Examining possibilities for adjustments in staffing within acute hospitals.

Christine A Kerr, J Colin Glass, Gillian McCallion, Donal G McKillop*, and Karl Stringer

University of Ulster
(* Queen's University, Belfast)

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Abstract
This paper illustrates how cost efficiency measures, based on input prices, can provide **comparative information for managers who are concerned with hospital staffing issues** in an environment of budgetary constraints. Using data on acute hospital services and associated labour inputs within Northern Ireland, and employing **Data Envelopment Analysis** (DEA) techniques, we estimate cost efficiency (based on labour prices) for each hospital. Where there is found to be evidence of cost inefficiency, relative to best practice within the region, we show that managers can identify whether this is due to allocative inefficiency, in other words the wrong mix of labour prices, or to technical inefficiency, that is paying labour prices that are proportionately higher than elsewhere in the hospital sector. Furthermore, we suggest that hospital managers can use measures of the relative over- or under-pricing of the individual labour inputs as a guide in planning a more appropriate skill-mix or grade-mix within each of the main categories of labour.

Contact Address:
Christine A Kerr
School of Business, Retail and Financial Services
University of Ulster
Cromore Road
Coleraine
BT52 1SA
Tel: (028) 70324149
e-mail: ca.kerr@ulst.ac.uk

SECTION I

Introduction

The provision of services within acute hospitals in Northern Ireland represents a substantial claim on resources secured for health programmes. During 1991-92 revenue expenditure on hospital, specialist and related services accounted for £538.2m, 50.6% of total revenue expenditure by the Health and Social Services Boards (N. Ireland Audit Office, 1993). However, community care services have remained considerably underdeveloped by comparison with the rest of the UK, and this has contributed to mounting pressure for a redistribution of resources and cost containment within the acute hospital sector (see Northern Ireland Economic Council, 1995). Labour costs account for almost 70% of the total revenue budget of these hospitals with the provision of nursing staff constituting the largest component. Consequently any initiative to improve the (cost) efficient use of resources within the hospitals must concentrate on reducing staff-related expenditures, namely by addressing issues of the skills and costs of different kinds of labour.

Proponents of the reform of skill mix in the NHS argue that there are opportunities for cost efficiency gains by substituting lower skilled (and less expensive) staff for higher skilled (and more expensive) staff. However, Maynard and Richardson (1995) comment that 'policy makers ought not to consider solely the unit costs of labour, but use these in combination with outcomes and data on time taken per task to identify the optimal skill mix'. Their review also notes the weaknesses of a number of studies of labour substitution in the health care sector, while acknowledging the numerous challenges facing any researcher in this area. Nonetheless, there is historical evidence of factor substitution within the NHS as found by Gray and McGuire (1989) for hospitals in Scotland, and the possibilities for adjustments in staffing to reduce cost pressures remains an area of priority interest for managers and policy makers in the health sector.

A notable initiative within the public sector over the last five years has been the drive to introduce rigorous approaches for comparing performance across similar providers. Generally this has required individual units to measure performance on specified aspects of service provision, with a view to identifying where practice is poor relative to performance across the particular sector. Such initiatives have been especially prevalent throughout all parts of the NHS, with the aim to support the dual objectives of improving economic efficiency in the use of resources, and securing health care services of an assured clinical quality (Department of Health, 1997).

This paper seeks to demonstrate how the technique of Data Envelopment Analysis (DEA) can contribute to a manger's understanding of a hospital's cost performance in relation to the average wage rates paid for different types of labour given practice elsewhere in the sector. In addition, we demonstrate how the technique can point to the direction of grade mix adjustment (or substitution of lower skilled for higher skilled staff) required within the different labour categories if cost efficiency is to be enhanced. The DEA literature includes applications to measuring performance within the public sector (e.g. Jesson, Mayston and Smith, 1987), and more recently DEA has been used for examining technical efficiency in the hospital sector by Hollingsworth and Parkin (1995), Rosenman, Siddharthan and Ahern (1997), and Kerr, Glass, McCallion and McKillop (1999).

Section II of the paper describes the DEA methodology and input price efficiency measures and Section III details the key issues that have to be addressed in applying this model to the hospital sector. Using this technique we estimate overall cost efficiency relative to average wage rates of the different types of labour for hospitals in Northern Ireland, and present the results in Section IV. Section V demonstrates how the results of the analysis can be utilised to guide managers in planning adjustments in staffing, namely the substitution of lower grade staff for higher grade staff

within each broad category of labour. Before concluding we discuss the possible limitations of such analysis in light of the relationship between skill and the quality of health care.

SECTION II

Methodology

We begin our study by examining cost efficiency relative to labour prices, or in other words, unit wage costs, for each individual hospital across the sector of interest. Employing the technique of DEA (overall) cost efficiency is estimated using an approach based on the input price efficiency model of Färe, Grosskopf and Lovell (1994). This technique constructs empirical production frontiers formed from best-observed practice among units within the sample. It is these efficiency frontiers which then provide the benchmark against which the performance of an individual unit, in this study a hospital, is measured. Those hospitals that are found to be operating on (and determining this frontier) are termed efficient, and those not operating on the frontier are termed relatively inefficient.

The input price efficiency model, of Färe *et al* (1994) departs from the usual assumption that input prices are taken as given and the choice variables are input quantities. Rather, it is assumed in this model that within each individual unit there is flexibility over input prices while input quantities must be regarded as fixed. In our study we have adapted this model to the scenario where the manager is not able to make changes to the numbers of staff employed, but does have a degree of flexibility over the average price paid for each type of labour, within the context of a given (total cost) staffing budget. Applied to the acute hospital sector, this type of analysis provides information on whether there exists the possibility for a manager to make changes in the average prices paid for labour within the hospital in a bid to improve cost efficiency and yet maintain the same level of service provision.

To proceed, we have calculated cost efficiency relative to (staff) input prices using the measure of overall input price efficiency developed by Färe *et al* (1994). Färe *et a1* demonstrate how to compute overall input price efficiency (which is the ratio of minimum staffing cost to observed staffing cost) for each individual unit. Minimum staffing cost for each hospital is found by minimising over (cost-normalised or cost-deflated) input prices. This gives an estimate of the minimum staffing cost at which the observed outputs of the hospital could have been produced, given labour usage by that hospital, and given the rates paid for each type of labour elsewhere within the sector under consideration. Where the estimated (potential) minimum cost is less than the observed cost of a hospital this is interpreted as evidence of overall cost inefficiency. In this situation it is possible for the hospital to provide the same services at lower cost by changing the prices it pays for staffing resources. Therefore, as will be illustrated below (in Section IV), managers and policy makers within the health sector can obtain an estimate of comparative cost efficiency for an individual hospital, given current rates paid for staff across the set of hospitals under consideration.

Where there is found to be evidence of cost inefficiency within a hospital this means that the input prices are non-optimal given practice elsewhere in the sector and given usage of labour inputs and the provision of services by that particular hospital. This may be due to a combination of two factors. Firstly, the average wage rates paid for the different types of labour may be proportionately too high, given practice elsewhere within the sector (termed input price technical inefficiency by Färe *et al* (1994)). Secondly, given the numbers of the different types of labour employed within a particular hospital, there may be the opportunity to reduce overall costs by changing the relative prices of staff (termed input price allocative inefficiency by Färe *et al* (1994)).

In order to estimate input price technical efficiency for each hospital we solve a linear programming problem that finds the greatest proportional reduction in (cost-deflated) input prices at which the hospital can achieve its observed output give a (minimum cost) target budget. Where such a reduction in observed (cost-deflated) input prices is found, this indicates that the hospital could potentially achieve its observed output with the (minimum cost) target budget by paying proportionately lower input prices. In other words, relative to best practice within the sample of hospitals, the given hospital is paying average labour prices that are proportionately too high (or technically inefficient).

Since overall cost inefficiency is due to some combination of technical and allocative input price inefficiency, an estimate of the latter type of inefficiency can be obtained from our estimates of overall cost and technical inefficiency. Färe *et al* (1994) show that the input price allocative efficiency measure is given by the ratio of the overall input price efficiency to input price technical efficiency measure. Where input price allocative inefficiency is found, this indicates that compared to best practice the hospital is paying the wrong relative prices for types of staff given its observed mix of staff quantities. It should be noted that the above input price measures of efficiency are obtained relative to a constant returns to scale technology.

Clearly, where there is allocative inefficiency it is important for managers to be able to identify wherein lie the roots of this inefficiency. Such insight can be gained by assessing whether there is relative over- or under-pricing of each type of labour employed. The measure that we have used in this paper is the ratio of the technically efficient price (given the observed input price mix) to the cost minimising price (given the optimal input price mix) of the labour input, where both are obtained as a by-product of the DEA. Where the ratio of these prices is less than one this indicates

relative under-pricing of the particular input. Conversely, where the ratio is greater than one this is evidence that the input in question is relatively over-priced.

SECTION III

The Data

This study applies the methodology described in Section II above to comparing efficiency across acute hospitals within Northern Ireland. However, in order to specify an operational model we have had to address three key issues, at least two of which will be common to any application of DEA techniques for comparison of performance within the hospital sector.

The first issue that confronts the practitioner is that she is concerned with comparing hospitals that typically provide a diverse range of services from a complexity of input factors. Moreover, one must be alert to the fact that the results of a DEA analysis are potentially sensitive to data misspecification particularly where the sample is small (see Smith, 1997). In view of this we have taken care to include all the main services of the acute hospitals and those inputs which account for the greater part of hospital revenue expenditure. However, before proceeding with a DEA study one must also ensure that the total number of inputs and outputs of the model is not too large relative to the size of the available data set (see Nunamaker, 1985). This means that in practice, to enable meaningful analysis, some aggregation is necessary, and so consequently in this study we decided to model each hospital as an independent unit producing five outputs and using four labour inputs.

The second issue relates to the possibility of significant year to year variation in efficiency for each hospital so that simple comparisons of annual performance may be misleading. For example, Parkin and Hollingsworth (1997) found the measured efficiency of Scottish hospitals varied considerably from one year to another. It must be acknowledged that to an extent the demand for

health care is uncertain (see Friedman and Pauly, 1981), and health care planners must allocate human resources to particular services on the basis of projections. Consequently, given employment contracts and the attendant wage commitments, and considering the limited catchment area for a particular hospital, then any significant local variations in demand (from that anticipated over the year) will influence measured efficiency. As such it is preferable to average annual performance over a period of consecutive years in order to limit potential bias from this source.

The third issue relates to the very small number of acute hospitals within the Northern Ireland region which were suitable for comparison; once specialist units were omitted these numbered just twenty-two over the period of our study, l990-92. Therefore, taking the latter two issues into consideration it was decided that an appropriate action would be to create a 3-year data set by pooling the annual observations of each hospital (see Lovell, 1993) from 1990-1992. By designing a data set comprised of three years of observations on each of the hospitals, we have in total 66 observations. This means, for example, that the performance of a hospital is compared relative to that all hospitals of the set in each year from 1990-1992. This permits us to track the performance of each hospital over the three year period or, alternatively, to measure the average efficiency of each over the period.

Finally, to clarify, within our model the main services provided by each hospital are classified into five categories: ' Surgical'; 'Medical'; 'Obstetrics and Gynaecology'; 'Accident and Emergency' ; and, 'Outpatients'. 'Surgical' measures total surgical inpatients during a year. 'Medical' and 'Obstetrics and Gynaecology' are similarly measured. 'Accident and Emergency' is the total number of visits to a unit over a year, and 'Outpatients' measures total visits to outpatient clinics over the year. The four inputs are nursing staff, medical staff, administrative staff, and ancillary staff. For each category of hospital staff we take the number of total employees, measured as full-time equivalents.

The average price or unit wage cost of each of these labour inputs was then found by dividing the total wage bill by the total number of employees.

SECTION IV

Discussion of Results

Table 1: Hospital Efficiency over the three year period, 1990-92.

Hospital	Overall Cost Efficiency	Input Price Technical Efficiency	Input Price Allocative Efficiency
1	0.468	0.616	0.759
2	0.485	0.593	0.819
3	0.579	0.607	0.954
4	0.560	0.613	0.916
5	0.606	0.766	0.792
6	0.571	0.723	0.791
7	0.957	1.000	0.957
8	0.673	0.862	0.782
9	0.956	0.992	0.963
10	0.614	0.666	0.927
11	0.820	0.880	0.933
12	0.642	0.806	0.798
13	0.974	0.994	0.979
14	0.997	1.000	0.997
15	0.568	0.644	0.889
16	0.628	0.918	0.686
17	0.722	0.786	0.926
18	0.906	1.000	0.906
19	0.700	0.764	0.916
20	1.000	1.000	1.000
21	0.942	1.000	0.942
22	0.549	0.847	0.651

Table 1 presents the overall cost efficiency results, as averaged over the three-year period, for each of the 22 hospitals of our data set. For those hospitals which are found to exhibit cost inefficiency, performance is variable and estimates of efficiency range from a value of 0.468 for hospital (1) to 0.997 for hospital (14). This suggests that costs within hospital (1) could have been reduced by over 50% (whilst maintaining the same level of services) by management changing the average prices paid for staff without making changes to the numbers of each type of staff employed within the hospital.

Nevertheless, our analysis has generally found much less scope for cost reduction within this group of hospitals, with the (overall) cost efficiency score for the group estimated to be 0.700. This indicates that, on average, there was potential for a maximum reduction of 30% in staff-related expenditures over the period of this study. It is worth noting, however, that within a third of the hospitals, we found that there was opportunity for cost reductions of less than 10%.

As outlined in Section II above, overall cost inefficiency, as defined in this paper, is potentially due to a combination of both input price technical inefficiency and input price allocative inefficiency. Table 1 above presents the efficiency scores for these constituent parts for each of the 22 hospitals. The estimates of input price technical efficiency range from 0.593 for hospital (2) up to 0.994 for hospital (13), with a mean score for the group of 0.808. This means that, on average, there was a loss of almost 20% in performance on costs, because the wage rates paid to all categories of staff were proportionately higher than in the efficient hospitals of the set.

For those hospitals found to be operating off the best-practice frontier, the scores for input price allocative efficiency range from 0.651 for hospital (22) up to 0.997 for hospital (14). We found the mean score for the group to be 0.871. This can be interpreted as a measure of the average loss to hospital efficiency performance caused by paying the wrong relative labour prices, given the chosen combination of nursing, medical, administrative, and ancillary staff, and best practice elsewhere in the region.

With the ongoing debate over the appropriate scale of operations within the acute sector (see Ferguson *et al*, 1997), it is interesting to examine cost efficiency performance by hospital size. The

evidence suggests that cost inefficiency related to input pricing was more pronounced within the larger hospitals of the region, with the average score estimated to be 0.536 for hospitals (l) to (5) inclusive (see Table 2). By comparison, the remaining hospitals of the group achieved superior performance with an average cost efficiency score of 0.756.

As Table 2 summarises, the larger hospitals achieved relatively poor outcomes on technical efficiency with an average score of 0.635, as compared with 0.843 and 0.865 for the medium-sized and small hospitals respectively. In addition, as regards allocative efficiency, performance is to some degree poorer within the larger hospitals with a mean score of 0.844, as compared with 0.898 for the medium-sized hospitals and 0.874 for the small hospitals. From this information, one can discern that the relatively poor performance by the larger hospitals on overall cost efficiency is largely the result of input price technical inefficiency, or paying average rates for labour which were in excess of those paid by efficient hospitals elsewhere in the region.

Table 2: Hospital Size and Efficiency Performance

Hospital Size	Overall Cost Efficiency	Input Price Technical Efficiency	Input Price Allocative Efficiency
Large (1-5 inc.)	0.536	0.635	0.844
Medium (6-15 inc.)	0.756	0.843	0.898
Small (16-22 inc.)	0.756	0.865	0.874

SECTION V

Adjustments in Staffing / Labour Substitution

Within the NHS in the Northern Ireland region hospital managers face fixed bands of pay for each particular grade within medical, nursing, administrative and ancillary staff. In this respect, hospital managers must be regarded as price-takers. However, there exists a degree of choice over the grade mix within each broad category of staff. If it can be assumed, for example, that a higher grade mix

within the nursing staff of the hospital is associated with payment of a higher average wage rate for nursing services, then the hospital may be described indirectly as a price-maker. In this respect choice over the grade mix or skills mix within a category of staff confers a degree of flexibility for management over the unit wage costs of staffing, particularly over the longer term.

In view of this interpretation evidence of input price technical inefficiency within a hospital in our study means that the particular hospital is employing too high an average grade mix across the four main staff groupings. Likewise, the existence of input price allocative inefficiency implies that there exists the opportunity to make costs savings by changing the relative skills mix across the staffing groups. For example, this may be achieved by employing medical staff of a lower grade and nursing staff of a higher grade. Such analysis for management recognises the flexibility that can be afforded when management considers not simply whether nurses and doctors can be substituted for one another, for example, but how skills and associated tasks can be redistributed across the team.

Table 3 further illustrates the possibilities for making changes in staffing in the eight hospitals of our sample that had the poorest performance on input price allocative efficiency. For each of the four labour inputs we have calculated the ratio of the technically efficient price (given the observed input price mix) to the cost-minimising price (given the optimal input price mix). Where the ratio is greater than one this means that the optimal price of the input is lower than the technically efficient price. This suggests relative over-pricing of this input. Conversely, where the ratio is less than one this means that the optimal price of the input is in fact higher than the technically efficient price, thus suggesting relative under-pricing of this input. This input-pricing information provides management with a general guide to staffing and grade mix strategies, relative to best practice in the sample of hospitals.

Table 3: Ratio of technically efficient price to cost-minimising price for each type of labour

Hospital	Input Price Allocative Efficiency	Medical	Nursing	Administrative	Ancillary
22	0.651	1.031	1.910	0.700	1.155
16	0.686	1.198	1.701	0.670	1.509
1	0.759	0.984	1.434	1.306	2.091
8	0.782	1.055	1.711	0.812	0.807
6	0.791	1.030	1.350	1.792	0.770
5	0.792	1.052	1.512	1.093	0.776
12	0.798	1.172	1.562	0.798	0.846
2	0.819	1.041	1.082	3.183	2.661

For example, from Table 1 above there exists approximately 15% input price technical inefficiency in hospital (22) meaning that (relative to best practice) average wage rates could be reduced by 15% without a loss of service provision. However, when we consider Table 3 it is clear that the optimal average wage rate for nursing staff involves a further reduction of almost 50% (as shown by the value 1.910). At the same time, the optimal average wage rate to pay for administrative staff would be just over 40% higher than the technically efficient price (as shown by the value 1.710). This indicates to managers that it would be efficient to make changes in staffing such that the hospital employs nursing staff of a lower grade on average, and administrative staff of a higher average grade, as compared with present practice.

If we consider hospital (2), Table 3 indicates that the ratio for each staff type is greater than one. This suggests a degree of allocative inefficiency in terms of the average prices or unit costs of all staffing types as compared to practice in efficient hospitals within the region. Therefore, there were opportunities to make cost savings by altering the grade mix within all categories of staff. However, the results on allocative inefficiency suggest that a drive towards greater efficiency would require making relatively larger adjustments in terms of lowering the average grade of both administrative and ancillary staff employed within the hospital and thus reducing the unit wage cost of these categories of staff. By contrast, relatively smaller adjustments would have been possible with nursing and medical staff within that particular hospital.

Of the eight hospitals of our sample where allocative inefficiency is most prevalent it is almost consistently the case that our research indicated the possibility to make relatively large adjustments in the grade mix of nursing staff. The results suggest that cost efficiency will be enhanced by replacing some higher grade nurses with lower grade staff. It is likely, however, that lesser skilled staff may, require more supervision by senior nursing and medical staff while carrying out certain tasks. In addition, lower grade staff with less experience may take longer to complete tasks. Consequently, an improvement in cost efficiency performance is not guaranteed by simply replacing higher cost staff by lower cost staff (see Richardson and Maynard, 1995). Therefore, it would be interesting, but outside of the scope of this paper, to investigate how nursing staff were organised in efficient hospitals of the sample so as to make such adjustments possible. While DEA analysis assists the manager in identifying comparative inefficiencies related to the unit costs of staff and the information obtained points to the direction of grade adjustment necessary at the macro level of staffing, questions of how staff are effectively organised and supervised are not addressed by this methodology.

SECTION VI

The quality of health care

In any comparison of the performance of hospitals, it is desirable that the method should take into account both the quantity and quality of the health care provided. In respect of our own study, omitting to take account of the quality of care raises the possibility that some of the hospitals classed as cost efficient may have sacrificed the quality of care provided by deploying less expensive but lower skilled staff. This is a particular concern here when one considers the evidence of Carr-hill *et al* (1995) from a study looking at the link between nursing skill and the quality of health care provided. Using grade as a proxy for skill, their study found that 'both grades

and skill mix have an effect on the quality of care, in that the higher the grades (and skills) of the nurses who provide care, the higher the quality of care'. Moreover, the research indicated that costs increase with the quality of nursing care.

However, as encountered in earlier studies of hospital performance (eg Söderlund *et al*, 1997), adequate adjustment for output quality is an exceedingly complex matter. For example, Thanassoulis *et al* (1998) have noted that there are two distinct aspects to the quality of health care, namely, the medical outcome (or clinical quality), and the associated manner of delivery (or service quality). Both raise complex measurement problems as detailed further in McCallion *et al* (2000). Nevertheless, even if one had reliable information on the quality of health care within each hospital there still remains the difficult decision of what weights to assign to each aspect of quality. Moreover, how should we value quantity versus quality in the event of any trade-off between the two when there is excess demand for health care within the region?

Despite the difficulties, it is clear that the issue of quality is too important to be ignored. In the absence of reliable data on the quality of hospital care for the period of our study, we have been able to include only output quantity variables in our model. However, as a partial check on quality we have relied on auditor's evaluations of whether the (clinical) quality of care has maintained a satisfactory standard in each hospital. The report of the Northern Ireland Audit Office 1993, found no evidence that quality had been regularly compromised in any part of the acute hospital sector.

In Section IV above we discussed the possibility indicated by our findings for substituting some higher grade staff with lower grade staff within nursing. When we look to the evidence of Carr-hill *et al* (1995), the organisation and supervision of staff seems key to minimising any drop in the quality of care provided in this situation. For example, their study found that while lower grade

staff may be associated with lower quality care, the difference is lessened when such staff work in combination with more senior staff. Again this points the practitioner to the need for follow-up case studies of team organisation patterns within hospitals in order to identify efficient peers where quality of care is most likely to be highest.

SECTION VII

Conclusion

As illustrated by this study the DEA methodology can be adapted for assessing cost efficiency performance relative to prices or average wages costs within the hospital sector. Since the price efficiency model of Färe *et al* (1994) takes account of outputs as well as input quantities and prices it then indicates where factor substitution can be cost efficient. Furthermore, because the analysis is relative to best practice within the hospitals of the given sample it can provide an assessment of comparative performance as desired by current policy. It should be noted, however, that the chief contribution of DEA analysis in this area is as a tool to identify better performers and indicate where staffing practice may be cost-inefficient within a region. As such, more micro-based studies of labour organisation within the efficient hospitals are needed to ascertain how staffing can be successfully adjusted without compromising the quality of outcomes.

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