Productivity growth, case mix and the optimal size of hospitals. A 16-year study of the Norwegian hospital sector

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Abstract:

Background and objectives: This paper analyses productivity growth in the Norwegian hospital sector over a period of 16 years, 1999 to 2014. The period is characterized by a large ownership reform with subsequent hospital reorganizations and mergers. We describe how technological change, technical productivity, scale efficiency and the estimated optimal size of hospitals have evolved during this period.

Material and methods: Hospital admissions are grouped in diagnosis-related groups (DRGs) using a fixed grouper logic. Four composite outputs; elective and emergency inpatient care, day care and outpatient care are defined. Inputs are measured as operating costs. Productivity and efficiency are estimated with bootstrapped Data Envelopment Analyses (DEA).

Findings and conclusions: Mean productivity increased by 24.6 percentage points from 1999 to 2014, an average annual change of 1.5 %. There was a substantial growth following the ownership reform. Post reform (2003-2014), average annual growth is less than 0.5 %. There is no evidence of technical change. Estimated optimal size is smaller than actual size of the majority of hospitals.

Contribution to knowledge: The study addresses the issues of both cross-sectional and longitudinal comparability of case mix between hospitals, and thus provides a framework for future studies. This study adds to the discussion on optimal hospital size.

Keywords: health care reform; health services research; hospital economics; organizational efficiency; financing; long term effects; case-mix; diagnosis-related groups

1   Introduction

The past 20 years many countries have undergone large changes in the way health care is organized, financed and delivered. Under the umbrella of New public management there has been an increase in choice and competition and increased use of activity- and results based financing. Also, in traditionally public tax-based systems, such as the UK and Norway, public hospitals have been reorganized into trusts with a large degree of autonomy [1]. At the same time several countries have pursued a policy of centralization, both in terms of exploiting perceived scale efficiency in the provision of services and

by shifting power from local to central authorities [2, 3]. Finally the recession in 2009 spurred a policy of fiscal austerity that has put health care, together with other publicly funded welfare services, under pressure.

Health care reforms, as well as increased fiscal pressure imply increased focus on how resources allocated to health care are used. Efficient use of available resources is an important policy goal in all health care systems. Regulators and policy makers will typically be interested in the level of productivity, whether and at what rate productivity increases or decrease over time and the relationship between productivity and different regulatory, structural or financial policy measures. Hospitals constitute a major part of the health care sector, thus policy makers are particularly interested in assessing their performance. Comparisons of productivity across hospitals are, however, inherently difficult because of differences in case-mix. These are often sought reduced by using patient classification systems such as the diagnosis-related groups (DRGs) to describe hospital activity (e.g. [4]).

In this paper we provide a description as well as a discussion of how hospital productivity has evolved in Norway from 1999 to 2014. This 16 year period enables us to look at productivity in a long term perspective and also includes one major healthcare reform. In 2002 hospital ownership was transferred from 19 counties to the state [2, 5] and the responsibility for the provision of services was given to five (currently four) regional health authorities. Hospitals are owned by the regional health authorities, and organized as trusts. Following the reform there has been major structural changes as the number of hospital trusts has decreased through mergers and reorganizations. Throughout this paper we will denote the organizational units as "hospitals" while acknowledging that these units often encompass several locations/physical hospitals.

The paper consists of three parts. First, we propose a way of describing hospital activity that captures both longitudinal and cross-sectional differences in case-mix. This is crucial in order to capture the effect of changes in treatment procedures on hospital productivity and enables us to relate the observed change in productivity to the institutional and structural changes that have taken place during this period. In addition to the hospital reform in 2002, there has also been a substantial transition from inpatient to day care and outpatient treatment. To determine the long term effects of reforms and policy changes it is important to use data over a longer time span. This is not commonly done, the majority of hospital efficiency analyses are either cross sectional or else apply a two year time span; one before and one after a reform (see e.g. [6, 7]). In this analysis we employ Data Envelopment Analysis (DEA) with a long time series and case-mix adjusted output measures. Thus we are in line with [8] who employed data from nine years in their analysis of child and adolescent mental health services, and [9] who used a ten year data span when evaluating a hospital financing reform. However, these two Norwegian studies did not adequately adjust for longitudinal changes in case mix.

Second, we estimate Malmquist indices [10, 11] to analyse to what extent observed changes in productivity are due to technical change (the good becoming better) or changes in relative efficiency ("catching up"). Technical change will not be unrelated to the institutional environment of the hospital, but can still be seen more as the result of a general development than local policy initiatives, since it is based on the performance of the best practice hospitals rather than each hospital observation. Thus the relative share of the catching up and technical change elements will provide an indication of the relationship between institutional environment, policy measures and provider performance.

Third, following the reform in 2002 average hospital size has increased substantially, both through reorganizations, mergers and hospital closures. There are arguments both for economics and diseconomies of scale in the literature [11-13]. Our approach allows us to measure both scale efficiency as well as optimal scale, and track changes in these.

2 Materials and methods

2.1 Measuring hospital inputs and outputs

Information about hospital episodes in all Norwegian somatic hospitals in the period 1999-2014 were provided by the Norwegian Patient Register. Only hospitals providing emergency care are included in the analysis.

There are two issues that need to be dealt with in an analysis of productivity growth. First differences in case-mix *between hospitals* need to be adjusted for. Relative cost-weights (DRG prices) can be used to aggregate individual DRGs larger groups of hospital activity. Such aggregation, however, requires the assumption that relative treatment costs are independent of hospital case mix and size. Furthermore, results are usually sensitive to the type of case-mix adjustment that is chosen [6, 14, 15]. Too many output categories can artificially inflate the number of efficient hospitals as more rare combinations of outputs determine the estimated best-practice front. For instance using all DRGs as outputs may result in hospitals specializing in only one DRG group to be effective. A different approach would be is to aggregate all hospital activity into one group, but that would underestimate differences between hospitals. Our point of departure is that the aim of any aggregation of groups should be to enable us to capture essential structural differences between hospitals. Thus, in this analysis, we make the distinction between four composite types of hospital activity to summarize the activity and the technological profile of each hospital:

- Emergency inpatient discharges
- Elective inpatient discharges
- Day-care
- Outpatient visits and treatments

The second issue is related to case-mix comparability *between years.* Over the period covered in this analysis there has been changes in the documentation of diagnoses and procedures, changes in DRG rules (grouper logic) as well as technological changes (which may shift patients between different types of hospital activities). The funding scheme is set up to accommodate this by annual adjustments of relative prices, and when needed also by changing the DRG logic (i.e. which procedures and treatments belong to which group). Consequently, technological changes may be captured by the annual changes in either DRG-logic or the cost weights and we will be unable to capture their effect on productivity. To avoid this we regroup all hospital episodes using a common grouper. Furthermore we apply fixed cost-weights. Technological change will thus be captured as productivity growth, and not "hidden" in changes in relative prices or changes in grouper logic. For more details we refer to the appendix.

Inputs are measured as deflated total hospital operating costs. These costs are routinely used in productivity analyses and have been shown to have good comparability across time and units [16, 17]. Capital costs and personnel were not used as distinct inputs due to longitudinal comparability (as data were only available for shorter time spans).

We aggregate the hospital activity data to the level of the cost data. The level of analysis is the operational ownership level; i.e. hospitals before the hospital ownership reform in 2002, and hospital trusts after the reform. There are 506 observations in the data after aggregation.

2.2 Methods: estimating productivity and efficiency

Productivity is the relationship between inputs and outputs, while efficiency is the relationship between the observed productivity and the best possible productivity. A production frontier is the boundary of the production possibility set; the frontier thus describes the optimal possibility of conversion of inputs to outputs. Two related but distinctively different methodologies are commonly applied for estimating frontiers and subsequently efficiency (Fried et al 2008; Mortimer 2002). Stochastic Frontier Analysis (SFA) is a parametric approach in which the efficiency frontier has a specific functional form, and the method incorporates random errors in the estimation of the production function. The other main approach is Data Envelopment Analysis (DEA). First suggested

in 1957 [18] it was developed in 1978 [19]. The method has been used at different levels: comparing nations [20], regions [21] but more commonly hospitals. In Norway and the Nordic countries there are numerous examples of DEA used for estimating hospital productivity [9, 11, 17, 22-27]. The method is favoured in environments where substantial measurement errors are unlikely and with multiple inputs and/or outputs [7, 28, 29]. This is assumed to apply to the public Norwegian hospital sector with the data described above, and we have thus chosen the DEA approach.

We estimate a production frontier and compare each hospitals annual production to that frontier. If a hospital is on the frontier it is efficient with a DEA score of 1.0. If a hospital is behind the frontier it is considered inefficient, with a score less than one representing the relative distance to the frontier.

The Malmquist index of productivity growth compares the same decision making between two periods. This Malmquist index is then decomposed into efficiency change and technical change. In the analysis of change we compare two years so that a result larger than 1 indicates improved productivity, and less than 1 indicate a decreased productivity. We assume sequential (accumulated) frontiers. The productivity for a unit may be compared with best practice hospitals at the frontier in the same year and also earlier years, but never with observations in the future. It is likely that the productivity of a hospital in 1999 may be attainable by the hospitals in 2014, but the opposite will generally not be the case.

We assume variable returns to scale (VRS), and provide a measure of scale efficiency as the distance between the VRS and the CRS frontier.

We calculate the estimated optimal size of a hospital by multiplying each hospital's observed productivity by its cost, and then dividing by the relative distance to the optimal scale efficient hospital. A confidence interval is created based on the distribution of the bootstrapped estimate of the relative distance to the optimal scale efficient hospital.

When summarizing results from the analyses we calculate the mean annual level of productivity weighted by hospital operating cost. However, the annual input scale efficiency of the average hospital is based on the sample average unit (SAU, which provides an implicit weighting). To calculate confidence intervals, the sample results are bootstrapped ([30, 31]).

3   Results

Table 1 shows the shares of each output (relative to total case-mix adjusted number of episodes) and how average hospital size has changed during the period of analysis. The average hospital has more

than tripled in size since 1999, primarily through reorganizations and mergers as the number of hospital have more than halved in this period from 55 in 1999 to 22 in 2014. Outpatient treatment has increased in importance as the relative volume has increased by 45 % since 1999. The share of day care of the total production has increased with 28%, while the share of inpatient treatment has decreased by 11% for emergencies and 5% for elective treatments.

----TABLE1 ABOUT HERE----

In figure 1 the development in productivity is shown with 1999 normalized to 1. We find an overall increase in mean annual productivity level by 24.6 percentage points from 1999 to 2014. There is a wide confidence interval, thus not all annual changes are significantly different from the previous year. In the years prior to the hospital reform there are no significant changes in productivity. However we find a substantial shift from 2002 to 2003, and also a positive trend from 2003 until 2014.

----FIGURE1 ABOUT HERE----

Measures of total productivity growth, technical change and catching up are presented in table 2. We find a large improvement in productivity around the reform with annual changes around 5-6 percent from 2001/2002 and 2002/2003. In the following years, however, annual changes are generally small, and three of the years had a negative productivity growth (2000/01, 2008/2009 and 2011/2012). The estimates for annual front shifts are only statistically significant for 1999/2000 and 2003/2004. The estimates for catching up however indicate that there are periods characterized by a hospitals falling behind as well as catching up.

----TABLE2 ABOUT HERE----

While the mean size of hospitals has more than tripled during this period, average scale efficiency remain stable. There was slightly higher scale efficiency in the period 2008 to 2014 than in 1999 to 2007. In 1999 10 of the 55 hospitals were smaller than estimated optimal hospital size, but in 2003 only 3 of the 30 hospitals were smaller than estimated optimal hospital size. In 2012-2014, all of the hospitals were larger than estimated optimal hospital size. Figure 2 shows the actual observed hospital sizes and the estimated optimal size (including 95 % confidence interval for the estimated optimal

size). More detailed numbers on scale efficiency and optimal size are available as supplementary material.

----FIGURE2 ABOUT HERE----

4 Discussion

The main policy reform occurring in the period covered by this analysis was the hospital reform in 2002. It was not obvious *a priori* what the effect of the reform on hospital productivity would be. It has been argued that the reform included both elements of centralization (state ownership) and decentralization (regional health authorities) [2]. Early empirical work [32] indicated that productivity increased by approximately 5 % after the reform. This study confirms that the major shift in productivity in the 16 year period covered here indeed took place around the time of the reform. Overall we find a productivity increase of 24.6 percentage points from 1999 to 2014. In the years after the reform (2003-2014) we find an average annual growth of less than 0.5 %.

Separating productivity growth in one component capturing "catching up", i.e. the less efficient hospitals improving and "technical change", i.e. the production frontier shifting outwards could give potentially important information for policy makers. However, the results presented here fail to provide a clear picture. Mostly the estimates are not statistically significant, and even when they are it is difficult to see a clear pattern.

Following the hospital reform in 2002, the number of hospitals have been substantially reduced. This reduction is mainly the result of organizational mergers; however these have also been accompanied by internal restructuring. The number of hospitals has more than halved, while the mean hospital size is more than tripled. A major motivation for the transfer of hospital ownership to the state was to avoid unnecessary duplication of services across hospitals. Thus we would expect scale efficiency to increase and also that actual hospital size would be closer to optimal hospital size. While somewhat higher in the last years of our study, there has not been any significant change in scale efficiency in the period. These results are in line with [11] where scale efficiency in Norway was estimated as comparatively high, yet they found that hospitals were larger than optimal size. In this paper we also estimate optimal hospital size as quite small, and for the years 2012-2014, all of the hospitals were larger than the estimated optimal hospital size. However, average optimal size did increase as the number of hospitals were reduced from 2002 to 2005. This reflects that some of the merged hospitals

performed well enough to define the optimal size from that point in time. However these estimates rely on good case-mix adjustments particularly for the largest hospitals. If cases are more severe or quality higher *within each DRG* in large hospitals than in small, the data does not fully capture the production of the large hospitals, and our estimate of optimal scale will consequently be downwards biased.

Change of diagnostic registrations might be one explanation for the observed productivity growth. Norwegian hospitals are funded by a combination of fixed budgets and activity based financing, and income thus partly relies on the recording of diagnoses and procedures. If more diagnoses and procedures were recorded, this may lead to an increase in outputs through more expensive DRGs, and subsequently higher estimates of technical productivity. This effect would however only be short term as the prices are updated after two years to reflect average costs for each treatment in each group. Any large scale wrongful upcoding would thus not yield long term effects. There is currently more use of secondary diagnoses than in the early years, but this shift is only to a small extent linked to DRG-level prices[33]. In the present study, we have used a common grouper and fixed weight for all years to avoid some of the issues related to upcoding. However even after regrouping data we cannot exclude that some changes are due to upcoding rather than real changes in activity.

Some recent studies have incorporated quality indices as an output measure or otherwise controlled for quality [23]. In this paper we have measured only the hospital production by volume based on average costs, not the contents of that production. Both quality and actual health improvements are very important and will possibly have changed over such a long time span and we suggest further research should be made into this question.

In this paper we have improved comparability of the output measurement by using a fixed DRG logic and weights for all years. This has enabled us to utilize a dataset of sixteen years for hospital level analyses, which to the best of our knowledge is an unprecedented long time span for a hospital level productivity analyses. We claim that it is important in studies related to reform not only to analyse one year before and one year after but instead apply a longitudinal perspective.

5   Conclusion

The present study showed that mean productivity increased by 24.6 percentage points from 1999 to 2014, an average annual change of 1.5 %. There was a substantial growth following the ownership reform in 2002. Post reform (2003-2014), average annual growth has been less than 0.5 %. There was

no evidence of technical change. Estimated optimal size is smaller than actual size of the majority of hospitals.

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Table 1 Output shares, relative hospital size and # hospitals, N=506

	Emergency	Elective	Day care	Outpatient	Size (1999=1)	# Hospitals
1999	0,51	0,32	0,05	0,12	1,0	55
2000	0,50	0,32	0,05	0,13	1,0	54
2001	0,49	0,33	0,05	0,13	1,1	54
2002	0,49	0,33	0,05	0,12	1,7	36
2003	0,47	0,34	0,06	0,12	2,1	30
2004	0,48	0,34	0,06	0,13	2,1	30
2005	0,48	0,33	0,06	0,13	2,2	29
2006	0,48	0,33	0,06	0,13	2,3	29
2007	0,48	0,32	0,06	0,14	2,4	28
2008	0,48	0,32	0,06	0,14	2,4	28
2009	0,48	0,30	0,06	0,15	3,1	23
2010	0,49	0,29	0,07	0,15	3,3	22
2011	0,47	0,30	0,07	0,17	3,3	22
2012	0,46	0,30	0,07	0,17	3,5	22
2013	0,46	0,30	0,07	0,17	3,3	22
2014	0,45	0,30	0,07	0,18	3,4	22

Table note: Hospital size measured as mean real operating costs relative to 1999 mean.
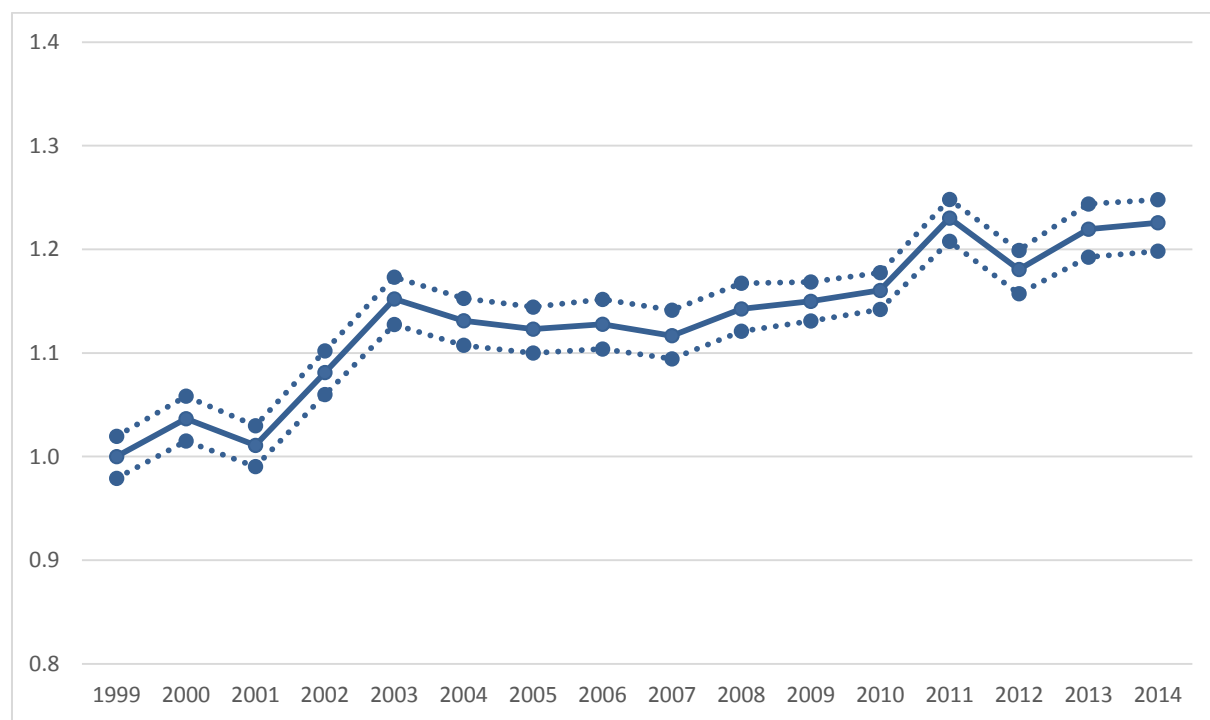

Figure 1 Bootstrapped productivity estimates, weighted mean unit, pooled base, 95% confidence interval, development from 1999

Table 2 Decomposition of productivity growth (M) into catching up (MC) and front shift (MF), with 95 % CI, weighted mean

| Year	N	Malmquist index of productivity growth	Efficiency change / catching up	Technical change / front shift
1999/2000	54	1.046 (1.034-1.059)	0.963 (0.920-1.014)	1.086 (1.026-1.133)
2000/2001	53	0.971 (0.960-0.982)	0.966 (0.944-1.004)	1.005 (0.962-1.031)
2001/2002	19	1.056 (1.045-1.067)	1.069 (1.048-1.109)	0.987 (0.947-1.011)
2002/2003	30	1.062 (1.047-1.077)	1.024 (0.992-1.066)	1.038 (0.992-1.074)
2003/2004	30	1.000 (0.988-1.011)	0.936 (0.896-0.985)	1.069 (1.013-1.113)
2004/2005	28	1.007 (0.996-1.017)	1.018 (0.990-1.062)	0.989 (0.943-1.016)
2005/2006	29	1.008 (0.993-1.021)	1.003 (0.976-1.048)	1.005 (0.961-1.028)
2006/2007	28	1.005 (0.989-1.021)	1.009 (0.985-1.049)	0.996 (0.959-1.017)
2007/2008	28	1.021 (1.011-1.030)	1.028 (1.011-1.063)	0.993 (0.960-1.007)
2008/2009	21	0.981 (0.966-0.995)	0.984 (0.966-1.007)	0.996 (0.974-1.015)
2009/2010	21	1.001 (0.990-1.012)	0.988 (0.972-1.016)	1.013 (0.987-1.030)
2010/2011	22	1.054 (1.036-1.069)	1.032 (1.004-1.071)	1.021 (0.989-1.047)
2011/2012	22	0.958 (0.948-0.968)	0.963 (0.947-0.994)	0.995 (0.966-1.008)
2012/2013	22	1.037 (1.025-1.048)	1.042 (1.027-1.074)	0.995 (0.967-1.007)
2013/2014	22	1.006 (0.997-1.016)	0.996 (0.982-1.027)	1.010 (0.984-1.016)
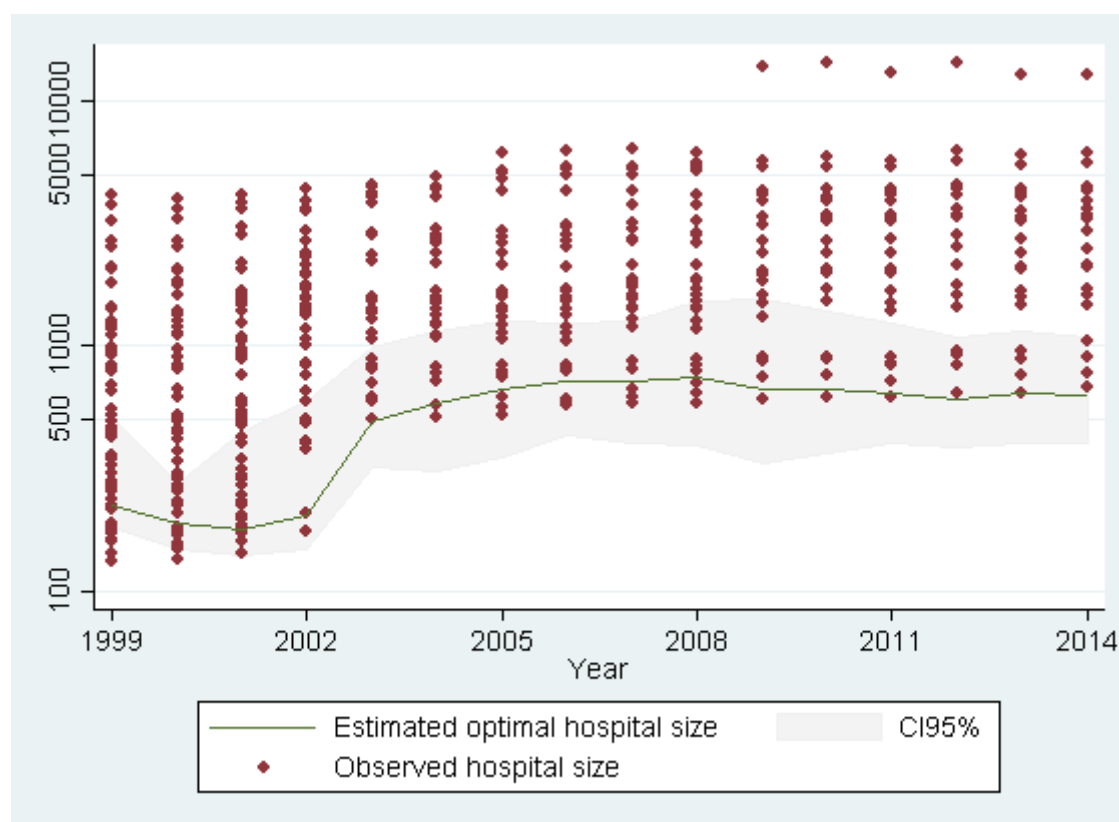
Figure 2 Observed hospital size and estimated optimal hospital size (with 95 % confidence interval). Logarithmic scale for hospital size as measured by real operating costs.