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Economies of scope in Norwegian hospital production - A DEA analysis

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by

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Abstract

From 2002 the Norwegian hospital sector is to be transferred from county to state ownership, organised through regional semiautonomous companies. A major motivation for the reform is to allow for more specialised hospital production. If there are economies or diseconomies of scope, the production of hospital services in a region could become more efficient by exploiting any cost savings that may stem from an optimal division of service production between units. While the theory of economics of scope is well developed, applications have chiefly been concerned with testing for natural monopoly, and few studies of hospital production have been concerned with scope.

This paper estimates a multiple output cost function from data on Norwegian hospitals using the non-parametric Data Envelopment Analysis (DEA) method. The cost function is specified with total running costs as the only input, but with seven different outputs to focus on the properties of the output transformation frontier. To overcome the methodological assumption of convexity inherent in DEA, the sample is split into relative specialised and differentiated hospitals, before comparing costs. This partitioning is achieved through grouping as specialised the first and fifth quintiles of the hospitals ranked by the share of the relevant output, since in fact no hospital is fully specialised by producing only one output, or nothing of an output.

Exploring scope economies of the best practice cost frontier along three different dimensions, strong economies are found for surgical and medical services, intermediate for inpatient and outpatient production, while elective and emergency care cases have only week economies of scope, which may not be statistically significant. Results for the output mix of individual observations, reveal both economies and diseconomies in the last of these three dimensions.

Contrary to these results, average efficiencies are found to be lower for differentiated than specialised hospitals, in all of the dimensions mentioned, although the differences are not very large. Since the DEA method measures hospitals with the largest production of each output as efficient by default, the results for average efficiency may be due to the methods employed.

1 Introduction

From 2002 the Norwegian hospital sector is to be transferred from county to state ownership, organised through regional semiautonomous companies. A major motivation for the reform is to allow for more specialised hospital production. If there are economies or diseconomies of scope, the production of hospital services in a region could become more efficient by exploiting any cost savings that may stem from an optimal division of service production between units. While the theory of economics of scope is well developed, applications have chiefly been concerned with testing for natural monopoly, and few studies of hospital production have been concerned with scope.

The term specialization is not always clearly defined. For hospitals, specialization can be described in terms of treatment capacity (e.g. by the allocation of beds by speciality), in terms of use of different types of staff (by ratios of physician specialities or different occupations), or by the composition of diagnosis (e.g. ICD10 or DRG). In a previous study we have used a Herfindahl-Hirschman index of concentration to describe the degree of specialization along these dimensions. These indexes give divergent results, depending on the choice between capacity and activity measures, and even on the actual variable used.

An alternative approach is to use aggregated measures the relative share or intensity of hospital activities along dimensions one would expect to be in need of different treatment technology[2]. We have chosen here to focus on three important dimensions:

Emergency care versus elective patients

The demand for hospital services is in principle a stochastic variable. Even so, one can for part of the activities plan when and where the treatment is to be given, and thereby reduce the uncertainty about the necessary treatment capacity. Purely elective activity should in theory be

[2] In ongoing research we will attempt to analyse to what extent these approaches give similar results.

possible to plan without uncertainty, while a pure emergency care unit must accept fluctuating demand and uncertainty about the necessary capacity and personnel on call. Friedman and Pauly (1981) model this uncertainty and show how part of the workforce can be seen as quasi-fixed, with higher costs as a result. On the other hand, a large share of emergency cases would be expected to be more predictable and therefore less costly than a low share. The difference in costs is therefore not necessarily between hospitals that are purely elective and purely emergency care, but between the hospitals that are specialised and those that have a mix of services.

Medical patients versus surgical patients

The division between medical and surgical patients is motivated from the different technologies used for these patient types. Surgical patients need access to operating theatres, anaesthetics, and recovery, and will in many cases be more technology intensive than medical patients. Medical patients are often elderly, and may have a larger element of nursing care. One would therefore expect specialised hospitals to have operating conditions and technology that set them apart from differentiated hospitals. It is not obvious which type of hospitals will be the more cost efficient. It is often more difficult to diagnose correctly medical than surgical patients, and to the extent that this introduces greater uncertainty in resource needs and treatment plans one would expect that specialisation in the direction of surgical patients would be more efficient.

Outpatient versus inpatient patients

The dichotomy between outpatient/day care and activities in the inpatient wards is also motivated from expected differences in operating conditions and technology. Hospitals with a high share of outpatients will need to relate to a larger number of patients. This can lead to efficiency gains by using assembly line organisation, but will involve challenges in the logistics of patient and staff deployment. We are assuming that the data is corrected for the resource needs of the different patient groups, so that the analysis of economies of scope is not an analysis of whether there are medical reasons for outpatient or inpatient treatment.

Aletras, Jones and Sheldon (1997) report a survey of a large number of empirical studies of economies of scale and scope in hospital services production, with a view to giving recommendations to the British National Health Service (NHS) on the desirability of hospital mergers. Most of the studies considered indicate that there are few economies of scale in hospitals beyond 200-300 beds. These findings are irrespective of whether the analysis was based on flexible cost functions, flexible production functions, Data envelopment analysis, survival analysis, studies of multi-hospital firms or more ad hoc studies.

For the economies of scope, the survey reports few findings. Using flexible cost functions Sinay and Campbell (1995) find some economies of scope between emergency care and elective activity prior to mergers, but not afterwards. Other studies of merging hospitals in most cases find higher costs after merging hospitals, except for small hospitals in rural districts, but it is difficult to decide whether this is due to diseconomies of scope or diseconomies of scale.

Using a method similar to ours, Prior and Solà (2000) find strong economies of scope (which they term economies of diversification) in Catalan hospitals using data from 1987 to 1992. They formalize the analysis in Kittelsen and Førsund (1992) to define a measure of the degree of economies for each observation, but only compare hospitals that are predefined as specialised or diversified. In this paper we extend their analysis to look at economies of scope along three specific dimensions of the product mix space, and let the data determine the classification of sepcialised and diversified hospitals.

2 Data and classification of activities

2.1 General data description

Establishing a dataset that distinguishes along the three dimensions outlined above requires five different hospital service categories, medical emergency help, medical elective, surgical emergency help, surgical elective and outpatient visits respectively. The first four of these are available as the number of patient visits weighted by diagnosis related groups (DRGs), while the outpatient visits are measured as outpatient income in million Norwegian kroners (MNOK) since

DRG weights are not available. In addition, we have included births in DRG-weighted visits, and long stays in length of stay above a DRG-specific trim point. Since the focus of the analysis is the cost effect of different outputs service mixes, we have only included total operating costs on the input side[3].

The data represents an unbalanced panel of 62 Norwegian hospitals for the eight-year period 1992 to 1999, totalling 467 observations. The data are mainly from the partially DRG-based reimbursement scheme financing Norwegian hospitals, and have been error checked by SINTEF Unimed as part of the official statistics on hospitals prepared for the Department of Health. Summary statistics for the variables are presented in the first columns of table 1.

Table 1: Summary statistics for 467 hospital observations 1992-99, for all hospitals, and separately for observations in the highest and lowest quintile in the share of Elective visits, Surgical visits and Outpatients respectively.

		All		Mean for groups					
				Elective		Surgical		Outpatients	
		Mean	St.Dev.	High (A)	Low (E)	High (A)	Low (E)	High (A)	Low (E)
Input									
BD	Operating costs in MNOK	334	366	437	241	514	133	670	143
Output									
MEC	Medical emergency care visits, DRG-weighted	4882	4443	4441	4570	5511	2485	8977	2590
MEL	Medical elective visits, DRG-weighted	1454	1976	2719	558	2840	484	3102	521
SEC	Surgical emergency care visits, DGR-weighted	1791	2112	2236	1406	2891	641	3543	775
SEL	Surgical elective visits, DRG-weighted	2729	3377	4610	1288	5335	700	5509	1086
BIR	Births, DRG-weighted	873	1006	726	844	942	448	1720	266
OUT	Outpatient income in MNOK	36	45	49	23	57	11	86	8
LON	Long term care	776	1145	924	523	1239	325	1692	389

[3] Good capital measures are unfortunately hard to find.

To separate relatively specialised and differentiated hospitals, we have constructed quintile groups defined by intensities along each of the dimensions discussed above. For the elective versus emergency care dimension, all observations are ranked by the number of elective DRG-weighted patient visits as a share of total DRG-weighted patient visits. The fifth of observations with the highest elective share are then categorised in the elective A (high) group, continuing with groups B, C, D until the fifth of observations with the lowest elective share are put in elective E (low) group. This latter group will in general encompass the observations with the highest emergency care share, but the share of outpatients, births and long term care may play a confounding role. We will also use the term specialised about the groups A and E, while the groups B, C and D in between will be termed differentiated in terms of this dimension.

Similar categorisation is done for the medical versus surgical dimension by quintiles of the share of surgical visits in total DRG-weighted visits, while for the outpatient visits the categorisation is done by the quintiles of outpatient income as a share of total operating expenses. Arithmetic means for the variables are shown in the last columns of table 1 separately for the A and E groups along each dimension.

Table 2: Correlation between shares of different outputs and beds.

	Share of elective	Share of emergency care	Share of surgical	Share of medical	Share of births	Share of outpatients	Share of long term care	Beds
Share of elective	1							
Share of emergency care	-0.92	1						
Share of surgical	0.73	-0.71	1					
Share of medical	-0.51	0.69	-0.87	1				
Share of births	-0.36	-0.03	-0.17	-0.34	1			
Share of outpatients*	0.22	-0.28	0.21	-0.25	0.11	1		
Share of long term care**	-0.17	0.14	-0.25	0.19	0.10	-0.18	1	
Beds	0.24	-0.34	0.40	-0.47	0.19	0.48	0.06	1

*Share of outpatients is calculated as outpatient income divided by total operating expenses.
**Share of long-term care is calculated as long-term days above trim point divided by total DRG-weighted visits.

Results for the different specialisation dimensions will be difficult to interpret if there is a high correlation between the defining variables of each dimension. Table 2 shows the correlation between the shares for each of the variables in the data set.

The share of elective visits is clearly negatively correlated with the share of emergency visits, which reassuringly means that our grouping of high (A) to low (E) elective share on the whole corresponds to a low to high emergency care share. Similarly, the share of surgical visits is strongly negatively correlated with share of medical visits. More troublesome are the substantial correlations between share of elective and share of surgical visits, and between share of elective visits and share of emergency care visits. This is intuitively reasonable, since most (about 2/3) of elective visits are surgical and most (about 2/4) of emergency care visits are medical, but it may easily mean that we will get similar results along these two dimensions and will have difficulty in interpreting which factor is decisive.

2.2 Emergency care versus elective visits

Table 3 shows the share of DRG-weighted visits that are classified as elective or emergency care and surgical or medical visits respectively for each year in the observation period.

Table 3: Distribution of activity shares for each year

	1992	1993	1994	1995	1996	1997	1998	1999
Share of elective	34.4 %	34.7 %	33.6 %	33.2 %	32.2 %	34.1 %	31.7 %	30.2 %
Share of SEL	22.8 %	22.5 %	21.6 %	21.3 %	20.1 %	22.8 %	21.8 %	21.4 %
Share of MEL	11.6 %	12.1 %	12.0 %	11.9 %	12.1 %	11.3 %	9.9 %	8.8 %
Share of emergency care	58.0 %	58.0 %	58.9 %	59.5 %	60.6 %	60.4 %	62.7 %	64.1 %
Share of SEC	13.6 %	13.3 %	13.2 %	13.0 %	12.7 %	13.5 %	14.3 %	15.0 %
Share of MEC	44.4 %	44.7 %	45.8 %	46.5 %	47.9 %	46.9 %	48.4 %	49.1 %

During the period, the relative importance has been shifted from elective visits towards increased emergency care. In particular this is due to the fall in share of elective medical visits and a corresponding increase in the share of emergency care medical patients. For the surgical patients the relative changes are smaller. A similar picture appears if we tabulate the share of elective and emergency care patients in the specialised groups A and E along the elective/emergency care dimension.

Table 4: Share of elective and emergency care visits in specialised groups in the period 1992 to 1999.

		1992	1993	1994	1995	1996	1997	1998	1999	All
Share of elective visits in group	Elective A (high)	48,0 %	46,6 %	47,2 %	48,3 %	47,4 %	50,6 %	48,1 %	45,8 %	47,8%
	Elective E (low)	21,1 %	23,5 %	21,4 %	21,1 %	20,4 %	21,3 %	19,6 %	17,7 %	20,7%
	Ratio high/low	2,27	1,99	2,20	2,29	2,32	2,38	2,45	2,59	2,31
Share of emergency care visits in group	Elective A (high)	47,2 %	47,6 %	47,8 %	47,5 %	48,6 %	45,4 %	48,7 %	49,6 %	47,5%
	Elective E (low)	72,4 %	69,3 %	70,5 %	71,4 %	72,6 %	73,3 %	75,8 %	77,4 %	72,9%
	Ratio high/low	1,54	1,46	1,47	1,50	1,49	1,61	1,55	1,56	1,53

From table 4 we see that the average share of elective patients in the elective A (high) group is stable until 1997, after which it falls somewhat. The elective share in the low group varies more, but also falls after 1997. The distance between the two groups increases substantially, but the share in the high group is consistently more than twice that of the low group. As a reflection, the share of emergency care increases overall, but most markedly in the elective E (low) group. The relative share of the two groups does not actually change.

What is striking is that the fifth of the observations (93) that have the highest share of elective visits on average still have less than half (47.8) of their production as elective. Similarly the group that is most specialised in emergency care (elective E) on average has less than three quarters (72.9%) of their production as emergency care visits. The term specialised as used here is only relative, as no hospitals in fact have only elective visits, and no hospitals have only emergency care visits.

2.3 Surgical versus medical visits

A similar picture of relative specialisation is presented for the surgical/medical dimension in table 5. The definition of surgical visits follows the DRG reimbursement system in that the patient must have been subject to an intervention that needed the use of an operating theatre. As before, the shares are calculated of total DRG-weighted visits, which do not include outpatient visits.

The total share of surgical patients fell substantially from 92 to 96, but has since increased to the original level. The total share of medical patients has increased slightly during the same period. The collective share of surgical and medical patients has in fact increased slightly at the expense of births. It is interesting to note that the share of surgical inpatient visits has increased during the same years as there has been an increase in the use of outpatient surgery. Also worth mentioning is that while the share of surgery and share of elective visits were clearly correlated in table 2, their time trends are markedly different.

Table 5: Share of surgical and medical visits in specialised groups in the period 1992 to 1999.

		1992	1993	1994	1995	1996	1997	1998	1999	All
Share of surgical visits in groups	All (ABCDE)	36.4 %	35.8 %	34.8 %	34.3 %	32.8 %	36.3 %	36.1 %	36.4 %	35.3%
	Surgical A (high)	45.2 %	45.0 %	44.6 %	44.8 %	43.2 %	47.6 %	46.6 %	46.4 %	45.5%
	Surgical E (low)	26.3 %	28.8 %	25.8 %	24.9 %	22.8 %	27.4 %	27.4 %	26.8 %	26.2%
	Ratio high/low	1.72	1.56	1.73	1.80	1.89	1.74	1.70	1.73	1.73
Share of medical visits in groups	All (ABCDE)	56.0 %	56.9 %	57.8 %	58.4 %	60.5 %	58.2 %	58.3 %	57.8%	57.9%
	Surgical A (high)	48.4 %	48.6 %	49.1 %	49.3 %	50.1 %	47.6 %	49.5 %	48.9 %	48.7%
	Surgical E (low)	67.2 %	67.1 %	70.2 %	71.3 %	72.5 %	69.5 %	68.2 %	68.3 %	69.5%
	Ratio high/low	1.39	1.38	1.43	1.44	1.45	1.46	1.38	1.39	1.43

Comparing the shares separately in the Surgical A and E, table 5 shows parallel developments in both subgroups with slight increases from 1992 to 1999 of both surgical and medical patients, and unchanging relative intensities in the specialised groups.

2.4 Outpatient versus inpatient visits

Table 6 shows the share of outpatient activity measured as outpatient income divided by operating expenses, both for all observations and for the two specialised groups A and E along this dimension. Note that part of the outpatient activity was included in the DRG-based reimbursement system from 1999, with the implication that pure outpatient income fell. To facilitate the comparison of outpatient service production over time, we have calculated what the outpatient income would have been under the previous system.

We see from the table that the outpatient share has a marked shift upwards from 1996 to 1997. The outpatient income tariffs were revised that year, and the changes may well have exceeded the general inflation rate. It is therefore uncertain whether the changes we observe in the table represent a real increase in outpatient care production.

Table 6: Share of outpatient visits in specialised groups in the period 1992 to 1999.

		1992	1993	1994	1995	1996	1997	1998	1999	All
Share of outpatient visits in group	All (ABCDE)	9.6 %	9.6 %	10.0%	10.1%	9.8%	11.6%	11.3%	10.9%	10.3%
	Outpatient A (high)	14.2 %	14.2 %	14.2 %	15.0 %	14.3 %	15.8 %	15.7 %	15.3 %	14.9%
	Outpatient E (low)	5.6 %	5.5 %	5.6 %	5.6 %	5.8 %	7.3 %	7.2 %	6.9 %	6.0%
	Ratio high/low	2.54	2.59	2.53	2.66	2.48	2.17	2.19	2.21	2.48

It is clear from the table that there is a high, though somewhat decreasing, ratio between the shares in Outpatient A and E groups. Even so, the outpatient share in the outpatient intensive group A is as low as 15%, which makes the use of the term “specialised” a bit dubious. The alternate activity of inpatient care is in all groups the greatly dominating one. Nevertheless, the Outpatient A group has more than twice the share of outpatients as the E group, and we will retain the use of the word “specialised” as a relative term.

2.5 Conclusion on the data description

To span out the multi-dimensional product space, we need a large number of hospital observations in each of the groups. We have therefore chosen to disregard the time dimension and use all observations as a cross section material in the rest of the paper. We must emphasise that the observations of several years for the same hospitals will not be independent, but since we are interested in the shape of the frontier of the production possibility set rather than efficiencies, this dependence is not a serious problem. However, the nominal degrees of freedom reported for subsequent results will be larger than the true degrees of freedom, thus making statistical tests over reject null hypothesis. We intend later to use the time dimension to look at the differences in productivity development between specialised and differentiated hospitals.

Table 7 summarises the share of an activity in the specialised groups along each dimension. In a strict sense, one can only speak of absolute specialisation for medical visits and emergency care. Both for surgical visits and for emergency care the specialised activity represents less than half of total production even for the highest quintile. This could be because our groups are too large, and we have therefore also shown the activity shares on average for the top or bottom 5% in each dimension. Since the 23 units in the 5% tail is from an eight-year panel, they will usually represent 3 or four actual hospitals. Even for such small groups, we find no complete specialisation in an absolute sense, and must continue to use the word as a relative term if it is to have any empirical content.

Table 7: Share of specialisation in the specialised groups

Share of	**Mean of 20% (group A or E)**	**Mean of 5%**
Elective visits in top of elective dimension	47.8 %	58.8 %
Emergency care visits in bottom of elective dimension	72.9 %	79.2 %
Surgical visits in top of surgical dimension	45.5 %	54.4 %
Medical visits in bottom of surgical dimension	69.5 %	75.5 %
Outpatient visits in top of outpatient dimension	14.9 %	17.2 %

3 Method

Baumol, Panzar and Willig (1988) develop the theory of economies of scope, but are chiefly concerned with contestable markets and the criteria for the existence of natural monopolies. They define a measure of economies of scope as the cost saving of producing a vector of outputs in completely specialised units compared to producing the same bundle in one differentiated unit. If this measure is greater than zero there are economies, and if it is less than zero there are diseconomies of scope. For the empirical analysis of Norwegian hospital production, there are two problems with this approach.

Firstly, this scope measure presupposes knowledge of the cost in completely specialised hospitals, i.e. units that produce only one of the service outputs. As in many applications, there are no observations of completely specialised hospitals, and any cost function estimate would need to extrapolate to a large extent. Secondly, the cost comparison is made between two specialised and one differentiated units. These are not the actual policy alternatives in Norway. In practice it is more relevant to ask whether existing hospitals should become more specialised and have a greater division of tasks, keeping the number of hospitals constant. As Baumol, Panzar and Willig (1988) show, the scope measure is composed of a scale effect reflecting the cost advantage of different scales of operation, and a convexity effect reflecting the cost advantage of the mix of outputs alone. In this paper we are primarily interested in the pure convexity effect, and will use the term "economies of scope" in this narrower sense.

Several authors have pointed to the need to interpolate from actual observations rather than extrapolate to hypothetical completely specialised units. Among them, Färe, Grosskopf and Lovell (1994) have based their analysis on estimates of production function frontiers, rather than cost functions. In our data the only input is operating costs, so the cost function and production function approaches coincide. We follow Färe, Grosskopf and Lovell (1994) in using the non-parametric Data envelopment analysis (DEA) method to estimate the (cost) frontier separately for specialised and differentiated units, and using the output increasing Farrell (1957) efficiency measure to compare the cost of specialised and differentiated production. As in Kittelsen and Førsund (1992), we focus on the pure convexity component of economies of scope.

Farrell (1957) suggested the non-parametric method that was later developed by Charnes, Cooper and Rhodes (1978) and named Data envelopment analysis. The method estimates the technology by enveloping all observations of inputs and outputs as closely as possible by piecewise linear facets. As shown by Banker (1984), DEA is the minimum extrapolation estimate of a technology that fulfils a) feasibility (absence of measurement error), b) free disposal and c) convexity.

Figure 1 illustrates the envelopment. In the left panel the volume of service output is on the horizontal axis and the total costs on the vertical axis. The observations that produce the most with the least costs are at the lower right of the panel, and the piecewise linear frontier that envelopes the data from below is then the estimate of the least costs necessary to produce a given service output. Cost efficiency for a production unit is the ratio of necessary costs at the frontier and the actual costs of the observed behaviour with a given level of service production. In the figure the necessary costs for a hospital A would be measured at the point on the frontier F, which has the same level of output as A.

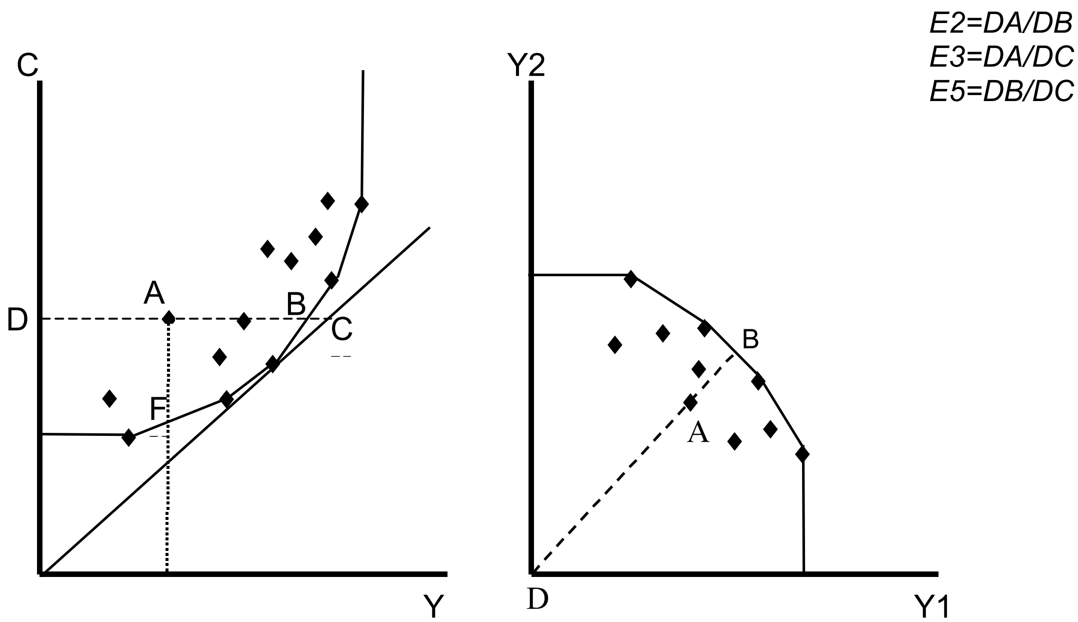


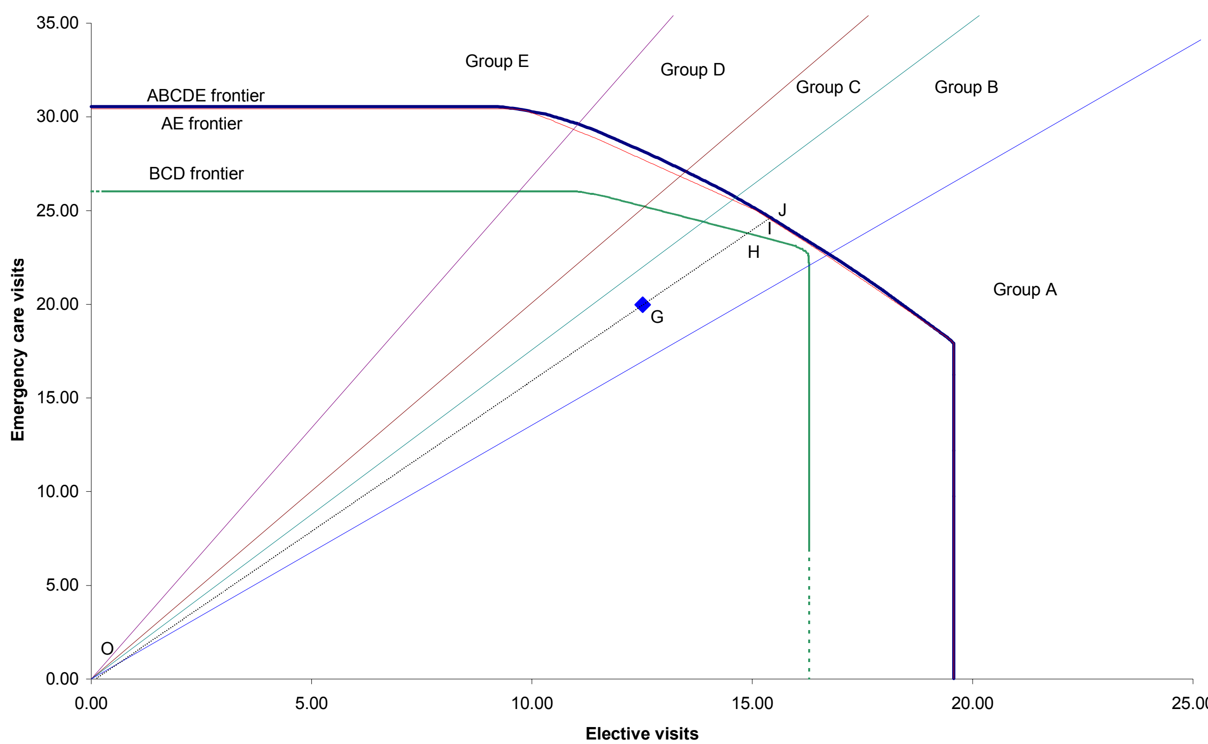
Figure 1: Cost functions estimated by DEA in cost-output space and in output-output space

More of interest in our perspective is how much more one could have produced of hospital services without increasing costs. The cost indirect efficiency, which in our one-input case is equivalent to the output increasing technical efficiency E_2, is the ratio of potential maximal service production to the actual service production at a given cost. For hospital A in the left panel this output efficiency is the ratio DA/DB. Productivity is a term closely related to efficiency, and is used here as the ratio of production and costs. Points with the same productivity ratio will be on lines from the origin of the diagram. The highest observed productivity is drawn in the diagram, and normalised by this level, the productivity estimate E_3 of hospital A can be calculated as the ratio DA/DC.

When analysing economies of scope it is essential to be able to describe the cost or production function with several different types of hospital services produced in the same hospital. The right panel of figure 1 shows the same cost function in the output-output plane where each of two hospital services is measured along the axes. All hospitals shown in the diagram have the same observed total costs. The most efficient hospitals will be those that produce the most at a given cost, in other words those that are furthest from the origin. The output increasing efficiency can be defines as the ratio of actual to potential production when all outputs are increased proportionately, without increasing costs. The output efficiency of hospital A in the figure is DA/DB.

Like the Translog and Cobb-Douglas parametric functional forms, DEA assumes convexity at the outset. It is still possible to reveal non-convexities using DEA if one partitions the observation into groups based on different output intensities, and estimate separate frontiers for each subsample. Such a partitioning is done in section 3 above, where for each dimension the most and least intensive quintiles A and E form the specialised subsample, and the medium intensive quintiles B, C and D form the differentiated subsample. If the estimated frontier for the differentiated hospitals is more productive than the estimated frontier for the specialised hospitals, at constant costs and for the output mixes of the differentiated hospitals, we will have economies of scope. If the differentiated frontier is less productive, the hospitals that are differentiated could collectively have produced more by becoming specialised, and we would

Figure 2: DEA frontiers estimated from whole sample (ABCDE), differentiated subsample (BCD) and specialised subsample (AE) intersecting a plane through the average hospital G.



have diseconomies of scope.

Figure 2 shows the analysis of the elective versus emergency care dimension, for a hospital, which in the diagram is the hypothetical average hospital with the sample, average for each input and output[4]. The plane depicted is defined by the constant level of the average total operating costs, births, outpatient care and long term care, while the elective and emergency care visits vary whether they are surgical or medical cases. The three estimated are shown where they intersect this plane. The thick line is the full sample (ABCDE) frontier estimate, coinciding almost perfectly with the frontier estimated from the specialised hospitals (AE), while the frontier estimated from the differentiated hospitals (BCD) is within the other two.

The hypothetical average unit in the figure has diseconomies of scope. While one can at a given cost increase production proportionately of both elective and emergency care visits up to the point H when compared to the best practice of other differentiated hospitals defining the BCD frontier, one can increase production further to the point I when compared with the specialised hospitals defining the AE frontier. A numerical expression of the degree of economies of scope can be constructed by the ratio of the output efficiency measures with respect to the specialised and differentiated frontiers, i.e. defining the measure

$$S_2 = E_2^{AE} \big/ E_2^{BCD} \qquad (0.1)$$

which for will be greater than one if there are economies of scope and less than one if there are diseconomies of scope, in the pure convexity sense. It measures the proportionate production increase possible at constant costs of using differentiated rather than specialised units. For the average hospital in figure 2, the efficiency with respect to the AE frontier is OG/OI, while to the BCD frontier is OG/OH, so that the scope or convexity advantage measure is OH/OI in the diagram, and clearly less than one. The formal statement of the measures is given in an appendix.

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[4] This hospital is in fact in group B because it is the arithmetic average unit and not the median unit, and the largest hospitals are intensive in elective visits.

It must be emphasised that any specialisation advantages indicated by a convexity measure less than one can only be harvested if there are two or more hospitals with approximately the same product mix and size that can reallocate their production between them and become specialised. This is probably still a more common situation than one where one contemplates the division of a single hospital into several specialised hospitals.

The convexity advantage measure is based on the best production behaviour on the frontier, i.e. if the hospitals in question are able to be efficient. There could be different factors determining the average performance of the differentiated and specialised hospitals than those that determine the frontier performance. Differentiated hospitals could be more or less productive than specialised hospitals on average, and this could be described as economies or diseconomies of scope in average performance. In the results below we report the efficiency estimates of each group, and these could be an indication of the average scope advantages. Unfortunately, there are methodological biases because the DEA method will estimate some extreme valued units as efficient by default, among them the hospitals with the highest output value for each output variable. Results that show higher efficiency levels for specialised than for differentiated hospitals does therefore not necessarily support the existence of average specialisation advantages.

4 Results

We are interested in two types of questions. Firstly, we want to use the scope or convexity advantage measure S_2 to see whether there are economies or diseconomies of scope on the frontier. Secondly, we would like to compare the average productivity and efficiency in the different quintiles of each dimension to see whether there are average economies or diseconomies of scope.

4.1 Elective versus emergency care

Table 8 Main efficiency and productivity results for the elective dimension

	Output efficiency E2				Output productivity E3			
Quintile group	Mean	StDev	Median	Average unit	Mean	StDev	Median	Average unit
Elective A (high)	0.941	0.069	0.978	0.899	0.916	0.081	0.943	0.857
Elective B	0.910	0.090	0.929	0.897	0.892	0.091	0.896	0.865
Elective C	0.896	0.081	0.903	0.853	0.867	0.078	0.871	0.897
Elective D	0.898	0.086	0.909	0.862	0.874	0.088	0.878	0.846
Elective E (low)	0.931	0.068	0.945	0.863	0.916	0.073	0.913	0.861
Elective Specialised (AE)	0.936	0.069	0.966		0.916	0.077	0.933	
Elective Differentiated (BCD)	0.901	0.086	0.914		0.878	0.086	0.882	
All	0.915	0.081	0.918	0.861	0.893	0.084	0.892	0.863
T(AE>BCD)	4.62**				4.92**			

The specialised hospitals of groups A and E are clearly both more efficient and more productive as measured by the arithmetic mean and the median level in each intensity group. In fact the difference between the specialised and the differentiated groups together is statistically significant, but it should be remembered that the DEA method will measure the extreme observations as efficient by default. This implies that the specialised hospitals on average are closer to the best practice frontier than the differentiated hospitals are. The specialised hospitals seem to be more homogenous than the differentiated.

While the median is a more robust measure of central tendency than the mean, the performance of the average unit of each quintile is also robust in that it probably will not be affected by this methodological problem. The efficiency of the average unit (AU) in each intensity group in fact falls on the whole as one moves from the elective intense A group to the emergency care intense E, and the scale independent productivity measure for the AUs are if anything higher in the differentiated groups than in the specialised. While the mean and medians indicate clear average cost advantages of specialisation, the AU results show that there is no clear conclusion.

Table 9 Convexity scope measure S_2 for the elective dimension

Quintile group	Mean	StDev	Median	Average unit	T-value for mean>1	P-value
Elective A (high)	0.826	0.172	0.871	0.869	-9.79	0.0000
Elective B	1.043	0.151	1.024	0.992	2.74	0.0073
Elective C	1.028	0.140	1.008	0.998	1.94	0.0554
Elective D	1.043	0.143	1.022	1.000	2.87	0.0050
Elective E (low)	0.926	0.087	0.933	0.915	-8.19	0.0000
Elective Specialised (AE)	0.876	0.145	0.909		-11.71	0.0000
Elective Differentiated (BCD)	1.038	0.145	1.020		4.39	0.0000
All	0.973	0.150	0.998	1.003	-3.90	0.0001

Moving on to the economies of scope on the frontier, table 9 shows the convexity scope advantage measure S_2 by intensity group along the elective dimension. The differentiated hospitals of groups B, C and D have a convexity scope measure greater than one, implying that the best practice differentiated frontier is outside the best practice specialised frontier. This means that the efficiency of the best differentiated hospitals is higher than that of the specialised and there are cost advantages to being specialised[5]. While the mean scope measure is significantly larger than one, with a t-value of 4.39, it must be remembered that the dependent structure of the panel data may imply that the degrees of freedom are overestimated and the t-value may not be conclusive in rejecting a hypothesis of no convexity.

Looking at the robust measures, the median is only slightly over 1 for the differentiated groups, and the AU-values almost identically equal to one. In fact, S_2 is estimated for each observed hospital, and the distribution can be fully exposed as in figure 3, where they are ordered by increasing scope measure within each intensity group. The widths of the columns are proportional to the operating costs of each hospital observation, and one sees clearly how the larger hospitals are usually elective intensive. Curiously, quintile B that is the second most elective intense group, has one group of small hospitals with scope measure around 1, and

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[5] Because of the very conservative extrapolation of the frontier, the measure S_2 for the specialised hospitals will almost certainly be less than one, and are reported here only for completeness.

another group of large hospitals with clear economies of scope. The other differentiated groups C and D are more evenly spread out on both sides of one, but with a tendency for the larger hospitals to have higher scope measures. Rather than support a general conclusion of cost advantages in differentiation, the diagram conveys the impression that there are on the whole economies of scope in the elective versus emergency care dimension for the larger hospitals, but diseconomies for the smaller ones.

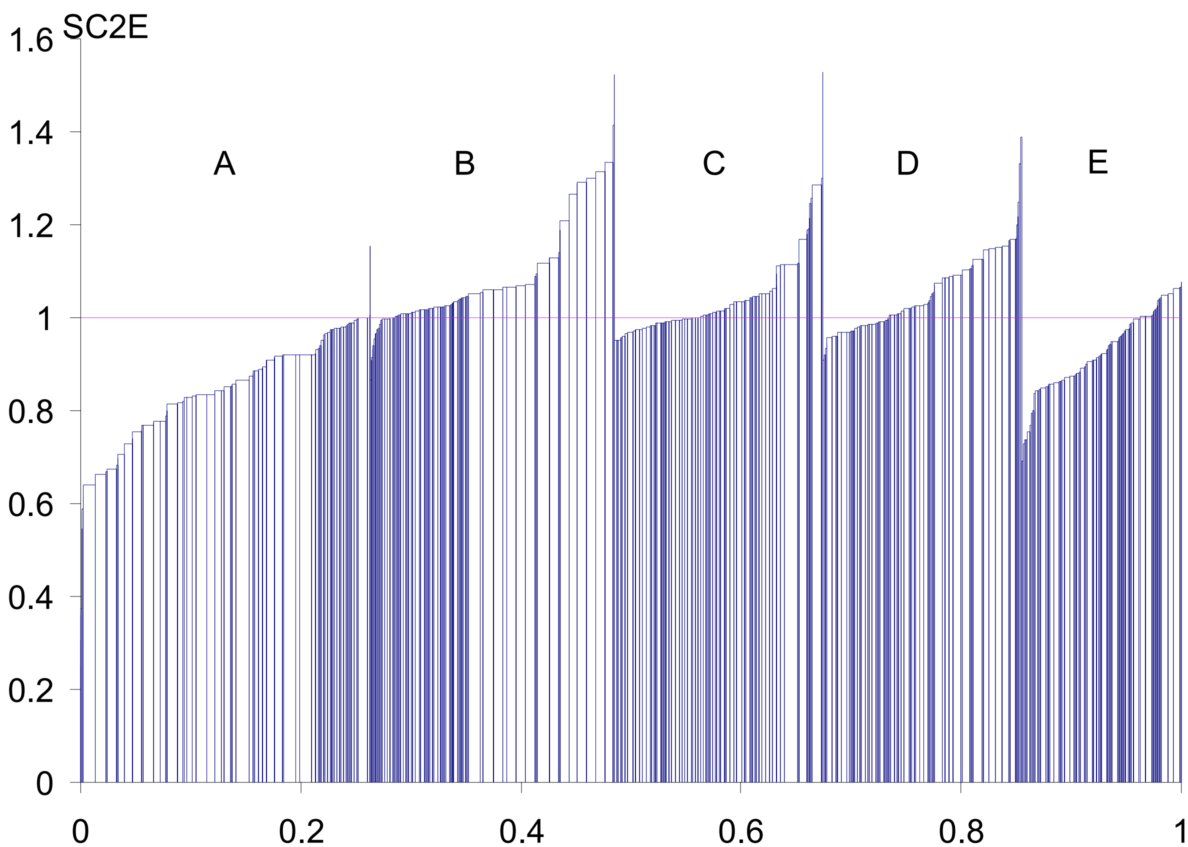

Figure 3 Convexity scope advantage measure in elective dimension arranged by intensity group.

4.2 Surgical versus medical

Table 10: Main efficiency and productivity results for the surgical dimension

	Output efficiency E2				Output productivity E3			
Quintile group	Mean	StDev	Median	Average unit	Mean	StDev	Median	Average unit
Surgical A (high)	0.950	0.062	0.980	0.920	0.927	0.067	0.943	0.857
Surgical B	0.900	0.076	0.897	0.872	0.872	0.081	0.870	0.892
Surgical C	0.908	0.082	0.917	0.858	0.882	0.081	0.893	0.870
Surgical D	0.914	0.090	0.934	0.878	0.893	0.096	0.895	0.848
Surgical E (low)	0.906	0.084	0.918	0.848	0.893	0.086	0.894	0.875
Surgical Specialised (AE)	0.928	0.077	0.950		0.910	0.079	0.925	
Surgical Differentiated (BCD)	0.907	0.083	0.916		0.882	0.087	0.883	
All	0.915	0.081	0.919	0.861	0.893	0.084	0.892	0.812
T(AE>BCD)	2.67**				3.45**			

Table 10 average efficiency and productivity along the surgical versus medical visits dimension. The conclusion depends on whether the specialisation is in surgical or medical cases. The hospitals with the highest share of surgical visits in group A, have markedly higher efficiency and productivity than both the differentiated hospitals and the hospitals with the lowest share of surgical visits in group E (high share of medical patients). This supports the supposition that medical patients are more heterogeneous, and that it is more difficult to plan the resource requirements of these. It might also reflect the higher share of emergency care among medical patients.

While it seems to be easier to be efficient if one is specialised in surgical patients, medical cases must also be treated and there is only a cost saving if the combined efficiency of the specialised hospitals is higher than the differentiated. The mean efficiency of the specialised hospitals as a group is still significantly higher than for the differentiated hospitals, but there is still the problem of independence, and the default efficiency of extreme observations. The median paints in general the same picture as the mean, but the AU measure of productivity is seems to be higher for the differentiated hospitals. Overall, there is week evidence of average specialisation advantages, but no clear conclusions.

Table 11 Convexity scope measure S_2 for the surgical dimension

Quintile group	Mean	StDev	Median	Average unit	T-value for mean>1	P-value
Surgical A (high)	0.874	0.124	0.905	0.909	-9.83	0.0000
Surgical B	1.054	0.070	1.040	1.042	7.40	0.0000
Surgical C	1.077	0.048	1.074	1.078	15.31	0.0000
Surgical D	1.095	0.085	1.073	1.087	10.76	0.0000
Surgical E (low)	0.993	0.071	1.005	1.017	-0.91	0.3668
Surgical Specialised (AE)	0.934	0.117	0.973		-7.66	0.0000
Surgical Differentiated (BCD)	1.076	0.072	1.064		17.61	0.0000
All	1.020	0.107	1.040	1.039	4.12	0.0000

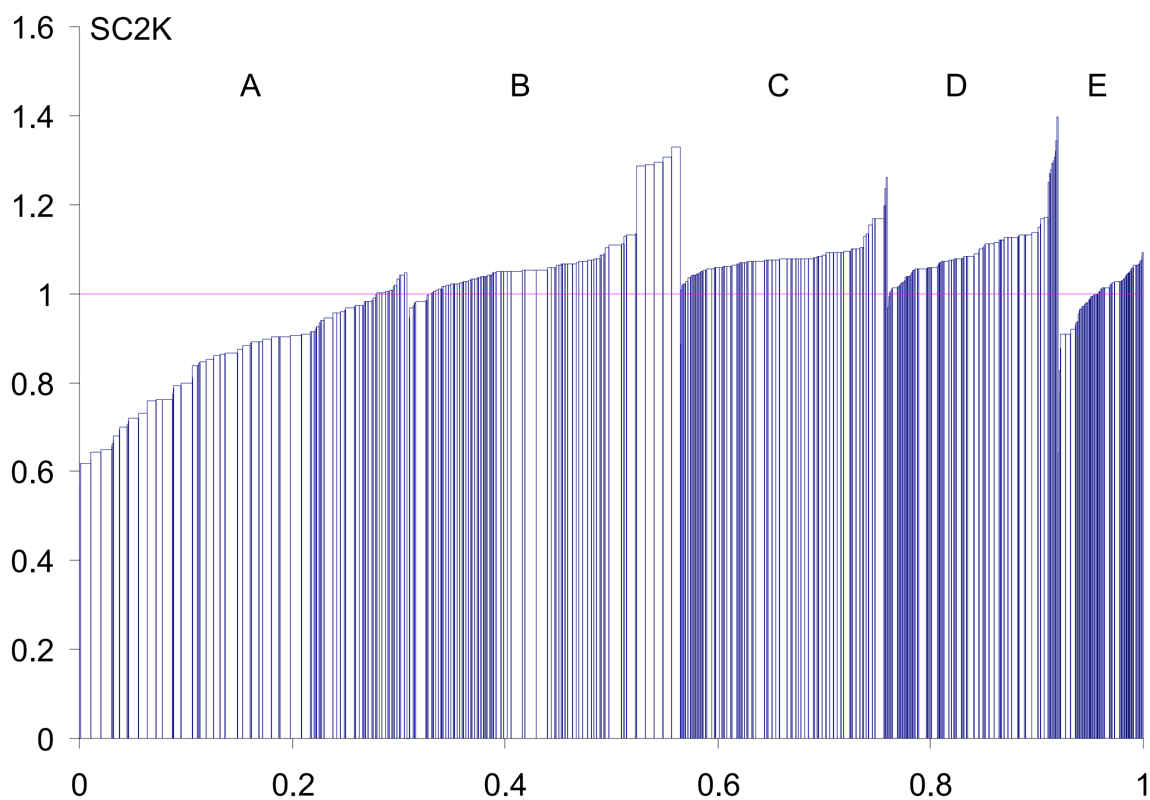

Figure 4: Convexity scope advantage measure in surgical dimension arranged by intensity group.

The results for the economies of scope along the surgical dimension on the best practice frontier are much clearer than along the elective dimension. On average, there is a 7-8% production potential at constant costs if hospitals produce a mix of surgical and medical visits compared to a specialised set-up. These results are highly significant, even in each of the groups B, C and D, and are reflected in equally high medians and AU-measures for the same groups. Interestingly, even though there was a high correlation across hospitals between elective and surgical shares, the scope measure results are quite different. The individual scope measures shown in figure 4 are almost all higher than one in the differentiated groups. The figure also reveals that the hospitals that are intensive in surgical cases are on average much larger than the hospitals that are specialised in medical cases.

4.3 Outpatient share

Table 12 reveals that efficiency and productivity is rising in increasing share of outpatients. Hospitals with high share of outpatients are nearer best practice than those with a low share. These differences are quite strong in view of the fact that the outpatient share only varies in the range 5-15%, but it may be noted that the outpatient share is also correlated with the size of the hospital, and we may in fact measure some size related efficiency differences.

Table 12: Main efficiency and productivity results for the outpatient dimension

	Output efficiency E2				Output productivity E3			
Quintile group	Mean	StDev	Median	Average unit	Mean	StDev	Median	Average unit
Outpatient A (high)	0.967	0.044	0.993	0.925	0.949	0.049	0.954	0.857
Outpatient B	0.928	0.058	0.934	0.879	0.905	0.061	0.899	0.924
Outpatient C	0.897	0.078	0.889	0.840	0.865	0.080	0.851	0.878
Outpatient D	0.902	0.084	0.910	0.823	0.882	0.088	0.886	0.815
Outpatient E (low)	0.883	0.101	0.888	0.804	0.867	0.105	0.864	0.816
Outpatient Specialised (AE)	0.925	0.089	0.955		0.908	0.092	0.928	
Outpatient Differentiated (BCD)	0.909	0.075	0.914		0.884	0.079	0.881	
All	0.915	0.081	0.919	0.861	0.893	0.084	0.891	0.804
T(AE>BCD)	2.09*				3.01**			

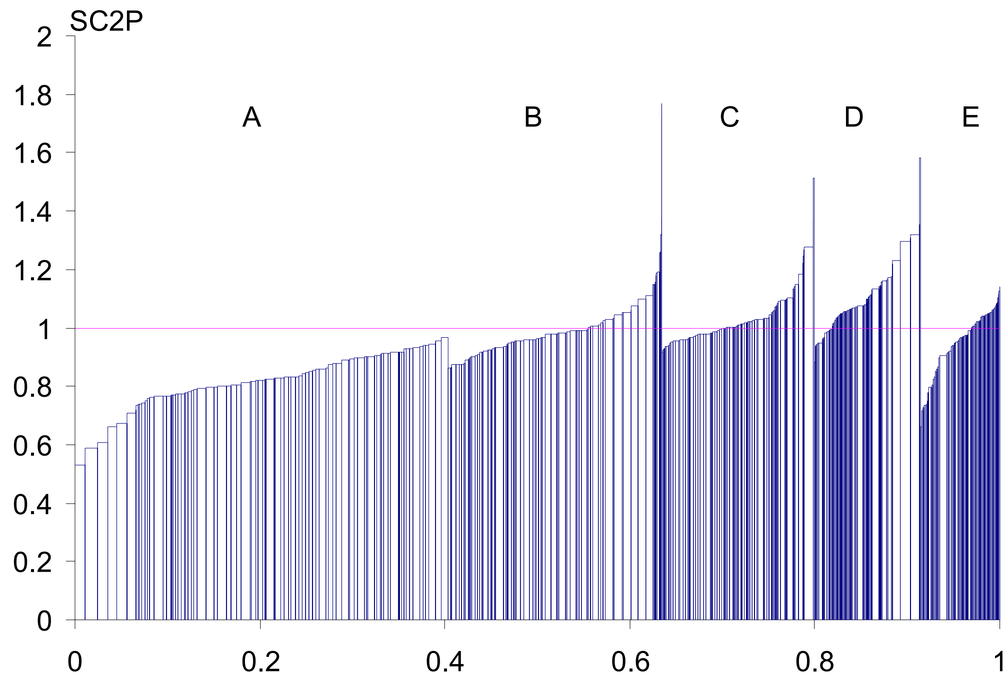

Figure 5: Convexity scope advantage measure in outpatient dimension arranged by intensity group

When viewed as a group, the specialised hospitals are slightly more efficient and productive than the differentiated. Even though nominally significant at the 5% and 1% levels, these differences are probably not significant when one takes into account the problems of dependence and efficiency by default. Again, the AU-measures show quite a different pattern than the means and medians.

Table 13 Convexity scope measure S_2 for the outpatient dimension

Quintile group	Mean	StDev	Median	Average unit	T-value for mean>1	P-value
Outpatient A (high)	0.831	0.083	0.831	0.825	-19.63	0.0000
Outpatient B	1.010	0.147	0.978	0.925	0.63	0.5282
Outpatient C	1.043	0.105	1.012	0.998	3.93	0.0002
Outpatient D	1.087	0.104	1.066	1.049	8.03	0.0000
Outpatient E (low)	0.969	0.110	0.996	0.988	-2.71	0.0081
Outpatient Specialised (AE)	0.900	0.120	0.907		-11.40	0.0000
Outpatient Differentiated (BCD)	1.046	0.124	1.018		6.24	0.0000
All	0.988	0.137	0.989	0.924	-1.92	0.0550

The scope measure for the outpatient dimension in table 13 again shows the existence of economies of scope. These are, however, only significant for groups C and D, and the robust measures of medians and the average unit are only clear that group D has cost advantages of being differentiated. This is borne out by the individual results in figure 5, where one sees that without the outlier in group B, the conclusion would be that for this group there are diseconomies of scope. The implication would seem to be that at the frontier, the best performance is achieved by hospitals that are either have a high share of outpatients, or a low share, but not as low as in the bottom quintile. If this is not a spurious result due to the correlation with size or other factors, there could be some cost savings if the outpatient share could be increased without sacrificing health outcomes and quality.

4.4 Discussion

For all three dimensions considered we find evidence that efficiency and productivity may be higher in specialised than in differentiated hospitals. This would indicate some diseconomies of scope in average performance, contrasting with the evidence of economies of scope in the best practice frontiers.

There are, however, several reasons why the average findings of diseconomies may not be robust. In addition to the dependence over time of the observations for the same hospitals, which also affects the frontier convexity scope measure, the average figures are affected by the efficient by default problem of extreme observations in the DEA method. The measures for the average unit in each group, which would be much less affected by this source of error, show a different pattern. Here there is little evidence of diseconomies of scope, and sometimes evidence of economies. All in all, the evidence on average scope effects is inconclusive, and any real effects are likely to be small. Nevertheless, there is clear evidence that hospitals that have a relatively large share of surgical patients have higher efficiency than those that have a large share of medical patients, and that those with a large share of outpatient are similarly more efficient.

On the other hand, in all the dimensions considered here, there is evidence of economies of scope on the best practice frontier. If one was able to get the differentiated hospitals to realise any potential efficiency gains, the conclusion seems to be that they would represent the most productive way of organising hospital production. However, the strength of these findings varies a lot between the different dimensions. Only in the surgical versus medical dimension is the conclusion clear-cut with evidence of substantial cost advantages of differentiated production. For the outpatient dimension, this is valid only for hospitals in the D group. For the elective versus emergency care dimension the problem of time dependence of observations may well be sufficient to invalidate the findings, and a lack of both economies and diseconomies are supported by the more robust results for the average unit.

The conclusion is therefore only clear for the best practice frontier measures of scope convexity advantages along the surgical and outpatient dimensions, where there are findings of higher productivity if production is differentiated with a mix of service outputs.

5 Conclusion

The paper developes a method of identifying economies of scope in the pure convexity sense for specific dimensions in the ouput mix space using the nonparametric DEA method. The results show clear economies of scope for the surgical and outpatient dimensions. For the elective dimension, methodological problems may be large enough to cast doubt on the validity of the results.

Several avenues for further research are apparent. Among relevant tasks is to look at bootstrapping the non-parametric estimation results for greater statistical control, attempting parametric and semiparametric estimation of the cost functions, and formalising the relationship between the Baumol scope measures and the Farrell efficiency based measures used in this and other work in the productivity measurement field.

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Appendix: Technical details

The DEA method estimates the production possibility set or technology $\hat{T}$ from observations of output vectors and input vectors $(\mathbf{y}^j, \mathbf{x}^j)$ for each hospital $j \in N$. By defining groups of hospitals $G \subseteq N$ one can express the estimate of the production set of each group as

$$\hat{T}^G = \left\{ (\mathbf{x}, \mathbf{y}) \middle| \mathbf{y} \leq \sum_{j \in G} \lambda_j \mathbf{y}^j, \mathbf{x} \geq \sum_{j \in G} \lambda_j \mathbf{x}^j, \sum_{j \in G} \lambda_j = 1 \right\} \tag{0.2}$$

Output increasing efficiency $\hat{E}_2$ and productivity $\hat{E}_3$ for any hospital *i*, which need not belong to group *G* can following Farrell (1957) then be estimated as

$$\begin{aligned} \hat{E}_{2i}^G &= E_2(\mathbf{x}^i, \mathbf{y}^i; \hat{T}^G) = \text{Min}\left\{ \theta \middle| (\mathbf{x}^i, \mathbf{y}^i/\theta) \in \hat{T}^G \right\} \\ \hat{E}_{3i}^G &= E_3(\mathbf{x}^i, \mathbf{y}^i; \hat{T}^G) = \text{Min}\left\{ \theta \middle| (\gamma \mathbf{x}^i, \gamma \mathbf{y}^i/\theta) \in \hat{T}^G \right\} \end{aligned} \tag{0.3}$$

the first of which one may note is equal to the Shephard (1970) output distance function. Scale efficiency $\hat{E}_5$ can further be derived by

$$\hat{E}_{5i}^G = \hat{E}_{3i}^G / \hat{E}_{2i}^G \tag{0.4}$$

The scope convexity measure, which expresses how much the frontier estimated from differentiated units in BCD is more productive (>1) or less productive (<1) than the frontier defined from the specialised units in AE, can for each hospital *i* be defined as

$$\hat{S}_{2i} = \hat{E}_{2i}^{AE} / \hat{E}_{2i}^{BCD} \qquad \hat{S}_{3i} = \hat{E}_{3i}^{AE} / \hat{E}_{3i}^{BCD} \tag{0.5}$$

for efficiency and productivity respectively. Hospital i can belong to either (or neither) group, so that the distance between frontiers is measured in the direction in output space that corresponds to the output mix of hospital i. The scope convexity measure will only be relevant for the differentiated hospitals in BCD when the question is whether these would be more productive if they remained differentiated than if the same product mix was produced separately in specialised hospitals of the same approximate scale.