INSTITUTE OF FOOD AND RESOURCE ECONOMICS
UNIVERSITY OF COPENHAGEN

MSAP Working Paper Series
No. 04/2012

The scale of hospital production in different settings: One size does not fit all

Mette Asmild
Institute of Food and Resource Economics
University of Copenhagen

Bruce Hollingsworth
Division of Health Research
Lancaster University, UK

Stephen Birch
Centre for Health Economics and Policy Analysis
McMaster University, Canada

The scale of hospital production in different settings: One size does not fit all

Mette Asmild[1*], Bruce Hollingsworth[2], Stephen Birch[3]

1. FOI, University of Copenhagen, Denmark,
2. Division of Health Research, Lancaster University, UK.
3. Centre for Health Economics and Policy Analysis, McMaster University, Canada.

* Corresponding author:

Email: meas@foi.ku.dk

Keywords: Data Envelopment Analysis (DEA), Scale, Efficiency, Hospitals, Provinces

Acknowledgements

We acknowledge the PIs on the overall project - Gail Tomblin Murphy, Linda Lee O Brien Pallas, and Lynn Lethbridge who was especially helpful at all times. We thank two referees and the Editor for their helpful comments.

Abstract

This paper analyses the productive efficiency of 141 public hospitals from 1998-2004 in two Canadian provinces; one a small province with a few small cities and a generally more rural population and the other a large province that is more urban in nature, with a population who mainly live in large cities. The relative efficiencies of the hospitals, the changes in productivity during this time period, and the relationship between efficiency and the size or scale of the hospitals are investigated using data envelopment analysis. The models for the production of health care use case mix adjusted hospital discharges as the output, and nursing hours as inputs.

We find clear differences between the two provinces. Making use of 'own' and 'meta' technical efficiency frontiers, we demonstrate that efficient units in the larger and more urban province are larger than non-efficient units in that province. However, efficient hospitals in the smaller and more rural province are smaller than non-efficient hospitals in that province. Overall, efficient hospitals in the larger more urban province are larger than efficient hospitals in the smaller more rural province. This has interesting policy implications - different hospitals may have different optimal sizes, or different efficient modes of operation, depending on location, the population they serve, and the policies their respective provincial governments wish to implement. In addition, there are lessons to be learned by comparing the hospitals across the two provinces, since the inefficient hospitals in the small rural province predominantly use hospitals from the large urban province as benchmarks, such that substantially larger improvement potential can be identified by inter-provincial rather than intra-provincial benchmarking analysis.

1. Introduction

Much work has been undertaken on measuring the efficiency of hospitals (e.g. Hollingsworth (2003, 2008), Hollingsworth and Peacock (2008)), particularly with respect to estimation of technical efficiency using non-parametric approaches such as Data Envelopment Analysis (DEA). A number of these studies have used variable returns to scale models, but little evidence has been found regarding significant economies of scale (see for example Hollingsworth (2003, 2008), Hollingsworth and Peacock (2008)), Ozcan (1992), Burns and Pauly (2002)).

Scale effects are potentially particularly relevant for hospital efficiency, given the nature of the production process (Cowing and Holtman (1983)) and the substantial size differences between, for example, rural and urban hospitals. There is a large body of literature concerning the measurement of scale and efficiency in general (outside the hospital sector), see for example Fried, Lovell and Schmidt (2008). If constant returns to scale (CRS) cannot reasonably be assumed in the hospital sector, the most common alternative is to assume that the returns to scale are variable (VRS). This can mean increasing or decreasing returns to scale, such that outputs rise more or less than proportionally with respect to changes in inputs used.

There are many sources of potential economies of scale in hospitals. Some are related to capital (Dranove (1998)), for example the more efficient use of massed reserves, such as technology. Such production factors are often used more as a hospital grows, leading to economies of scale with larger hospitals potentially benefitting in efficiency terms. However, some activities, such as labour use, may have few fixed costs to 'spread' as capacity increases, potentially leading to decreasing scale returns, that is smaller units may hold the advantage, because of potential co-ordination and congestion problems as a hospital increases in size.

A further problem with economies of scale, raised by, among others, Vitaliano (1987), is that the minimum efficient scale size is highly sensitive to the choice of functional form of the input-output relationship[1]. A final issue raised by Dranove (1998) is that of the use of outputs to measure size. Generally it is difficult to use the output measure as an indicator of size, since this would confound efficiencies and scale effects in the sense that an inefficient hospital will consequently appear smaller than it really is. We therefore investigate capacity separately here, i.e. as an exogenous factor.

Here, we use the non-parametric DEA approach to analyse the efficiencies and scale effects in the use of variable, or short run, resources – specifically labour. Outputs are in our study assumed exogenous, in the sense that hospitals respond to patient demand, and cost minimising behaviour is presumed, allowing the effective use of production parameters, given the theory of duality (see, for example Greene (2008)). Overall, using case mix adjusted Canadian data, we find that 'optimal' scale, or the presence of economy or diseconomy of scale, does not appear to be consistent across hospitals in different locations and therefore not accounting for this could bias results.

[1] This is not an issue for us in empirical terms, as the models used here are non-parametric in nature.

We show how, even in a relatively small sample of hospitals, valuable additional information can be generated using the methods demonstrated here. We show that introduction of comparative samples, even serving quite different populations, can be used to illustrate how large and small hospitals can improve productive efficiency in the key area of health care.

The rest of this paper is structured as follows: In section 2 we briefly describe the setting for the analysis, which is the Canadian health care system, specifically within the provinces of Ontario and New Brunswick, and section 3 describes the data used in the analysis. Section 4 defines the methodologies used, specifically Data Envelopment Analysis and the global frontier shift. In section 5 the various results of the analyses are presented and section 6 provides a discussion.

2. Background

The empirical analysis investigates the relationship between scale and efficiency effects in two very different Canadian provinces, one predominantly rural and one predominantly urban, using a balanced panel of 141 Canadian hospitals across the two provinces. The Canadian hospital system is characterised by 'first dollar public funding' (Birch and Gafni (2005)), with medically needed services free at the point of delivery. This is enabled by a publically funded insurance plan, Medicare, which is made up of a number of provincial programs, governed under the auspices of the 1984 Federal Canada Health Act. Under this Act the population of a province are covered by a provincial plan, and a comprehensive range of services, including hospital services, are offered.

Canadian hospitals are largely still funded through block funding, with an amount transferred each year to cover operational expenses. Marginal volume payments are made on top of these to cover certain cardiac, orthopaedic, and other surgical activities. Funding of hospitals would ideally follow the 'need' for care. The notion of need is important here because of its relationship with efficiency: Firstly, since technically inefficient hospitals are using too many resources relative to the amount of output they produce, this weakens their argument for needing those resources. Secondly, even if hospitals are technically efficient they may be operating at the wrong scale and thus implicitly be wasting resources by not achieving the highest possible ratio of outputs to inputs coming from operating at the optimal size.

Mixed evidence has been presented since the Act was passed on the economic efficiency of Canadian hospitals. Using Canadian data, Preyra and Pink (2006) explicitly consider scale economies using a cost function approach and conclude that there may be large unexploited scale economies, in terms of potential hospital consolidation. Bilodeaua et al. (2002), using data from Québec, demonstrate economies and diseconomies of scale are found to be quite evenly distributed. Bilodeaua et al. (2004) use data envelopment analysis (DEA) to analyse this same sample, and find that most hospitals have decreasing returns to scale, even in rural areas.

In fact the system has been under attack as inefficient (Steinbrook (2006)). There is even a debate as to the legitimacy of the system, and the fact that private providers are traditionally not permitted to offer certain core services, although this may be changing somewhat (Steinbrook (2006)). Here we focus on the scale of production, and its potential impact on the organisation of care delivery, especially with regard to issues of hospitals which serve more rural versus more urban populations in different provinces, of different sizes, with different governments. Canadian hospitals are generally independent not-for-profit institutions, funded by the respective provinces (Shamian and Lightstone (1997)), and we take a regional approach in our analysis, asking questions such as: is it more efficient to have a smaller scale of production in one province, relative to another? Are hospitals in some provinces operating inefficiently and if so, are there efficiency changes, ideally improvements, over time? There may also be concerns about nursing skill-mix (Sochalski, Aiken and Fagin (1997)), and the efficiency of use of nursing labour in one or both of the provinces we concentrate on. These are all issues (scale, efficiency changes over time, regional differences, capacity differences) which could be generalised to any hospital setting in any country, and would have policy implications in terms of recommendations for (different) optimal modes of health care delivery.

3. Data

The Discharge Abstract Database (DAD) was used as the source of data on inpatient episodes of care. This database is managed by the Canadian Institute of Health Information based on data provided by each province on hospital inpatient services. It provides a standardized record of each inpatient case at discharge including age and gender of patient as well as diagnoses, procedures received and length of stay. A separate database, Management Information System (MIS), records information on hospital resources including nursing, administration, 'hotel' and diagnostic and therapeutic hours. Each province records information on this system.

As data on the hours of nursing were not available separately for registered nurses and registered practice nurses for both provinces for all years, the two categories of nursing were combined. Data on worked nursing hours was used since benefit hours (sick time and vacation) do not represent time that nurses are available for service delivery. Inpatient nursing hours were given by the aggregate of hours across medical/surgical, obstetrics, pediatrics, psychiatric and rehabilitation. Nursing administration hours were identified specifically for inpatient care. Total worked hours per year by were divided by 1,950 to provide an estimate of full time equivalent (FTE) nursing hours by the five categories of nursing for each acute care hospital in each of the provinces. As a measure of capacity constraints the number of beds (rated bed capacity) of each hospital was used for subsequent analysis[2].

The number of inpatient episodes was 'weighted' by the Resource Intensity Weight (RIW) score for inpatient cases. Average RIW scores were calculated for each of five age groups (0-4, 5-19, 20-64, 65-74, 75+) and then multiplied by the total number of inpatient stays by patients in each of these age groups. The final data set covered 141 acute care hospitals from two provinces across 6 years (1998-2004), with 117 of the hospitals being from Ontario, and the remaining 24 from New Brunswick. The data set is a balanced panel, since no hospitals opened, closed or merged during the study period.

[2] As with other North American hospitals, physician data are unavailable across the sample, due to the nature of their employment.

In demographic terms the provinces are quite different – Ontario is largely urban (80% in population terms) with a population of 15 million living mainly in large cities, and New Brunswick largely rural (80%), with a population of less than 1 million living in a few small cities or more rural areas. Other standard demographics are similar – both provincial governments spend around $5,200 per capita on health care (2008), and have a life expectancy of around 80. The average values for the variables in each year and for each province are given in Table 1 below. It can be seen that, on average, Ontario hospitals (i.e. those in the more urban region) have over double the number of discharges New Brunswick hospitals have (i.e. those in the more rural region).

Table 1 here.

4. Methods

We make use of Data Envelopment Analysis (DEA) based methods, as the non-parametric nature of the analysis provides more freedom and enables us to look not only at different aspects of efficiency, but also frontier shifts in ways other techniques do not. For example we consider 'global shifts' (see below) which provides information beyond standard analysis of this type. Snapshots of efficiency are often not as useful to decision makers as movements in efficiency over time – we take this further by relating the changes over time estimated using global frontiers to the differences in location and in scale of production.

4.1. Data Envelopment Analysis

To formally define the DEA methodology in this case, consider the 141 hospitals in the data set, of which 117 are from Ontario and 24 are from New Brunswick, which all use 8 different inputs, nursing hours in different categories, to produce a single output, RIW-adjusted discharges. The data set is a balanced panel with observations for each hospital for each of the years *t*=1998, … , 2004. The input-output vector for hospital *j*, *j=1,…,N* in year *t* is given by $(\mathbf{x}_j^t, y_j^t) \in \Re_0^8 x \Re_+$. The efficiency scores are generally estimated relative to observations from the same year, that is using the annual frontiers, though mixed-period scores are required for the calculations of the frontier shifts. The input-efficiency score for hospital_0^t relative to the frontier of year t' is denoted by $\theta *_0^{t,t'}$ where the subscript (0) indicates the hospital in question, the first superscript (t) the year for which the efficiency for that hospital is assessed and the second superscript (t') the frontier it is being compared to, and it is given by

$$
\begin{aligned}
&\theta *_0^{t,t'} = \text{Min } \theta \\
&\text{s.t.} \\
&\sum_j \lambda_j^{t'} x_{ji}^{t'} \leq \theta \, x_{0i}^t, \; i=1,\ldots,8 \\
&\sum_j \lambda_j^{t'} y_j^{t'} \geq y_0^t, \qquad\qquad (1) \\
&\lambda_j^{t'} \geq 0, \; \forall j=1,\ldots,N. \\
&\sum_j \lambda_j^{t'} = 1 \text{ (only for VRS assumption)}
\end{aligned}
$$

where the lambdas are so-called intensity variables used in the optimisation to create convex combinations of observed best-practice hospitals that other, less efficient, hospitals are compared to.

4.2. Global Frontier Shift

To estimate the movements of the frontier over time, we apply the global frontier shift component of the Global Malmquist Index of Asmild and Tam (2007). This directly provides an overall measure of the movement of the frontier, as opposed to the standard Malmquist Index of Färe et al. (1994) which estimates the frontier shift specifically to each observation. The global frontier shift, or global technical change, between period t' and period t'' is given by

$$TC^{G}(t',t'') = \left(\frac{\prod_{\substack{j=1,\ldots,141 \\ t=1998,\ldots,2004}} \theta^{*t,t'}_{j}}{\prod_{\substack{j=1,\ldots,141 \\ t=1998,\ldots,2004}} \theta^{*t,t''}_{j}} \right)^{1/(141*7)} \quad (2)$$

It can be seen from Eq. 2 above that the global frontier shift is the geometric mean of the ratio of the efficiencies for all observations in the sample (all j=1,...,141 hospitals in all t=1998,...,2004 years) measured relative to one frontier (t') and relative to another frontier (t'') and thus an overall measure of the relative distance between those two frontiers. The two frontiers do not simply have to be for the same observations in different time periods (like in the traditional Malmquist Index) but can be any two different frontiers and here also the province-specific frontiers, such that the second superscripts (t' and t'') instead refer to the frontiers for Ontario and for New Brunswick.

To avoid mixed-period infeasibilities, the efficiency scores in (2) are estimated relative to a CRS frontier, that is ignoring the convexity constraint on the lambdas in (1). This is supported by the argument of Wheelock and Wilson (1999) that Malmquist indices should be estimated using CRS regardless of the true technology.

5. Results

We first look at patterns of efficiency over time, before moving on to considering the importance of scale.

5.1. Pure technical efficiency over time

Consider first the efficiency scores, calculated within each year across both provinces (i.e. for N=141 observations each time), using equation (1). The average values of these scores for the whole sample, and the average of the scores for the hospitals within each province but still calculated relative to the frontier for all observations that year, are illustrated in Figure 1 below.

Figure 1 here.

Figure 1 clearly shows how the hospitals in Ontario (the larger province with the more urban population) are consistently more efficient on average than the hospitals in New Brunswick (the smaller province with the predominantly rural population). Since the figure illustrates VRS scores, this is a matter of pure technical efficiency. If traditional scale efficiency is considered as well (c.f. Banker, Charnes and Cooper (1984)), the difference between the two provinces does in fact become even larger, since the hospitals in New Brunswick can be shown to be less scale efficient than those in Ontario.

Note, in Figure 1, how the average efficiency scores overall, but especially for New Brunswick, seem to fall quite drastically from 2000-2002 after which they increase again. Since these scores are calculated relative to different (annual) frontiers, they are not directly comparable. Therefore we cannot determine whether the productivity decreased in those years, without a direct investigation of the movements of the frontier, as will be done below. Thus at this stage, we can only conclude that there was increased variation between the hospitals' performance in those years.

In order to compare the efficiency scores over time Figure 2, below, shows the average score for each province in each year calculated relative to a pooled or meta-frontier, where all the observations from all years are pooled into one data set (i.e. the frontier is constructed from all 7*141=987 observations). That these scores are all measured relative to the same frontier means that they can be compared directly. It also means that the efficiency score of a hospital may be determined through comparisons with observations in different years and thus may not represent obtainable benchmarks.

Figure 2 here.

In Figure 2 we again clearly see how the hospitals in more urban Ontario are significantly more efficient, on average, than their more rural New Brunswick counterparts in all years of the study period. We also observe that average relative performance actually seems to be decreasing over time, for New Brunswick fairly consistently over the study period and for Ontario mainly since 2002.

5.2. Frontier movements over time

Where the above considered changes in the average performance over time, we in this section specifically investigate the movement of the frontier, that is whether the best performing hospitals improved over time, which could potentially indicate improvements in production technology.

For this purpose we use the concept of the global frontier shift (Asmild and Tam (2007)), which directly estimates the overall or mean movement of the frontier, as opposed to the more commonly used frontier shift component of the Malmquist index (Färe et al. (1994)) which estimates the frontier shifts for each individual observation, and which can then subsequently (but less accurately cf. Asmild and Tam (2007)), be aggregated to determine the overall shift.

Calculating the global frontier shifts using equation (2) shows that the global frontier shift between 1998 and 2004 was 0.81. This means that during the whole study period the frontier has deteriorated, to the extent that if all observations were projected onto the 2004 frontier, they would actually only have an average efficiency of 0.81 if measured against the 1998 frontier instead.

The changes between consecutive years are shown in Table 2 below:

Table 2 here.

From Table 2 we see how the frontier especially improved from 2001-2002 and deteriorated from 2002-2004. These values indicate the overall shift of the frontier, but the overall deterioration is likely not to be a parallel shift. In particular it can be shown that the frontier shifts the individual units observed were in the range of [0.19; 2.07]. We can also show that 89 out of the total 987 observations (9%) actually experienced an improving frontier overall for the period of 1998-2004[3] and further investigation reveals that these observations are much smaller on average (in terms of all input- and output variables as well as capacity) than those experiencing a deteriorating frontier (in both provinces). So while the frontier overall has deteriorated during the whole study period, some of the smaller observations (amongst which New Brunswick is overrepresented) have witnessed an overall improving frontier, meaning that some of the best performing smaller hospitals, especially in the smaller, more rural province, were in fact improving over time.

An additional advantage of using the global frontier shift concept is that it enables us to estimate the overall relative distance between any two frontiers, here specifically the distance between the frontiers of the two provinces, rather than only changes over time for a balanced panel data set. For each year we therefore obtain the global distance between the

[3] Determined by the observation's projections onto the 1998 and the 2004 frontiers respectively

frontier for Ontario and the frontier for New Brunswick shown in Table 3 below. Note that values greater than one indicate that the frontier for Ontario is superior to that of New Brunswick from a global point of view.

Table 3 here.

The results in Table 3 imply that the mean distance between the frontiers for Ontario and for New Brunswick was 1.89 in 1998, meaning that the Ontario frontier was 89 percent better than then New Brunswick frontier[4]. So it appears that the best performing hospitals in Ontario are consistently substantially better than their New Brunswick counterparts and that the difference is generally increasing over time. This conclusion does, however, not take any scale or size effects into consideration – an issue we return to in the next section.

Consider next the frontier shift over time within each province separately - the results of which are shown in the last two columns of Table 2 above. From these results we see that the frontier for the smaller province (NB) has worsened slightly every year since 1999, resulting in an overall frontier deterioration (frontier shift=0.81) throughout the study period. For the larger province (ONT) there are larger variations in the frontier movements over time, with improvement from 1999 to 2002 but a decline in the remaining years, and a decline of a larger magnitude, resulting in an overall frontier decline (frontier shift=0.79) throughout the study period. So the overall changes are quite similar in the two provinces, but the movements within the years are at times rather different in the two regions. We go

[4] Again this value indicates the average (super) efficiency score all observations projected onto Ontario frontier would get if they were measured relative to the New Brunswick frontier instead.

on to investigate whether the province differences are related to the size or scale of the hospitals in the two provinces, but for now the immediate province specific results indicate that:

- The best performing hospitals in Ontario, the larger and more urban province, are substantially better than the best performing hospitals in smaller and more rural New Brunswick for all years in the study period;
- The average efficiency (relative to the meta frontier) for New Brunswick has been decreasing during the study period;
- The frontier for New Brunswick has worsened slightly in all years in the study period resulting in an overall "negative" frontier shift of 0.81;
- The average efficiency (relative to the meta frontier) for Ontario has been stable 1998-2001 but decreasing in 2002-2004;
- The frontier for Ontario has improved during 1999-2002 but deteriorated more in the remaining years, resulting in an overall "negative" frontier shift of 0.79.

5.3. Technical efficiency vs. size

To further investigate the efficiency differences between the provinces we next consider the relationship between technical efficiency (relative to annual frontiers) and the size of hospitals in the two provinces as shown in Table 4A and 4B below:

Tables 4A and 4B here.

Table 4A shows how the hospitals in New Brunswick are substantially smaller on average than the Ontario hospitals. Here size is measured by discharges (volume), but a similar pattern is present if using the rated bed capacity as a measure of size.

Comparing the results in Table 4A and Table 4B reveals that the technically (VRS) efficient units from New Brunswick are smaller on average than the average of all the hospitals in New Brunswick. Conversely, the efficient hospitals in Ontario are larger on average than the average hospital in this province.

To further investigate these findings we perform a series of one-tailed t-tests for the significance of size-differences, measured on discharges, between different groups of hospitals, specifically the efficient hospitals vs. the inefficient hospitals in both New Brunswick (NB) and Ontario (ONT) and between the efficient hospitals in the two provinces. A summary of the results of these tests is shown in Table 5 below.

Table 5 here

Table 5 shows that for all years (for which the tests can be done):

- Efficient hospitals in NB are significantly smaller than the non-efficient hospitals in NB (measured by discharges);
- Efficient hospitals in ONT are significantly larger than the non-efficient hospitals in ONT (measured by discharges);

- Efficient hospitals in ONT are significantly larger than the efficient hospitals in NB (measured by discharges).

While these results indicate that there are different optimal modes of operation in the two provinces, this does not necessarily imply that the provinces should be treated as having incomparable production technologies. Instead, considering which hospitals are used as benchmarks for the inefficient hospitals reveals that, even under VRS, the inefficient hospitals in New Brunswick predominantly benchmark (mainly small) efficient hospitals from Ontario. Therefore one could argue that it is still relevant and important to benchmark the hospitals in the two provinces against each other, and here especially the NB hospitals against those from ONT. This enables the hospitals in New Brunswick to also learn from the small hospitals in Ontario, and thus improve more than if they were simply benchmarked against the best performing hospitals from their own province. The differences between intra- and inter-provincial benchmarking is analysed further in the following section.

5.4. Intra-provincial vs. inter-provincial benchmarking

Since it appears that the (inefficient) hospitals from New Brunswick especially benchmark the efficient small hospitals from Ontario, we now define subsets of the data set based on the sizes of the hospitals. Specifically, we define hospitals with a rated bed capacity of less than 100 as "small" and those with a capacity above 100 as "large", noting that a capacity of 100 is close to the median in the data set.

Analysing the small hospitals separately, but pooled across the two provinces and across all years, we find that the average VRS efficiency score for the small NB hospitals is 0.53, whereas is would be 0.87 if the small NB hospitals were only benchmarked against each other. This reveals the possible loss, in terms of identification of improvement potential, that would arise if the fact that there are different optimal modes of operation in the two provinces was used as an argument for having to do the analysis separately within each province.

Similarly, considering the large hospitals separately, but pooled across the provinces and across all years, shows an average efficiency score for the large NB hospitals of 0.56 whereas it would be as high as 0.99 if the large NB hospitals were only benchmarked against each other. Again it is clear that there is a much greater potential for learning and improvement being identified for the NB hospitals if they are also benchmarked against the hospitals from Ontario that are of a similar size.

For the Ontario hospitals, however, be they small or large, there is no difference in the average efficiency whether they are also benchmarked against the NB hospitals or not – thus the learning appears rather one-sided. Note also that the inclusion of the hospitals from Ontario enables benchmarking of the NB hospitals within each year separately (cf. e.g. Figure 1), which would not otherwise have been possible due to the so-called 'curse of dimensionality'.

Finally, to further investigate the impact on efficiencies of the sizes of the hospitals, we next consider differences between large and small hospitals in the two provinces within each year.

5.5. Size (capacity)-province interaction vs efficiency

Table 6 below provides the average efficiency scores for each year (measured relative to the annual frontiers) for the small and large hospitals in the two provinces respectively.

Table 6 here.

Simply considering the average efficiency scores indicates the following ranking:

Eff (NB large) < Eff (NB small) < Eff (ONT small) ≤ Eff (ONT large)

Formal tests of the differences, using the Mann-Whitney test (with 95% confidence level), confirms that:

- The hospitals in ONT are (strongly) significantly more efficient than the hospitals in NB throughout the study period;
- There is generally (except for 1998) no significant difference in efficiencies between large and small hospitals overall (across provinces); but:
- Small hospitals (capacity<100) in NB are significantly more efficient than the larger hospitals in NB early in the study period (1998, 1999, 2000) but the difference is insignificant in 2001-2004 (borderline significant in 2003);
- Small hospitals in ONT are significantly more efficient than small hospitals in the NB for all years in the study period (though only marginally in 1998);
- Larger hospitals (capacity 100+) in ONT are only significantly more efficient than the smaller hospitals in ONT in 1998, otherwise the differences are insignificant.

6. Discussion

Initial analysis appears to show that the hospitals in the larger, more urban province (Ontario) consistently outperform their counterparts in the smaller, more rural province (New Brunswick), in terms of technical efficiency. Further investigation, making use of 'own' and 'meta' technical efficiency frontiers, demonstrates that the efficient units in the Ontario are larger than the efficient units in New Brunswick. The efficient hospitals in Ontario produce a lot more output than the non-efficient hospitals. The opposite occurs for New Brunswick, where the efficient hospitals are a lot smaller than the non-efficient hospitals. So operational size may be important in the larger, more urban province, but may not be in the smaller, more rural province. Over time, for both provinces, smaller hospitals improved performance more than larger hospitals, this is alongside the whole sample becoming less productive overall. This could well indicate evidence of a scale effect, where larger hospitals may be demonstrating decreasing returns, or smaller hospitals may have increasing returns to scale. Equally as important could be the rurality effect - one size does not fit all – there seem to be two different modes of operation that could be efficient: Smaller hospitals in the less (densely) populated regions and larger hospitals in more urban areas. However, comparing hospitals of the same size but in different regions results in the identification of much larger improvement potentials than if the hospitals are only compared to those from the same region, specifically for the hospitals from New Brunswick which can potentially learn, and thereby improve, a lot from being benchmarked against the small hospitals from Ontario..

Of course, the differences may be due to many other factors, for example the size of the provinces. New Brunswick is largely made up of a few small cities and then a rural population, whereas the vast majority of the population of Ontario lives in large cities. Also, or perhaps for that exact reason, Ontario experienced a population growth of around 13% between 1996 and 2006, whereas the population of New Brunswick actually decreased slightly during that period[5]. This could be expected to result in improved productivity in Ontario compared to New Brunswick, perhaps at the expense of quality of care, if the same resources served more people, but our results indicate that this has not been the case. Therefore we have not investigated this issue further. Other factors that could influence the differences between the provinces may be associated with different provincial programmes, in terms of finance and delivery, since health care is a provincial government responsibility, outside of broad federal parameters associated with public payment and administration.

It could also be argued that the differences we find between smaller and larger hospitals in different provinces could be caused by the use of technology. However, in a developed country technology and operating environment (besides any scale factors) should be similar and transferable between regions, so we think that it is justified to use inter-regional frontiers across provinces and compare all hospitals, at least of similar sizes, to the same frontier. Also, it may be that larger urban hospitals are simply more efficient at processing cases, as they have more Emergency Room, and day case beds. This may lead to more rural hospitals admitting more patients for treatment. Our data do not allow closer investigation of this issue.

[5] We thank a referee for bringing this to our attention

Given these caveats the results are still interesting in terms of potentially pointing towards differences. Bilodeaua et al. (2009) find that large hospitals may fail to efficiently use technology, while smaller hospitals, which do not have access to the latest technology, may be more efficient at using the technology they do have access to. This may have been evident if we had been able to assess quality of care, which may be impacted upon by technological developments. Although our output measures are case mix adjusted we can say little about the quality of care on offer.

There may also be differences in the hospitals in terms of levels of services offered – there may be some hospitals, for example, 'stuck in the middle' - lacking the volume to undertake many highly complex cases in order to exploit economies of scale. These hospitals may be located in such a place that they must continue to offer certain service lines, as other hospitals are too far away for patients to get to (see Ozcan and Lynch (1992), Lynch and Ozcan (1994) for a discussion on hospital closures related to efficiency).

As with many production analyses in health care (see Hollingsworth (2008)) there are potential omitted variables, especially inputs to the process (physician labour for example) and a lack of 'quality' adjustment for outputs. Ideally a data set would account for re-admissions, quality of life changes, and include labour inputs specific to each procedure undertaken. We do not claim here that policy should be based on our results. However, we have illustrated the usefulness of a new means of comparison with reference to available data from Canada – generalizability of these methods is apparent as more data come on stream, or are available in other health care, and non-health care applications.

However, even with these caveats we illustrate here that comparing even what may appear to be quite different samples, serving quite different populations can lead to provision of useful extra information to managers and policy makers. This is important, as often samples are too small for like for like comparisons. The addition of extra information in this area is important, given health care in developing countries generally accounts for around 10% of GDP and under the current financial constraints more information on efficiency and productivity is crucial.

References

Asmild, M. and Tam, F. (2007), Estimating global frontier shifts and global Malmquist indices, *Journal of Productivity Analysis*, 27: 137–148.

Banker, R.D., Charnes, R.F. and Cooper, W.W. (1984), Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science,* 30: 1078–1092.

Bilodeaua, D., Crémieuxab, P.-Y., Jaumard, B., Ouellette, P. and Vovor, T. (2004), Measuring Hospital Performance in the Presence of Quasi-Fixed Inputs: An analysis of Québec hospitals. *Journal of Productivity Analysis* 21(2): 183-199.

Bilodeaua, D., Crémieuxab, P.-Y. and Ouellette, P. (2002), Hospital technology in a nonmarket health care system. *Southern Economic Journal* 58(3): 511-529.

Bilodeaua, D., Crémieuxab, P.-Y. and Ouellette, P. (2009), Hospital performance in a noncompetitive environment, *Applied Economics*, 41(4): 459-468.

Birch, S. and Gafni, A. (2005), Achievements and challenges of medicare in Canada: Are we there yet? Are we on course? *International Journal of Health Services* 35(3): 443-463.

Burns, L. and Pauly, M. (2002), Integrated Delivery Networks: A detour on the road to integrated health care. *Health Affairs* 21(4): 128-143.

Cowing, T.G. and Holtman, A.G. (1983), Multiproduct Short-Run Hospital Cost Functions: Empirical Evidence and Policy Implications from Cross-Section Data. *Southern Economic Journal* 49(3): 637-653.

Dranove, D. (1998), Economies of scale in non-revenue producing cost centers: implications for hospital mergers. *Journal of Health Economics* 17: 69-83.

Färe, R., Grosskopf, S., Lindgren, B. and Roos, P. (1994), *Productivity developments in Swedish hospitals: A Malmquist output index approach*, in Charnes, A., Cooper, W.W., Lewin, A.Y and Seiford, L.M. (eds.), Data Envelopment Analysis: Theory, Methodology and Applications, Kluwer Academic Publishers, Boston.

Fried, H.O., Lovell, C.A.K. and Schmidt, S.S. (2008), *The measurement of productive efficiency and productivity growth*. New York: Oxford University Press.

Greene, W. (2008), *The econometric approach to efficiency analysis,* in Fried, H.O., Lovell, C.A.K. and Schmidt, S.S. (eds). The measurement of productive efficiency and productivity growth. New York: Oxford University Press.

Hollingsworth, B. (2003), Non-parametric and parametric applications measuring efficiency in health care, *Health Care Management Science* 6(4): 203-218.

Hollingsworth, B. (2008), The measurement of efficiency and productivity of health care delivery, *Health Economics*; 17(10): 1107-1128.

Hollingsworth, B. and Peacock, S. (2008), *Efficiency Measurement in Health and Health Care*. UK: Routledge.

Lynch, J.R., and Ozcan, Y.A. (1994), U.S. Hospital Closures: An Efficiency Analysis. *Hospital and Health Services Administration* 39(2): 205-220.

Ozcan, Y. (1992), Sensitivity analysis of hospital efficiency under alternative output/input and peer groups: A review. *Knowledge, Technology and Policy*. 5(4): 1-29.

Ozcan, Y.A. and Lynch, J. (1992), Rural Hospital Closures: An Inquiry to Efficiency. In Scheffler R. M. and Rossiter, L.F. (eds.) *Advances in Health Economics and Health Services Research,* 13: 205-224.

Preya, C. and Pink, G. (2006), Scale and scope efficiencies through hospital consolidations. *Journal of Health Economics* 25: 1049-1068.

Shamian, J. and Lightstone, E.Y. (1997), Hospital restructuring initiatives in Canada. *Medical Care* 35(10 supplement): OS62-OS69.

Sochalski, J., Aiken, L.H. and Fagin, C.M. (1997), Hospital restructuring in the United States, Canada, and Western Europe. *Medical Care* 35(10 supplement): OS13-OS25.

Steinbrook, R. (2006), Private Health Care in Canada. *New England Journal of Medicine* 354(16): 1661-1664.

Vitaliano, D. (1987), On the estimation of hospital cost functions. *Journal of Health Economics* 6: 305-318.

Wheelock, D.C. and Wilson, P.W. (1999). Technical progress, inefficiency, and productivity change in US banking, 1984–1993, *Journal of Money, Credit, and Banking*, 31(2): 212–234.

Table 1. Average variable values

		Mean values								
		Diagnostic	*Hotel*	*Inpatient admin*	*Intensive*	*Med/Surg*	*Obstetrics*	*Pediatrics*	*Psych*	*RIW-adjusted discharges*
1998	**NB**	142,944	665,970	44,299	32,690	145,159	22,560	11,817	23,865	4,897
	ONT	222,054	1,160,439	56,463	69,553	243,535	46,722	10,343	19,760	11,075
1999	**NB**	149,889	672,858	42,255	33,207	150,200	22,964	11,712	23,234	4,907
	ONT	229,895	1,265,646	58,225	72,842	253,932	48,042	10,722	20,218	11,456
2000	**NB**	149,356	669,535	45,898	38,516	145,876	21,416	10,323	23,868	4,897
	ONT	236,723	1,463,677	60,506	70,963	254,054	49,011	10,960	21,661	11,441
2001	**NB**	136,812	750,567	49,867	34,831	141,165	20,185	10,094	22,747	4,990
	ONT	250,509	1,657,643	63,659	72,409	259,290	50,575	10,328	26,834	11,991
2002	**NB**	135,832	736,302	50,558	32,062	144,186	20,130	9,972	20,957	4,891
	ONT	257,269	1,730,173	67,180	73,103	262,833	50,663	9,818	26,577	11,763
2003	**NB**	135,164	762,997	52,955	34,158	143,016	20,275	10,122	18,874	4,816
	ONT	261,275	1,778,786	69,062	79,955	258,233	50,742	9,672	22,447	10,989
2004	**NB**	137,009	837,557	41,639	32,517	145,901	20,973	9,787	13,381	4,561
	ONT	271,943	1,870,602	68,237	83,342	259,689	50,032	9,952	22,776	11,122

Table 2. Estimated global frontier shifts between years for the overall dataset and for each province separately

	Global Frontier Shifts		
Years	*Frontier for all 141 hospitals*	*NB frontier (24 hospitals)*	*ONT frontier (117 hospitals)*
98-99	0.95	1.01	0.94
99-00	1.02	0.97	1.01
00-01	1.05	0.90	1.05
01-02	1.14	0.98	1.12
02-03	0.87	0.96	0.87
03-04	0.80	0.96	0.81
98-04	0.81	0.80	0.79

Table 3. Estimated global frontier 'shifts' (relative distances) between the provinces in each year

Year	*Relative distance ONT-NB frontier*
1998	1.89
1999	1.70
2000	1.90
2001	2.23
2002	2.42
2003	2.54
2004	2.07

Table 4A. Average annual discharges for all hospitals

Average discharges	1998	1999	2000	2001	2002	2003	2004
All	10,023	10,341	10,327	10,799	10,593	9,939	10,005
NB	4,897	4,907	4,897	4,990	4,891	4,816	4,561
ONT	11,075	11,456	11,441	11,991	11,763	10,989	11,122

Table 4B. Average annual discharges for VRS efficient hospitals

Average discharges amongst VRS efficient hospitals	1998	1999	2000	2001	2002	2003	2004
All	14,380	14,368	14,422	16,639	17,338	14,811	13,024
NB	1,772	1,882	1,297	319	N/A	2,199	934
ONT	15,527	14,903	14,808	16,906	17,337	15,254	13,599

Table 5. **One tailed t-tests for size differences (measured on discharges)**

Hypothesis: For NB the inefficient hospitals are larger than the efficient hospitals

	Mean size of inefficient hospitals	*Mean size of efficient hospitals*	*T-value*	*Test prob. P*
1998	5,939 (18)	1,772 (6)	2.59	0.018
1999	5,339 (21)	1,882 (3)	2.17	0.022
2000	5,224 (22)	1,297 (2)	2.35	0.023
2001	5,193 (23)	319 (1)	NA	NA
2002	4,891 (24)	NA	NA	NA
2003	5,054 (22)	2,199 (2)	2.00	0.029
2004	5,079 (21)	934 (3)	2.62	0.008

Hypothesis: For ONT the efficient hospitals are larger than the inefficient hospitals

	Mean size of efficient hospitals	*Mean size of inefficient hospitals*	*T-value*	*Test prob. P*
1998	15,527 (66)	5,313 (51)	4.76	0.00
1999	14,903 (70)	6,322 (47)	3.87	0.00
2000	14,808 (68)	6,768 (49)	3.63	0.00
2001	16,906 (61)	6,637 (56)	4.33	0.00
2002	17,338 (55)	6,637 (62)	4.32	0.00
2003	15,254 (57)	6,938 (60)	3.57	0.00
2004	13,599 (63)	8,232 (54)	2.26	0.013

Hypothesis: The efficient hospitals in ONT are larger than the efficient hospitals in NB

	Mean size of efficient hospitals in ONT	*Mean size of efficient hospitals in NB*	*T-value*	*Test prob. P*
1998	15,527 (66)	1,772 (6)	6.97	0.00
1999	14,903 (70)	1,882 (3)	6.41	0.00
2000	14,808 (68)	1,297 (2)	6.55	0.00
2001	16,906 (61)	319 (1)	NA	NA
2002	17,338 (55)	NA	NA	NA
2003	15,254 (57)	2,199 (2)	6.31	0.00
2004	13,599 (63)	934 (3)	6.36	0.00

The number of observations in each group are shown in brackets after the averages.

Table 6. Average efficiencies across provinces and sizes (capacity)

	Average efficiency scores			
	NB large (7 hospitals)	*NB small (17 hospitals)*	*ONT small (60 hospitals)*	*ONT large (57 hospitals)*
1998	0.55	0.78	0.89	0.96
1999	0.59	0.75	0.93	0.93
2000	0.63	0.77	0.93	0.94
2001	0.62	0.64	0.90	0.90
2002	0.52	0.57	0.85	0.89
2003	0.55	0.69	0.88	0.89
2004	0.66	0.73	0.90	0.91

Figure 1. Average annual VRS efficiency scores

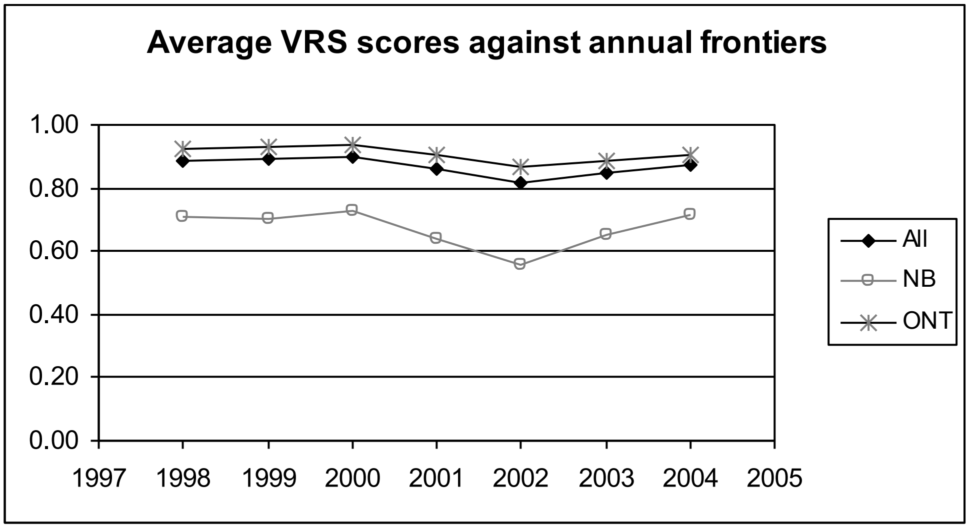

Figure 2. Average VRS efficiency scores relative to meta frontier