$

F = 10.20

R^2 = .1156

multicollinearity: none

heteroscedasticity: none

parameters: plausible

b) HOSPAC = 913.30 (9.66) + 15.62 ADJLOS (2.27) - 248.24 INSPAR (-2.94) - 42.06 OBS (-2.94)

- 470.79 TREM (-2.94) - 458.31 MALNEO (-2.94) - 195.62 CIRC (-2.94)

- 145.53 RESP (-2.94) - 245.39 NEURPSY (-2.94) - 389.20 GASENT (-2.94)

- 653.28 GENUR (-2.94) + 31.66 SURG (2.94) + 80.78 SPESURG (2.94)

Includes first principal component of casemix
Cum.% Eigenvalue = 35.8

F = 7.66 F on last regressor = 4.65

R^2 = .1660

multicollinearity: none

heteroscedasticity: none

parameters: GENUR, MALNEO unlikely

COMMENT: Adds significantly to analysis.

13.

c) HOSPAC = 868.07 + 14.27 ADJLOS - 417.22 INFPAR
(9.81) (2.06) (-3.55)

+ 177.18 OBS - 456.16 TREM - 20.01 MALNEO
(1.56) (-2.85) (-.07)

- 172.39 CIRC - 230.03 RESP - 125.18 NEURPSY
(-2.54) (-3.60) (-1.18)

- 307.63 GASENT - 543.80 GENUR + 166.03 SURG
(-2.19) (-2.35) (2.40)

+ 385.89 SPESURG
(2.45)

Includes first two principal components of casemix.
Cum.% of Eigenvalues = 58.0

F = 5.79 F on last regressor = 1.87

R^2 = .1861

multicollinearity: none

heteroscedasticity: none

parameters: most are plausible

d) HOSPAC = 746.10 + 18.99 ADJLOS + 176.82 URBAN
(7.97) (2.50) (1.47)

- 336.95 INFPAR + 199.72 OBS - 291.84 TREM
(-2.89) (1.77) (-1.84)

+ 155.25 MALNEO - 103.49 CIRC - 182.45 RESP
(.56) (-1.54) (-2.87)

- 35.47 NEURPSY - 169.28 GASENT - 312.57 GENUR
(-.34) (-1.21) (-1.36)

+ 159.87 SURG + 368.78 SPESURG
(2.33) (2.36)

Includes first two principal components

F = 4.95 F on last regressor = 2.15

R^2 = .2088

multicollinearity: slight

heteroscedasticity: none

parameters: all plausible

13.

e) HOSPAC = 704.73 (7.24) + 20.27 ADJLOS (2.61) + 116.64 URBAN (.82) + .27 BEDS (.81)

− 327.57 INFPAR (2.80) + 216.12 OBS (1.91) − 254.03 TREM (1.60)

+ 217.39 MALNEO (.78) − 86.76 CIRC (−1.28) − 176.08 RESP (−2.77)

− 9.03 NEURPSY (−.09) − 133.88 GASENT (−.96) − 254.77 GENUR (−1.11)

+ 165.41 SURG (2.41) + 380.67 SPESURG (2.43)

Includes first two principal components

F = 4.07 F on last regressor = 0.65

R^2 = .2157

multicollinearity: slight

heteroscedasticity: none

parameters: all plausible

f) HOSPAC = 522.67 (3.71) + 35.269 ADJLOS (2.80) + 32.04 URBAN (.21) + .29 BEDS (.88)

− 557.06 INFPAR (2.08) + 46.09 OBS (.22) − 335.11 TREM (−1.40)

+ 1101. MALNEO (1.62) + 67.36 CIRC (.62) − 226.08 RESP (−2.40)

+ 210.95 NEURPSY (1.30) − 25.02 GASENT (−.18) + 19.16 GENUR (.08)

+ 133.69 SURG (1.79) + 327.32 SPESURG (2.00)

Includes first three principal components. Cum.% Eigen. = 69.1

F = 3.83 F on last regressor = 2.25

R^2 = .2392

multicollinearity: slight

heteroscedasticity: none

parameters: plausible

13.

g) HOSPAC = 657.03 + 37.27 ADJLOS + 71.27 URGAN + .03 BEDS
(3.51) (2.91) (.45) (.06)

+ 340.56 TEACH - 548.28 INFPAR - 111.02 OBS
(1.12) (-2.05) (-.54)

- 621.84 TREM + 351.84 MALNEO - 95.72 CIRC
(-2.60) (.52) (.88)

- 245.69 RESP - 64.42 NEURPSY - 342.11 GASENT
(-2.61) (-.39) (-2.47)

- 508.37 GENUR + 60.59 SURG + 163.73 SPESURG
(-2.11) (.81) (1.01)

Includes first three principal components.

F = 3.468 F on last regressor = 1.24

R^2 = .2522

multicollinearity: some

heteroscedasticity: none

parameters: all plausible

h) HOSPAC = 655.89 + 37.44 ADJLOS + 69.92 URBAN + .05 BEDS
(3.54) (2.92) (.45) (.11)

+ 340.94 TEACH - 20.66 EXTCU - 546.82 INFPAR
(1.11) (-.23) (-2.03)

- 103.68 OBS - 621.52 TREM + 337.41 MALNEO
(-.50) (-2.59) (.49)

- 99.55 CIRC - 246.51 RESP - 68.32 NEURPSY
(-.91) (-2.60) (-.42)

- 344.67 GASENT - 515.20 GENUR + 63.67 SURG
(-2.48) (-2.13) (.85)

+ 170.32 SPESURG
(1.04)

Includes first three principal components.

F = 3.001 F on last regressor = .05

R^2 = .2527

multicollinearity: some

heteroscedasticity: none

parameters: all plausible

13.

i) HOSPAC = 514.78 + 40.48 ADJLOS + 65.77 URBAN + .24 BEDS
(5.48) (3.48) (.46) (.63)

+ 225.68 TEACH + 46.93 EXTCU - 12.61 FLO
(.81) (.55) (-4.06)

+ 437.76 INFPAR + 1093.2 OBS + 851.76 TREM
(1.79) (5.80) (3.91)

- 456.08 MALNEO - 77.95 CIRC + 81.14 RESP
(-.74) (-.78) (.95)

+ 85.66 NEURPSY + 447.16 GASENT + 442.08 GENUR
(.58) (3.54) (2.02)

+ 411.31 SURG + 874.71 SPESURG
(6.04) (5.87)

Includes first three principal components.

F = 5.06 F on last regressor = 16.36

R^2 = .3943

multicollinearity: some

heteroscedasticity: none

parameters: OBS, MALNEO and CIRC unlikely

COMMENTS: Addition of the FLO variable highly significant. Unfortunately plausibility of some parameters shaken. R^2 very low on these transformed data.

14. REGRESSION OF TRANSFORMED NON-CASEMIX VARIABLES AND PRINCIPAL COMPONENTS OF TRANSFORMED CASEMIX VARIABLES WITH DUMMY VARIABLES SUBSTITUTED FOR HOSPITAL DESCRIPTORS

a) HOSPAC = 1028 (5.97) - 10.86 FLO (-3.30) + 38.35 ADJLOS (-3.38) - 170.34 B19LESS (-1.40)

- 285.81 B2049 (-2.65) - 215.14 B50119 (-1.83) - 118.74 B120199 (-.94)

+ 110.21 B300MOR (.53) + 271.70 INFPAR (1.14) + 1062.3 OBS (5.89)

+ 796.76 TREM (3.82) + 74.46 MALNEO (.12) - 3.33 CIRC (-.04)

+ 29.38 RESP (.36) + 215.38 NEURPSY (1.53) + 506.40 GASENT (4.20)

+ 579.87 GENUR (2.76) + 430.60 SURG (6.60) + 928.12 SPESURG (6.51)

where:

B19LESS is a dummy variable = 1 if hospital has fewer than 20 beds; otherwise = 0.

B2049 is a dummy variable = 1 if hospital has 20-49 beds; otherwise = 0.

B50119 is a dummy variable = 1 if hospital has 50-119 beds; otherwise = 0.

B120299 is a dummy variable = 1 is hospital has 120-299 beds; otherwise = 0.

B300MOR is a dummy variable = 1 if hospital has more than 300 beds; otherwise = 0.

Includes first three principal components

F = 5.71

R^2 = .4529

multicollinearity: some

heteroscedasticity: none

parameters: several (OBS, TREM, CIRC) unlikely

COMMENTS: Better R^2 than 13, but otherwise little improvement. Subsequent regressions revert to the original data (untransformed for heteroscedasticity) but with one or more variables transformed into logarithmic form.

15. REGRESSIONS ON INDIVIDUAL VARIABLES (NOT TRANSFORMED FOR HETEROSCEDASTICITY) WITH SOME LOGARITHMIC TRANSFORMATIONS

						R^2
a)	HOSPAC =	1806.10 (14.82)	-	28.14 (-6.84)	FLO	R^2 = .3752
b)	HOSPAC =	652.15 (2.44)	+	33.61 (1.39)	ADJLOS	R^2 = .0243
c)	HOSPAC =	960.18 (18.73)	+	.84 (2.92)	BEDS	R^2 = .0984
d)	HOSPAC =	941.14 (14.60)	+	179.03 (1.81)	BLESS20	R^2 = .0403
e)	HOSPAC =	1053 (20.21)	-	286.03 (-1.94)	B50119	R^2 = .0461
f)	HOSPAC =	1004.7 (19.46)	+	167.14 (.89)	B120499	R^2 = .0100
g)	HOSPAC =	993.53 (20.87)	+	947.82 (3.15)	B500MOR	R^2 = .1128
h)	HOSPAC =	978.97 (5.65)	+	11.24 (.23)	LOGBEDS	R^2 = .0007
i)	HOSPAC =	994.41 (20.73)	+	.0007 (2.94)	BEDSSQ	R^2 = .0999
j)	HOSPAC =	3439.1 (10.78)	-	741.67 (-7.64)	LOGFLO	R^2 = .4282
k)	HOSPAC =	264.53 (.40)	+	317.73 (1.15)	LOGLOS	R^2 = .0166
l)	LOGCOST =	7.59 (77.87)	-	.027 (-8.08)	FLO	R^2 = .4559
m)	LOGCOST =	6.39 (28.32)	+	.043 (2.09)	ADJLOS	R^2 = .0529
n)	LOGCOST =	6.80 (153.94)	+	.0007 (2.77)	BEDS	R^2 = .0896
o)	LOGCOST =	6.78 (122.67)	+	.15 (1.81)	BLESS20	R^2 = .0404
p)	LOGCOST =	6.88 (154.18)	-	.25 (-2.01)	B50119	R^2 = .0490

15.

q)	LOGCOST	=	6.83	+	.23B120499	R^2 = .0253
			(155.47)		(1.42)	
r)	LOGCOST	=	6.83	+	.74 B500MOR	R^2 = .0930
			(165.43)		(2.83)	
s)	LOGCOST	=	6.80	+	.014 LOGBEDS	R^2 = .0015
			(45.73)		(.35)	
t)	LOGCOST	=	6.83	+	.0000006 BEDSSQ	R^2 = .0804
			(164.23)		(2.61)	
u)	LOGCOST	=	9.03	-	.67 LOGFLO	R^2 = .4736
			(34.39)		(-8.38)	
v)	LOGCOST	=	5.83	+	.43 LOGLOS	R^2 = .0410
			(10.48)		(1.83)	
w)	HOSPAC	=	1017.2	-	104.31 (FIRST COMPONENT)	R^2 = .0029
			(20.41)		(-.47)	
x)	HOSPAC	=	1017.2	+	155.4 (SECOND COMPONENT)	R^2 = .0028
			(20.41)		(.46)	
y)	HOSPAC	=	1017.2	+	208.10 (THIRD COMPONENT)	R^2 = .0041
			(20.43)		(.56)	
z)	LOGCOST	=	6.84	-	.16 (FIRST COMPONENT)	R^2 = .0093
			(160.74)		(-.85)	
aa)	LOGCOST	=	6.84	-	.01 (SECOND COMPONENT)	R^2 = .0000
			(160.0)		(-.05)	
bb)	LOGCOST	=	6.84	+	.13 (THIRD COMPONENT)	R^2 = .0021
			(160.2)		(.41)	

16. LINEAR REGRESSIONS USING HOSPITAL SIZE DUMMIES

a) HOSPAC = f (FLO) R^2 = .3752 F = 46.84

b) HOSPAC = f (FLO, B500MOR) R^2 = .4984 F = 38.25

c) HOSPAC = f (FLO, B500MOR, B50119) R^2 = .5009 F = 25.42

d) HOSPAC = f (FLO, B500MOR, B50119 B20LESS) R^2 = .5009 F = 18.82

e) HOSPAC = f (FLO, B500MOR, T50119, BLESS20, ADJLOS) R^2 = .5405 F = 17.41

f) HOSPAC = f (FLO, B500MOR, T50119, BLESS20, ADJLOS, B120499) R^2 = .5905 F = 17.54

g) HOSPAC = 1486.3 (5.74) - 37.25 FLO (-8.71) + 875.14 B500MOR (3.80)

+ 148.81 B50119 (1.35) + 123.93 BLESS20 (1.57) + 2.7367 ADJLOS (.11)

+ 257.97 B120499 (1.61) - 994.19 INFPAR (-2.47) - 71.94 OBS (-.29)

+ 1490.4 TREM (2.58) + 2563 MALNEO (2.82) + 346.30 CIRC (1.18)

- 200.69 RESP (-1.37) + 1786.5 NEURPSY (4.74) + 1866.9 GASENT (5.69)

+ 3373.7 GENUR (5.56) - 248.26 SURG (-3.90) - 542.10 SPESURG (-3.70)

Includes first three principal components.

Cum.% of Eigenvalues = 66.7

F = 15.12 F on three components = 4.80

R^2 = .6604

multicollinearity: some

heteroscedasticity: none

parameters: several are implausible.

17. LINEAR REGRESSIONS USING HOSPITAL SIZE DUMMIES, LOGFLO AND LOGLOS

a) HOSPAC = f (LOGFLO) R^2 = .4282 F = 58.40

b) HOSPAC = f (LOGFLO, B500MOR) R^2 = .5616 F = 49.31

c) HOSPAC = f (LOGFLO, B500MOR, B50119) R^2 = .5630 F = 32.63

d) HOSPAC = f (LOGFLO, B500MOR, B50119, BLESS20) R^2 = .5641 F = 32.63

e) HOSPAC = f (LOGFLO, B500MOR, B50119, BLESS20, LOGLOS) R^2 = .6241 F = 32.63

f) HOSPAC = f (LOGFLO, B500MOR, B50199, BLESS20, LOGLOS, B120499) R^2 = .6719 F = 24.91

g) HOSPAC = 4388.5 (6.03) - 1010.6 LOGFLO (-10.81) + 884.55 B500MOR (4.30)

+ 113.59 B50119 (1.16) + 97.03 BLESS20 (1.38) - 232.81 LOGLOS (-.88)

+ 270.75 B120499 (1.89) - 559.06 INFPAR (1.56) - 304.30 OBS (1.37)

+ 1060.1 TREM (2.06) + 2293 MALNEO (2.83) + 519.87 CIRC (1.99)

- 38.061 RESP (-.29) + 1393.6 NEURPSY (4.15) + 1625.90 GASENT (5.56)

+ 2887.70 GENUR (5.34) - 273.47 SURG (4.82) - 603.45 SPESURG (4.62)

Includes first three principal components

Cum.% of Eigenvalues = 66.7

F = 21.03 F on three components = 5.02

R^2 = .7300

multicollinearity: some

heteroscedasticity: none

parameters: several are implausible

18. LINEAR REGRESSIONS USING HOSPITAL SIZE DUMMIES, LOGFLO AND LOGLOS FOR HOSPITALS WITH TWENTY BEDS OR MORE ONLY

$$\begin{aligned} HOSPAC = {} & \underset{(9.09)}{3355.5} - \underset{(-6.74)}{764.22}\ LOGFLO + \underset{(4.52)}{712.53}\ B500MOR \\ & + \underset{(.94)}{105.77}\ B120499 + \underset{(.03)}{1.9025}\ B50119 + \underset{(5.53)}{1444.5}\ INFPAR \\ & - \underset{(-2.85)}{908.17}\ OBS + \underset{(2.10)}{1018}\ TREM - \underset{(-4.20)}{4946.2}\ MALNEO \\ & + \underset{(1.32)}{525.65}\ CIRC + \underset{(7.24)}{942.76}\ RESP - \underset{(-2.77)}{1315.3}\ NEURPSY \\ & + \underset{(6.47)}{1758.2}\ GASENT + \underset{(4.10)}{1793.8}\ GENUR - \underset{(-7.95)}{324.29}\ SURG \\ & - \underset{(-8.13)}{823.55}\ SPESURG \end{aligned}$$

Includes first three principal components

Cum.% of Eigenvalues = 78.6

F = 22.86

R^2 = .8081

multicollinearity: some

heteroscedasticity: none

parameters: largely implausible

19. LINEAR REGRESSIONS USING BEDS AND BEDSSQ

a) HOSPAC = f (FLO) R^2 = .3752 F = 46.84

b) HOSPAC = f (FLO, BEDSSQ) R^2 = .4742 F = 34.72

c) HOSPAC = f (FLO, BEDSSQ, BEDS) R^2 = .5474 F = 30.64

d) HOSPAC = f (FLO, BEDSSQ, BEDS, ADJLOS) R^2 = .5660 F = 24.45

e) HOSPAC = 1339.4 (5.25) - 37.13 FLO (-8.89) - .0006 BEDSSQ (-.95) + 1.46 BEDS (1.91)

+ 17.31 ADJLOS (.70) - 968.52 INFPAR (-2.37) + 11.12 OBS (.04)

+ 1745.7 TREM (2.97) + 2302.5 MALNEO (2.49) + 238.62 CIRC (.80)

- 189.51 RESP (-1.27) + 1846.5 NEURPSY (4.83) + 1927.2 GASENT (5.78)

+ 3480 GENUR (5.65) - 264.67 SURG (-4.09) - 581.04 SPESURG (-3.90)

Includes first three principal components

Cum.% of Eigenvalues = 66.7

F = 18.24 F on three components = 4.89

R^2 = .6394

multicollinearity: slight

heteroscedasticity: none

parameters: several are implausible

20. LINEAR REGRESSIONS USING BEDS, BEDSSQ, LOGFLO AND LOGLOS

a) HOSPAC = f (LOGFLO) R^2 = .4282 F = 58.40

b) HOSPAC = f (LOGFLO, BEDSSQ) R^2 = .5372 F = 44.68

c) HOSPAC = f (LOGFLO, BEDSSQ, BEDS) R^2 = .6194 F = 41.22

d) HOSPAC = f (LOGFLO, BEDSSQ, BEDS, LOGLOS) R^2 = .6547 F = 35.56

e) HOSPAC = 4383.5 (5.89) - 980.32 LOGFLO (-10.62) - .0006 BEDSSQ (-1.04)

+ .81 BEDS (4.04) - 195.52 LOGLOS (-.76) - 923.81 INFPAR (1.53)

- 921.69 OBS (-2.61) - 1120.2 TREM (-1.51) - 5138.9 MALNEO (-2.81)

+ 732 CIRC (1.92) + 489.19 RESP (2.06) + 616.51 NEURPSY (.77)

+ 1451.9 GASENT (1.78) + 4338.9 GENUR (2.94) - 254.60 SURG (-3.67)

- 610.61 SPESURG (-3.45

Includes first three principal components

Cum.% of Eigenvalues = 66.7

F = 27.07 F on three components = 6.09

multicollinearity: slight

heteroscedasticity: none

parameters: several are implausible

21. LINEAR REGRESSION USING BEDS, BEDSSQ, LOGFLO, LOGLOS

a) Hospitals with less than twenty beds

$$\begin{aligned} HOSPAC = {} & \underset{(6.55)}{5402.5} - \underset{(-6.98)}{945.2}\ LOGFLO - \underset{(-1.27)}{144.18}\ BEDS + \underset{(1.00)}{4.29}\ BEDSSQ \\ & + \underset{(1.87)}{633.45}\ INFPAR + \underset{(.62)}{184.35}\ OBS + \underset{(.44)}{291.06}\ TREM \\ & + \underset{(.70)}{756.43}\ MALNEO - \underset{(-1.34)}{504.38}\ CIRC + \underset{(1.33)}{308.63}\ RESP \\ & - \underset{(-2.19)}{800.13}\ NEURPSY - \underset{(-2.63)}{1831.1}\ GASENT - \underset{(-2.54)}{2922.8}\ GENUR \\ & + \underset{(.12)}{35.78}\ SURG + \underset{(1.38)}{661.67}\ SPESURG \end{aligned}$$

Includes first three principal components.

Cum.% of Eigenvalues = 57.7

F = 14.41

R^2 = .7621

multicollinearity: slight

heteroscedasticity: none

parameters: most are implausible

21.

b) Hospitals with more than twenty beds

$$\text{HOSPAC} = \underset{(9.39)}{3360.3} - \underset{(-7.20)}{781.69}\ \text{LOGFLO} + \underset{(2.00)}{1.07}\ \text{BEDS} - \underset{(-.76)}{.0003}\ \text{BEDSSQ}$$

$$+ \underset{(5.14)}{1356.}\ \text{INFPAR} - \underset{(-2.86)}{920.24}\ \text{OBS} + \underset{(1.93)}{942.48}\ \text{TREM}$$

$$- \underset{(-3.87)}{4594.5}\ \text{MALNEO} + \underset{(1.44)}{580.06}\ \text{CIRC} + \underset{(6.88)}{903.52}\ \text{RESP}$$

$$- \underset{(-2.56)}{1229.5}\ \text{NEURPSY} + \underset{(6.30)}{1729.1}\ \text{GASENT} + \underset{(3.98)}{1755}\ \text{GENUR}$$

$$- \underset{(-7.61)}{313.55}\ \text{SURG} - \underset{(-7.73)}{791.47}\ \text{SPESURG}$$

Includes first three principal components.

Cum.% of Eigenvalues = 78.6

F = 25.86

R^2 = .7991

multicollinearity: slight

heteroscedasticity: none

parameters: several implausible

22. LINEAR REGRESSIONS USING 'LOGCOST' AND HOSPITAL SIZE DUMMIES

a)	LOGCOST = f (FLO)		R^2 = .4559	F = 65.36
b)	LOGCOST = f (FLO, B500MOR)		R^2 = .5593	F = 48.87
c)	LOGCOST = f (FLO, B500MOR, B50119)		R^2 = .5638	F = 32.74
d)	LOGCOST = f (FLO, B500MOR, B50119, BLESS20)		R^2 = .5643	F = 24.28
e)	LOGCOST = f (FLO, B500MOR, B50119, BLESS20, ADJLOS)		R^2 = .5844	F = 20.81
f)	LOGCOST = f (FLO, B500MOR, B50119, BLESS20, ADJLOS, B120499)		R^2 = .6737	F = 25.15

g) LOGCOST = 7.11 (31.49) - .03 FLO (-11.41) + .63 B500MOR (3.86) + .16B50119 (1.98)

+ .09 BLESS20 (1.57) + .02 ADJLOS (1.09) + .27 B120499 (2.38)

- 1.01 INFPAR (-3.51) - .19 OBS (-1.07) + 1.10 TREM (2.67) + 2.88 MALNEO (4.45)

+ .49 CIRC (2.37) - .21 RESP (-2.01) + 1.66 NEURPSY (6.20) + 1.75 GASENT (7.46)

+ 3.16 GENUR (7.31) - .22 SURG (-4.87) - .48 SPESURG (-4.58)

Includes first three principal components

Cum.% of Eigenvalues = 66.7

F = 25.25 F on three components = 9.00

R^2 = .7645

multicollinearity: some

heteroscedasticity: none

parameters: several are implausible

23. LINEAR REGRESSIONS USING LOGCOST, LOGFLO, LOGLOS AND HOSPITAL SIZE DUMMIES

a) LOGCOST = f (LOGFLO) R^2 = .4736 F = 70.17

b) LOGCOST = f (LOGFLO, B500MOR) R^2 = .5864 F = 54.58

c) LOGCOST = f (LOGFLO, B500MOR, B50119) R^2 = .5880 F = 36.15

d) LOGCOST = f (LOGFLO, B500MOR, B50119, BLESS20) R^2 = .5909 F = 27.08

e) LOGCOST = f (LOGFLO, B500MOR, B50119, BLESS20, LOGLOS) R^2 = .6204 F = 24.19

f) LOGCOST = f (LOGFLO, B500MOR, B50119, BLESS20, LOGLOS, B120499) R^2 = .7062 F = 29.24

g) LOGCOST = 9.20 (15.74) - .89 LOGFLO (-12.39) + .66 B500MOR (4.21) + .12 B50119 (1.54)

+ .07 BLESS20 (1.23) + .05 LOGLOS (.23) + .29 B120499 (2.68)

- .61 INFPAR (-2.22) - .36 OBS (-2.13) + .78 TREM (1.98) + 2.54 MALNEO (4.08)

+ .61 CIRC (3.03) - .07 RESP (-.65) + 1.32 NEURPSY (5.12) + 1.53 GASENT (6.81)

+ 2.73 GENUR (6.56) - .24 SURG (-5.59) - .53 SPESURG (-5.32)

Includes first three principal components

Cum.% of Eigenvalues = 66.7

F = 28.15 F on three components = 8.33

R^2 = .7835

multicollinearity: slight

heteroscedasticity: none

parameters: several are implausible

24. LINEAR REGRESSIONS USING LOGCOST, LOGFLO, LOGLOS AND HOSPITAL SIZE DUMMIES

a) Hospitals with less than twenty beds

LOGCOST =	9.47	-	.84 LOGFLO	+	.45 B500MOR	+	.12 B120499	
	(28.76)		(-8.55)		(3.29)		(1.27)	
+	.04 B50119	+	1.56 INFPAR	-	.66 OBS	+	1.25 TREM	
	(.60)		(6.92)		(-2.38)		(2.97)	
-	5.16 MALNEO	+	.19 CIRC	+	.91 RESP	-	1.28 NEURPSY	
	(-5.06)		(.54)		(8.03)		(-3.11)	
+	1.54 GASENT	+	1.76 GENUR	-	.32 SURG			
	(6.54)		(4.64)		(-8.98)			
-	.82 SPESURG							
	(-9.35)							

Includes first three principal components

Cum.% of Eigenvalues = 78.6

F = 27.83

R^2 = .8368

multicollinearity: slight

heteroscedasticity: none

parameters: several are implausible

25. LINEAR REGRESSIONS USING LOGCOST, LOGFLO, LOGLOS, BEDS AND BEDSSQ

a) LOGCOST = f (LOGFLO) R^2 = .4736 F = 70.17

b) LOGCOST = f (LOGFLO, BEDSSQ) R^2 = .5626 F = 49.53

c) LOGCOST = f (LOGFLO, BEDSSQ, BEDS) R^2 = .6823 F = 54.41

d) LOGCOST = f (LOGFLO, BEDSSQ, BEDS, LOGLOS) R^2 = .6951 F = 42.75

e) LOGCOST = 9.04 (15.39) - .90 LOGFLO (-12.75) - .0000008 BEDSSQ (-1.92)

+ .002 BEDS (2.91) + .13 LOGLOS (.64) - .61 INFPAR (-2.19) - .33 OBS (-1.89)

+ .90 TREM (2.26) + 2.44 MALNEO (3.87) + .56 CIRC (2.76) - .06 RESP (-.62)

+ 1.36 NEURPSY (5.21) + 1.56 GASENT (6.90) + 2.78 GENUR (6.64)

- .25 SURG (-5.71) - .55 SPESURG (-5.45)

Includes first three principal components

Cum.% of Eigenvalues = 66.7

F = 34.96 F in three components = 8.19

R^2 = .7727

multicollinearity: some

heteroscedasticity: none

parameters: several are implausible

26. SIMPLE LINEAR REGRESSION OF CASEMIX VARIABLES ON 'LOGCOST'

a)	LOGCOST	=	6.96 (86.12)	-	2.31 (-1.69)	INFPAR	R^2 = .0353
b)	LOGCOST	=	6.79 (79.22)	+	.73 (.84)	OBS	R^2 = .0090
c)	LOGCOST	=	6.87 (63.77)	-	.34 (-.20)	TREM	R^2 = .0005
d)	LOGCOST	=	6.84 (92.42)	+	.35 (.11)	MALNEO	R^2 = .0002
e)	LOGCOST	=	6.89 (57.58)	-	.31 (-.34)	CIRC	R^2 = .0015
f)	LOGCOST	=	6.87 (63.00)	-	.11 (-.19)	RESP	R^2 = .0005
g)	LOGCOST	=	6.77 (70.44)	+	1.13 (.91)	NEURPSY	R^2 = .0105
h)	LOGCOST	=	7.14 (55.84)	-	3.72 (-2.40)	GASENT	R^2 = .0690
i)	LOGCOST	=	6.94 (60.00)	-	2.23 (-.82)	GENUR	R^2 = .0086
j)	LOGCOST	=	6.84 (105.42)	+	.03 (.09)	SPESURG	R^2 = .0001

27. LINEAR REGRESSIONS OF CASEMIX VARIABLES ONLY ON 'LOGCOST'

a)	LOGCOST = f (GASENT)	R^2 = .0690 F = 5.78
b)	LOGCOST = f (GASENT, INFPAR)	R^2 = .0948 F = 4.58 F on INFPAR = 2.16
c)	LOGCOST = f (GASENT, INFPAR, NEURPSY)	R^2 = .1186 F = 3.78 F on NEURPSY = 2.02
d)	LOGCOST = f (GASENT, INFPAR, NEURPSY, OBS)	R^2 = .1186 F = 2.80 F on OBS = .004
e)	LOGCOST = f (GASENT, INFPAR, NEURPSY, OBS, GENUR)	R^2 = .1186 F = 2.21 F on GENUR = .003
f)	LOGCOST = f (GASENT, INFPAR, NEURPSY, OBS, GENUR, CIRC)	R^2 = .1234 F = 1.89 F on CIRC = .40
g)	LOGCOST = f (GASENT, INFPAR, NEURPSY, OBS, GENUR, CIRC, TREM)	R^2 = .1313 F = 1.71 F on TREM = .65
h)	LOGCOST = f (GASENT, INFPAR, NEURPSY, OBS, GENUR, CIRC, TREM, RESP)	R^2 = .1595 F = 1.82 F on RESP = 2.39
i)	LOGCOST = f (GASENT, INFPAR, NEURPSY, OBS, GENUR, CIRC, TREM, RESP, MALNEO)	R^2 = .1617 F = 1.62 F on MALNEO = .19

j)

$$\underset{(10.10)}{\text{LOGCOST} = 7.89} - \underset{(-2.63)}{5.32\ \text{GASENT}} - \underset{(-2.52)}{4.54\ \text{INFPAR}} + \underset{(.71)}{1.09\ \text{NEURPSY}}$$

$$+ \underset{(.32)}{.41\ \text{OBS}} - \underset{(-.76)}{2.47\ \text{GENUR}} - \underset{(-.04)}{.07\ \text{CIRC}} - \underset{(-.57)}{1.41\ \text{TREM}}$$

$$- \underset{(-.19)}{.24\ \text{RESP}} - \underset{(-.84)}{3.02\ \text{MALNEO}} - \underset{(-1.51)}{1.65\ \text{SURG}}$$

F = 1.71 F on SURG = 2.29

R^2 = .1887

multicollinearity: severe

heteroscedasticity: none

parameters: several are implausible

28. LINEAR REGRESSIONS OF 'LOGCOST' AGAINST SELECTED TRANSFORMATIONS OF CASEMIX VARIABLES

a) LOGCOST = 6.48 + .36 EXPINFPAR R^2 = .0002
(2.09) (.12)

b) LOGCOST = 7.12 + .07 EXPOBS R^2 = .0250
(35.85) (1.41)

c) LOGCOST = 6.88 - 3.87 MALNEO + 69.4 MALNEOSQ R^2 = .0042
(64.5) (-.47) (.56)

d) LOGCOST = 8.99 - 2.05 LOGCIRC R^2 = .0079
(3.32) (-.79)

e) LOGCOST = 6.92 + .02 EXPRESP R^2 = .0010
(26.17) (.28)

f) LOGCOST = 7.31 - 21.78 GENUR + 218.62 GENURSQ R^2 = .0713
(36.56) (-2.43) (2.28)

g) LOGCOST = 7.51 - 14.38 GASENT + 67.03 GASENTSQ R^2 = .1206
(34.71) (-2.75) (2.13)

h) LOGCOST = 6.76 + .09 EXPSPESURG R^2 = .0001
(7.82) (.11)

29. LINEAR REGRESSION OF 'LOGCOST' AGAINST CASEMIX VARIABLES (INCLUDING SELECTED TRANSFORMATIONS), HOSPITAL SIZE DUMMIES, 'LOGFLO'

a) LOGCOST = 9.71 (45.77) - .91 LOGFLO (-14.01) + .57 B500MOR (3.56) + .22 B120499 (1.89)

+ .09 B50119 (1.21) - .42 INFPAR (-3.01) + .74 OBS (6.31) + 1.03 TREM (3.42)

- .008 LOGMALNEO (-1.53) - .89 CIRC (-5.58) - .26 RESP (-3.47)

+ .16 NEURPSY (.69) - .60 GASENT (-4.59) - .02 LOGGENUR (-4.37)

+ .16 SURG (-5.57) + .39 SPESURG (5.75) - 3.5 GASENTSQ (-4.73)

+ 2.4 SPESURGSQ (5.91) + .89 NEURPSYSQ (.78) + 7.16 TREMSQ (3.85)

+ .42 SURGSQ (5.83)

Includes first three principal components

Cum.% of Eigenvalues = 61.7

F = 36.21

R^2 = .7788

multicollinearity: none

heteroscedasticity: not tested

parameters: most are implausible

30. LINEAR REGRESSION: 'LOGCOST' ON CASEMIX*, LOGFLO, BEDS, BEDSSQ

a) LOGCOST = 9.94 (45.42) - .92 LOGFLO (-14.29) + .001 BEDS (2.85) - .0000007 BEDSSQ (-1.83)

- .23 INFPAR (-.92) - .50 OBS (-3.00) - 2.50 TREM (-5.58) + .96 MALNEO (1.28)

+ .72 CIRC (3.49) - .13 RESP (-1.39) - 1,09 NEURPSY (-2.99) + .25 SURG (4.70)

+ .57 SPESURG (4.76)

Includes first three principal components

Cum.% of Eigenvalues = 73.6

F = 40.83

R^2 = .7704

multicollinearity: some

heteroscedasticity: none

parameters: most are plausible

* Casemix respecified so that GENUR and GASENT are included in the residual and not estimated separately.

31. LINEAR REGRESSION: 'LOGCOST' ON CASEMIX*, LOGFLO, BEDS, BEDSSQ, URBAN, TEACH, EXTCU AND ADJLOS

a) LOGCOST = 9.53 (26.36) − .86 LOGFLO (−11.81) + .0006 BEDS (.77)

− .0000004 BEDSSQ (−.83) + .21 URBAN (1.19) + .35 TEACH (2.21)

+ .02 ADJLOS (1.12) + .05 EXTCU (.55) − .08 INFPAR (−.35) − .49 OBS (−3.00)

− 2.57 TREM (−5.89) + .50 MALNEO (.69) + .68 CIRC (3.36) − .09 RESP (−.91)

− 1.29 NEURPSY (−3.63) + .25 SURG (4.92) + .57 SPESURG (4.94)

Includes first three principal components

Cum.% of Eigenvalues = 73.6

F = 26.46

R^2 = .7932

multicollinearity: moderate

heteroscedasticity: none

parameters: mostly plausible

* Casemix respecified so that GENUR and GASENT are included in the residual and not estimated separately.

32. LINEAR REGRESSION: 'LOGCOST' ON CASEMIX*, FLO, FLOSQ, BEDS, BEDSSQ, URBAN, TEACH, ADJLOS AND EXTCU

a) LOGCOST = 8.08 (28.05) - .07 FLO (-6.47) + .0006 FLOSQ (3.50) + .0006 BEDS (.83)

- .0000005 BEDSSQ (-.92) + .21 URBAN (1.23) + .32 TEACH (2.03)

+ .02 ADJLOS (.94) + .07 EXTCU (.68) - .09 INFPAR (-.41) - .51 OBS (-2.95)

- 2.33 TREM (-5.52) + .52 MALNEO (.77) + .59 CIRC (3.26) - .14 RESP (-1.04)

- 1.34 NEURPSY (-3.13) + .25 SURG (3.50) + .56 SPESURG (4.43)

$F = 24.49$

$R^2 = .7984$

multicollinearity: moderate

heteroscedasticity: none

parameters: mostly plausible

* Casemix respecified so that GENUR and GASENT are included in the residual and not estimated separately.

HOSPITAL EFFICIENCY, MARGINAL COSTS AND HOSPITAL SYSTEMS PLANNING UNDER UNIVERSAL COVERAGE

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