ORIGINAL ARTICLE

Economies of scale in cardiac surgery

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Abstract

Objective: The objective of this paper is to investigate the impact of scale of surgical units on the productivity of patient processes.

Methods: The context, intervention, mechanism, output (CIMO) model of Evaluation research is used. The scale–performance mechanisms are examined through resource intensity and throughput time per patient. The productivity of Coronary Artery Bypass Graft (CABG) surgery in a very large and a smaller hospital are compared.

Results: While the large hospital performed 5.1 times more CABG surgeries per year than the smaller hospital, in terms of total resource consumption per patient it was 13% less productive. The large hospital had a 5% efficiency advantage in Operating Theatres (OTs), but it was 30% less efficient in ward care.

Conclusions: Economies of scale are not found at the patient process level. Operating policies seem to assume more importance than scale.

Key Words: Economies of scale, Healthcare operations management, Evaluation research, Hospital size, Surgery productivity

1 Introduction

The most efficient scale of a hospital has interested researchers and practitioners. If significant economies of scale could be demonstrated, efficiency could be improved with high-level decisions on investments, allocations, and mergers, rather than the more difficult route through process improvement and change management. Empirical research, however, has not provided conclusive answers about economies of scale in healthcare. Some studies find a positive effect between scale and performance, some others find no effect, and still some claim that economies of scale work in reverse direction.

The literature is not very specific in defining the hospital as a unit of analysis. Hospitals perform various clinical interventions with varying resource and performance profiles. There may be cross-subsidies between departments. Varying regulatory regimes may require different amounts of overhead and administration. As a hospital is a rather heterogeneous unit of analysis, it is conceivable, that even if scale–related mechanisms are present in one type of activity, the benefits may be consumed by the diseconomies of another. Moving the unit of analysis to a clinical specialty, such as cardiac surgery, and further to a patient process could provide an opportunity to examine in what ways health service production is different in a large *vs.* a small unit.

In this article we first examine the literature to find out what is known about the scale-performance connection in hospitals, and what units of analysis and metrics have been used. Second, we discuss appropriate methodologies and conclude that the context, intervention, mechanism, outcome (CIMO) model of Evaluation research is the most ap-

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propriate for the task at hand. The unit of analysis is a production line - a patient process that can deliver a solution to a medical problem within one clinical specialty. Third, we compare specific cardiac surgery production lines of a very large and a smaller hospital. Using detailed data we address the question; can effects of scale be demonstrated at the production line level? Fourth, we discuss the findings and present its implications. Finally, we make suggestions for further research.

2   Literture review

The literature examined was selected from ABI-INFORMS and JSTOR databases using the keywords "Scale OR volume AND Productivity OR Efficiency AND Healthcare OR Hospitals". This search was also supplemented by a Google Scholar search with specific keywords "Impact of scale or volume on efficiency or productivity in healthcare." Thirty-two articles were found, of which twelve were relevant for examining findings, unit of analysis used, and the definitions and measures of scale and of performance. The results from the selected papers are exhibited in Appendix 1.

The empirical findings on scale effects on hospital efficiency and productivity have been inconclusive. McCallion[1] found that larger hospitals are more scale efficient on average. Berry et al.[2] concluded from their study that hospital size is the single largest predictor of operating room productivity. To the contrary, Smet,[3] and Peltokorpi[4] concluded that smaller hospitals are more productive indicating that economies of scale work in reverse direction.

Kristensen[5] observed constant economies of scale for the medium-sized sub-groups of hospitals, and decreasing economies of scale for the largest sub-groups. Blank and Eggink[6] showed that economies of scale were present only for small hospitals while Wilson and Carey[7] found evidence of increasing returns to scale among hospitals above the median size. Scale efficient larger hospitals were found to be in the 222-358 bed range by McCallion.[1] Kristensen[5] estimated the optimal number of beds per hospital to be 275 beds per site.

Clinics focused on specific clinical pathways within a larger healthcare center may result in better service times and patient satisfaction at the expense of economies of scale.[8,9] In their study, Leleu et al.[10] found that a majority of intensive care units were operating at increasing returns to scale but at the hospital level diseconomies of scale prevailed. Langabeer and Ozcan,[11] in their study of cancer hospitals, found that despite advances in technology and higher scale, the efficiency of specialized cancer hospitals was marginal. Compared to hospitals with a wider range of service offerings, specialized hospitals did not seem to benefit from increasing returns to scale.

Literature linking scale with other measures like average length of stay (LOS) has also been inconclusive. Goodney et al.[12] found no consistent relationship between volume and mean LOS. Stock and McDermott[13] concluded that increased patient volume might be associated with higher costs possibly due to overutilization. Zhao et al.[14] found substantial scale economies in public hospitals and a clear negative log-linear association between average cost and the volume of activity. Coyne et al.[15] using data from hospitals of three bed size categories (1-50, 51-150, and 151 and above) found that hospitals in the medium size category had the lowest cost per adjusted patient day while larger hospitals had higher occupancy percentages and higher current asset turnovers. Sowden et al.[16] noted that volume's impact on surgery outcomes is not clear. Halm et al.[17] also noted in their review paper that though size may positively impact outcome, its magnitude varies widely across types of surgeries and the results may get confounded due to differences in case mix and processes across high and low volume providers.

Scale effects are often discussed by using number of beds as an independent variable and various measures of hospital performance as dependent variables.[1,3,7] However, the number of beds may not be a good indicator of scale for all healthcare services, as beds have a different role in surgery and internal medicine. Cowing et al.[18] demonstrated that analysis of scale effects on productivity suffered from confusion between long- and short-term effects. Different efficiency measures show substantial variation, such as economic efficiency, productivity, LOS, and mortality. Distribution of efficiency across hospitals in the data set also depends on the number of inputs and outputs considered.[19] Kittelsen and Forsund[20] argued that a fixed set of inputs might have increasing returns to scale when producing one output mix, and decreasing returns when producing another.

The variety of definitions and measures used explain why it has been difficult to build an empirical case for or against hospital scale economies. The unit of analysis is typically a hospital as an administrative unit. However, hospitals can be either focused or multi-variety, or specialized units within a hospital group or a hospital campus. Each process may have its own economies of scale, which cannot be captured if the entire hospital is taken as the unit of analysis.

Scale can be defined as fixed assets, such as number of beds, facilities, or staff. In some studies scale is defined as output volume, such as procedures, discharges, patient episodes, or bed days. Performance is typically defined as cost or productivity, or with clinical measures, such as mortality.

The literature provides limited insights on the role of mechanisms by which scale may have impact on the performance measures. Mechanisms are the precise means by which scale economies are exploited. They may involve technology including expensive capital equipment, increasing bargaining power with third party suppliers[7] as well as operative practices.[4]

We can conclude that the current body of literature suffers from methodological challenges and lack of clarity on the appropriate units of analysis and the possible mechanisms linking scale and performance in healthcare. Most hospitals have to operate at a scale that is determined by considerations other than efficiency. This creates a strong case to take a fresh look at the problem.

3   Methodology

The research problem (RP) can be formulated as: a large-scale surgical hospital has many production units or lines, while a small scale organization has few. Will the production units perform better in a large-scale organization (see Figure 1)?
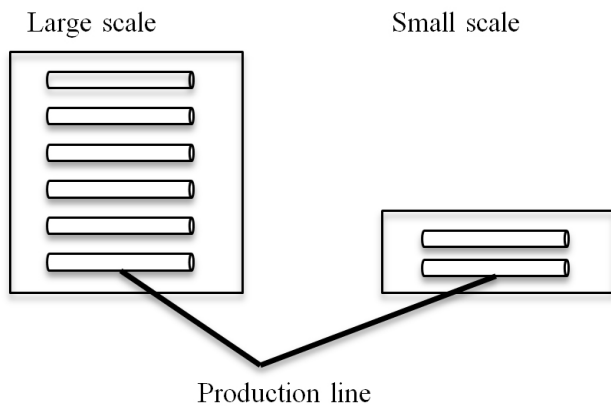

Figure 1: The research setting

To prove a causal or probabilistic connection, four conditions should be met. Take the case of smoking and lung cancer as an example. First, a correlation was discovered between smoking and lung cancer. Second, it could be shown that smoking precedes cancer. Third, a frantic search started for possible third factors that could explain both smoking and cancer independently, such as work conditions or socio-economic status. The matter was finally laid to rest when the cell-level mechanisms of carcinogenic substances could be proven.[21]

In a similar vein, the impact of scale on hospital performance has been studied looking for correlations. The literature is inconclusive. It is difficult to find empirical data to demonstrate, whether scale precedes performance, or is it the other way around. Third factors can be envisioned, such as good management or convenient location. Therefore, it is reasonable to look for mechanisms; following the methodology of Evaluation research.[22] The central formula is: context, intervention, mechanism, and outcome (CIMO).[23, 24] The CIMO–model is illustrated in Figure 2.
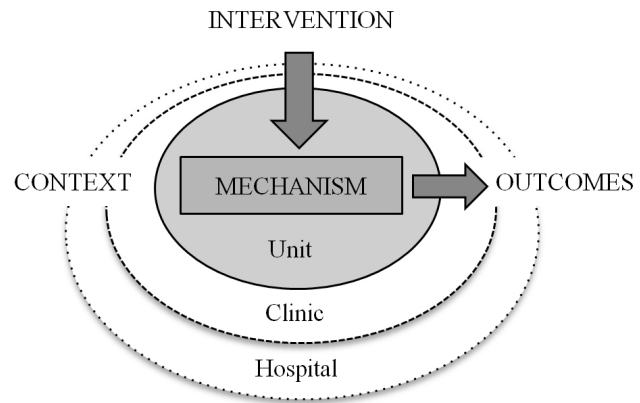

Figure 2: The CIMO-model

The context here is a hospital. As the literature review illuminates, the hospital as a unit of analysis needs to be clarified. In surgical operations, the units of analysis, from small to large, are:

- Operating theatre (OT) with a surgical team;
- A surgical unit specializing on one type of surgery and combining one or several OTs served by post-anesthetic care units (PACU), pre- and post-operative wards, and support (equipment, supplies, cleaning, *etc.*) into a production line, that can deliver a surgical care patient episode (see Figure 3);
- A surgical clinic combining different surgical units with different specialties within an multi-specialty hospital;
- A surgical hospital focusing entirely on surgical operations of various types.

For a bottom-up approach, surgical unit is the most relevant unit of analysis. It is the smallest organizational unit that can deliver a whole care episode to be used as the basis for performance measurement.

3.1   Intervention

The intervention is past decisions to invest, merge or acquire that have resulted in differences in scale. Such would be a decision to increase the number of surgical units. Scale is the independent variable. Scale should not be confused with volume. In ordinary accounting terms, scale is equal to assets, and volume is equal to sales. The sales figure alone is meaningless unless it is compared to the assets employed. The relation between scale and volume is similar to the relation between assets and sales. Scale is defined as the volume of the relevant assets, such as the number of OTs, beds, and staff.

3.2 Mechanisms

The mechanisms associated with scale are described in the Operations Management body of knowledge.[25, 26] First, the classical view is that scale allows division of labor, which enables specialization, which in turn makes possible standardization, from which follows that the amount of non-value-adding activities can be reduced. Consequently total cost and unit cost are reduced.

Second, a large-scale organization can devote more resources and knowledge to coordination and control. If some production resources are indivisible, such as OT's and diagnostic equipment, a large organization can assure a higher capacity utilization rate and reduce unit cost.
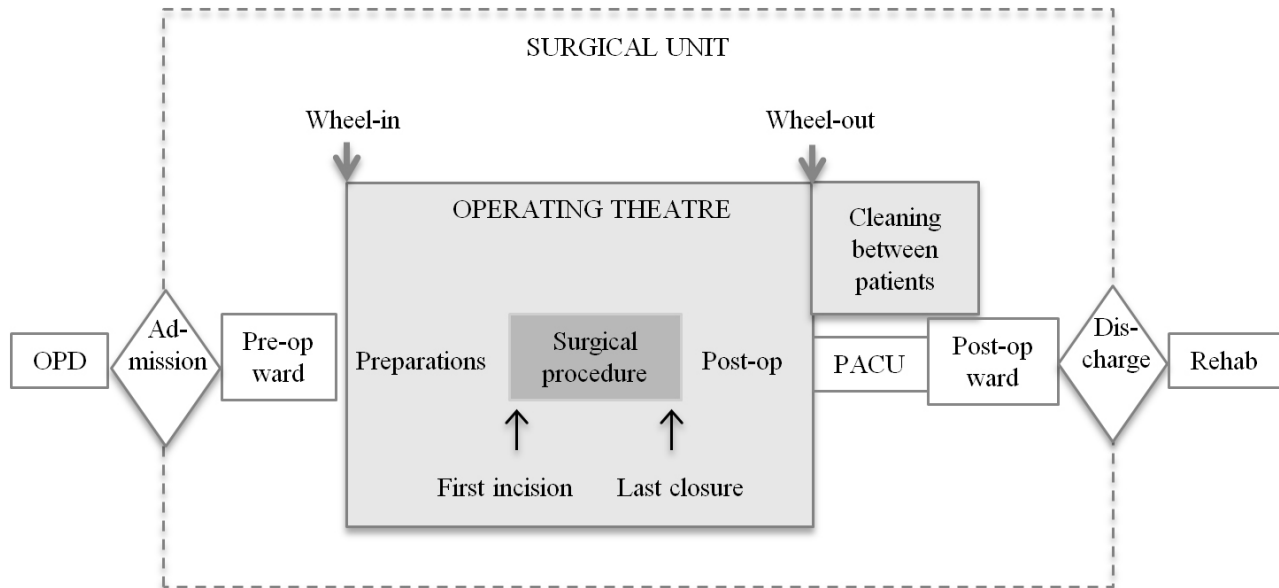

Figure 3: The cardiac surgery production line

Third, to the extent that large scale leads to large volumes, fixed costs can be spread over a larger number of units sold. The core mechanism is a reduction of the overhead burden of produced output, from which follows lower total costs and the possibility of low prices, which may further increase volume.

Fourth, in some industries scale has a technical definition. For physical reasons blast furnaces have a minimum scale defined by energy efficiency, below which cost penalties are inevitable. This is also known as the container effect, the larger a container, the less there is surface area to volume. In healthcare large hospitals can afford better, newer, or more specialized equipment than small ones, offer better career options, specialization areas, and collegial support.

Fifth, scale can mean the volume of repetition. The learning curve describes a situation where an individual becomes more proficient as the cumulative number of repetitions increase. The experience curve is essentially the same, but applies to a larger unit of analysis, such as a plant, where unit cost can be assumed to decrease at a calculable percentage as the cumulative volume doubles. The experience effect comes with improvements in processes, integration, and coordination.

Sixth, scale can increase the volume of purchases and the ensuing bargaining power over suppliers. In similar vein, a large establishment can command an important position in the regional economy and use its position to extract various benefits, i.e. become too big to fail.

Seventh, scale typically indicates the production of one product on one product line. The term scope is used to denote a situation where the volume of different, but complementary activities at one site allows sharing of infrastructure, but also promotes learning and synergies.

Finally, there is the notion of diseconomies of scale. As an organization grows, the need for coordination and control increases, hierarchies grow taller and/or the span of control gets wider. After a certain point the mechanisms of standardization, overhead, and technical issues may start to work in reverse.

Given the different contextual units of analysis from surgical unit to hospital, it can be assumed that different mechanisms work differently at different levels. For example, bargaining power over suppliers most likely works at the hospital level.

3.3 Outcomes

The outcome is performance. It can roughly be divided into economic and operational measures. Economic measures

are typically unit cost, long-range average cost (LRAC), profitability, or price-points. In international comparative studies economic measures are problematic due to different factor costs and varying exchange rates. Therefore, operational measures can be used, such as resource intensity (labor time per patient episode), throughput time, LOS, clinical quality and various satisfaction measures. Performance can be defined and measured as ratios, such as productivity: input defined as labor hours in relation to output defined as treated patients.

3.4 Research questions

Economies of scale can be said to be present only if it can be shown that on average one unit of output (one patient) can be produced (treated) with lesser resource consumption in a large facility than in a small one; assuming constant quality. Any increase in scale should be followed by a proportionally larger increase in output. The RP can be elaborated into specific research questions (RQ) for each of the above mentioned scale mechanisms. As the focus here is on production, the relevant RQ are:

RQ1: *Can comparable patients be treated with less resource intensity in a large unit than in a small one?*

RQ2: *Can comparable patients be treated with shorter throughput time in a large unit than in a small one?*

To answer the RQ, well-defined units of analysis and detailed performance data are required. As such data-sets are difficult to acquire, this study explores the questions by comparing two cases.

4 Comparative case analysis

Two case hospitals of different scale were selected to compare productivity in cardiac surgery. The large hospital (hospital 1) with 6,600 cardiac operations per year is located in South Asia; the smaller one (hospital 2), with 1,300 operations is located in North Europe. Both are highly reputed as world-class institutions. Coronary Artery Bypass Graft (CABG), the most common procedure in both hospitals, was selected as the case patient group. While the two hospitals operate in different circumstances, the argument here relies on the assumption that the CABG procedure and indications to operate are sufficiently similar to allow a rough comparison. Data was collected from hospital records and depict the situation in 2012. The case hospitals are described in Table 1.

Table 1: Description of case hospitals

Variable	Hospital 1	Hospital 2	Ratio 1 : 2
Hospital type	Private	Publicly funded	
Specialties	Multi-specialty	Multi-specialty	
Cardiac surgery organization	Fixed teams	Variable teams	
Number of Cardiac Operating Theatres	15	4	3.8 : 1
Number of Cardiac operations per year	6,600	1,300	5.1 : 1
CABG operations per year	2,400	475	5.1 : 1
Number of Cardiac Surgeons	18	11	1.6 : 1
Number of OT nurses in Cardiac OTs	141	25	5.5 : 1
Number of Cardiac Beds	373	40	9.3 : 1
Ward Nurse FTEs[*]	323	53.4	6 : 1

Note. [*] Full-time equivalent.

4.1 The production line

Cardiac surgery as a production system is illustrated in Figure 3. The patient process typically starts with diagnostics at a GP or a cardiac outpatient department (OPD). After a decision to operate, the inpatient episode starts with admission and pre-operative ward care. The process in the OT starts as the patient is wheeled in. Various preparations, such as anesthetics and attaching the patient to a heart-lung machine, are performed. The surgical procedure starts with the first incision and ends with closure. The patient is detached from OT equipment and wheeled out to a PACU for monitoring as the anesthetics wears off. Thereafter the patient is moved to post-operative ward care, and discharged when the condition allows. The surgical team for CABG typically consists of a chief surgeon, assistant surgeon, one or two anesthesi-

ologists, a perfussionist, and anesthesia and scrub nurses. In cardiac surgery the resources are not sharable between OTs; the team members need to be present in the OT during the duration of the surgery. In other types of surgery, such as orthopedics, the anesthesiologist can simultaneously serve several OTs.

4.2 Measures

Productivity is the input-output-ratio, which indicates how much resource must be spent to produce a unit of output, *i.e.* a treated patient. Inputs are labor with various skill sets (surgeons, nurses, technicians, *etc.*), supplies (disposables, consumables), and capital goods (equipment and facilities). The monetary costs of inputs vary according to factor prices and exchange rates. Therefore in cross-country comparisons, re-

source consumption in terms of labor hours, operationalized as OT-time, and LOS at ward care can be used as measures of input. When OT time, LOS and labor rates are known, the corresponding costs can be calculated. Supplies and capital goods are not included this analysis.

Performance measures are related to time measures of the various parts of the patient process (flow efficiency), and corresponding resource consumption (resource efficiency). The throughput time of both OTs and wards were measured at the patient level, which enabled analyzing the statistical significance of the differences. The number of resources and utilization rates were collected at the unit level.

The productivity measure is weighted average resource consumption per output. In surgery, output is determined by two factors: throughput time and OT utilization. The former is a matter of processes and skills while the latter is an outcome of scheduling efficiency. Input is determined by resource intensity, which is affected by Human Resource (HR) management policies and practices. The basic productivity model is illustrated in Figure 4.
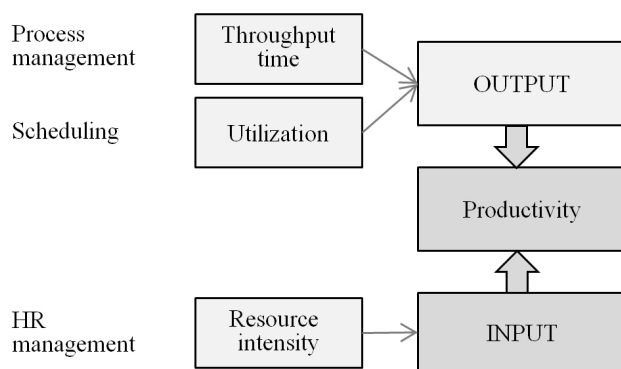

Figure 4: The basic productivity model

The productivity model enables observing the possible scale effects on productivity as well as its sub-measures. The submeasures, throughput time, utilization, and resource intensity can be linked to corresponding management methods. If scale economies are in place, larger scale should enable more efficient use of shared resources such as operating rooms, beds or nurses and therefore the utilization rates should be higher and/or resource intensity per production unit lower in the large-scale units.

In large-scale units, the teams and especially surgeons have better possibilities to concentrate on a specific subspecialty; therefore the number of repetitions can be increased. That should lead to standardization and learning curve effects which, based on literature, should lead to shortened throughput times and improved quality of operations.

4.3 The findings

As detailed in Table 2, the productivity difference measured by resource consumption per CABG inpatient episode was

13% in favor of the smaller Hospital 2. The larger Hospital 1 had a 5% better productivity in the operating unit, but in ward care 30% more resources per patient were needed. As detailed in Table 2, this was mainly due to significantly longer length-of stay. In the wards there were significant differences in the pre-operative LOS: 5.5 days in Hospital 1 and 1.1 days in Hospital 2 ($p < .01$). The effects of possible scale mechanisms did not appear in overall productivity measures.

In hospital 1 the OTs had longer opening hours (8:00 am to 8:00 pm) compared to hospital 2 (8:00 am to 4:00 pm), which enabled more surgery hours per OT.

In summary, the data shows that the larger Hospital 1 had more resources and larger scale. Using its scale, and longer operating hours, the larger hospital produced significantly higher volumes per OT and per surgeon. However, productivity, the resource consumption per CABG inpatient episode was better in the smaller hospital.

5   Discussion

The cross-case analysis shows that on the patient-level productivity measures based on resource intensity (RQ1), and throughput time (RQ2) the smaller hospital performs slightly better, even though the larger hospital with 3.8 times more OTs and 1.6 times more cardiac surgeons, and longer operating hours produce 5.1 times more CABG procedures per year.

The two compared hospitals are different not only in size and volume, but also in organization and environment. Therefore the findings do not allow generalizations. However, the results can be used to examine the assumed mechanisms associated with scale.

The larger Hospital 1 performs comparatively better on the OT-level, but worse in ward capacity utilization. This indicates that management policies and mechanisms are different for OTs and wards. The smallest differences between the two hospitals were OT resource consumption per CABG (5%), and OT turnover time (0%). Both hospitals are at the frontline on methods, technologies and practices. This supports the assumption that once the patient enters the OT, cultural and environmental differences are reduced, the clinical situation and technologies dominate to make the OT a universal production unit. Pre- and post-op ward care can be assumed to be more sensitive to the environment. The Asian hospital has a very large catchment area and patients travel from far away. It stands to reason that many patients hesitate to take a long journey only a few days after an open-heart surgery. Further, the Asian hospital caters to patients under a number of payment schemes. Many insurance packages stipulate a fixed amount of post-op ward care. Therefore the hospital has less incentive to reduce ward time, compared to the publicly financed European hospital.

Table 2: Differences in surgical productivity and submeasures

	Item	Definition	Hospital 1	Hospital 2	Difference (%)
Measure	Total resource consumption per CABG [resource hours]	*Sum of resource consumption in OT and Wards*	*216.8*	*192.5*	*13%*
	OT resource consumption per CABG [h]	*Number of OT FTEs divided by throughput time-weighted operations*	*90.5*	*95.2*	-5%
	Ward resource consumption per CABG [h]	*Number of OT FTEs divided by length of stay-weighted inpatient episodes*	*126.3*	*97.4*	30%
Submeasures	OT throughput time of CABG [h]	*Time between patient wheeled-in OT and patient out-of-OT*	6.34	5.5	15% ($p < .01$)
	OT Resource Hours per Surgery Hour	*Number of OT FTEs divided by sum of surgery hours*	*14.3*	*17.3*	-17%
	OT Surgery Hours per Operating Rooms	*Sum of OT throughput time divided by occupied OTs*	7.9	5.3	49 %
	Turnover time [h]	*Time between two patients in the OT*	0.3	0.3	0 %
	CABGs per Surgeon	*Number of CABGs divided by number of Surgeons*	367	118	210%
	Ward nurses per bed [FTE/bed]	*Sum of ward nurse FTEs divided by beds*	0.9	1.3	-31%
	Bed utilization rate	*Number of inpatient days per beds per 365*	82%	91%	-10%
	Length of Stay (LOS of CABG [d] Preoperation time out of total LOS [d]	*Time from patient admission to discharge*	15	8.3	81% ($p < .01$)
		Time from patient admission to start of operation	5.5	1.1	500% ($p < .01$)

Contradictory to expectations, the Asian hospital uses fewer ward nurses per bed than the European hospital. Cheaper wages apparently does not lead to larger consumption of labor. Since the LOS is longer, care intensity can be lower.

A large-scale facility means more volume, which enables specialization into narrow areas of expertise and offers the possibility of learning curve effects. At the larger hospital, the 18 cardiac surgeons on average per person per year performed 366 surgeries, of which 133 were CABG, while at the smaller hospital the 11 surgeons, on average per person performed 118 surgeries, of which 43 were CABGs. The surgeons at the larger hospital perform 3.1 times more procedures while their OT throughput time is 15% longer than in the smaller hospital. This indicates that the learning curve has reached a saturation point. Indeed, the learning curve is individual and can't be expected to progress forever. Thus if a group of surgeons includes juniors and seniors with varied cumulative experience, and recruitment and retirement proceed at similar paces, the aggregated effect of the learning curve should remain constant.

Further, this observation highlights the difference between volume and productivity. The Asian hospital achieves more surgeries per surgeon, which apparently reflects overall un-saturated demand and scarcity of professional resources. Doing more leads to more output, while the resource consumption per output, productivity, may remain the same.

It appears that scale effects on productivity at the OT level are not in effect, when the team size is optimal, specialization and learning curves are driven to their practical limits. The remaining question is the effect of shared infrastructure (see Figure 1). Would a large hospital be able to share support resources between production lines and thereby increase the capacity utilization of such resources?

Here the difference between the productivity frontier and the asset frontier is crucial.[27] The productivity frontier is an empirical measure of actual productivity. The asset frontier is a theoretical construct depicting the highest possible productivity given the current technologies and skillsets. The difference between the frontiers can, following the Lean production terminology[28] be called waste. If a large organization can achieve a higher level of coordination and control than a small one, reducing waste increases productivity. This is contingent on managerial action and hinges on the question, are managers at large hospitals more keen to introduce best practices in process management? If this is the case, it could explain the findings[6] that very small hospitals

with less than 200 beds typically exhibit low performance. Further, if large scale means that more can be invested in cutting-edge technologies, it is possible that a large hospital can be the first to penetrate the asset frontier.

A surgical team performs professional work with the characteristics of craft production. While a CABG is a routine process, there are variations between patients that do not allow further standardization or automation with current technologies. Such a production type can be called routine craft. Typical to it is that production lines are complete, self-containing units that perform a task from end to end. The units have an optimal staffing level; adding one more surgeon to a team would not increase output proportionally to the increased resource. Such do not share a lot of assets with other similar units. Adding production lines would increase volume but not productivity. Productivity can increase if the production lines can share resources that are not fully utilized within the unit. Such could be anesthesiologists or cleaning crews. In CABG surgery the former are fully occupied during a procedure and therefore not sharable, and the impact of the latter is most likely minor. In orthopedic surgery it is common that anesthesiologists simultaneously serve several OTs. From this follows that the mechanisms are dependent on the organization of work, especially on how various assets are utilized during production. This explains why comparing hospitals with various specialties produce inconsistent results.

This analysis lends support to the conclusion reached by researchers employing different methodologies.[29] Decisions to invest, allocate or merge, do not in a straightforward way lead to productivity gains on the patient level The mechanisms linking scale and performance depend on the organization of work and managerial action. While the conclusions must be tentative, given that they are based on only two cases with an unknown amount of possible environmental impacts and differences in policies, it never the less is significant to observe that an overwhelming advantage in scale does not result in equally overwhelming advantage in performance.

This conclusion does not exclude the possibility that scale can have other positive effects beyond the patient process level, such as bargaining power, the ability to attract talent, cross-disciplinary synergies, purchasing, and facilities management. Research to identify such effects, however, requires different approaches and data.

6 Further research

The comparative setting in this research involved two hospitals, the larger with 6,600 and the smaller with 1,300 cardiac operations per year. If the smaller hospital had been much smaller, say, with only a few hundred operations, the conclusion could have been different. 1,300 operations per year apparently is sufficient to achieve world-class performance. The questions remains, what might be the minimum efficient scale?

The choice of the unit of analysis was based on the assumption that as the CABG procedure is rather standard, differences between patients are averaged out. However, differences in case mix may have an impact on the results.[16] Therefore a more detailed, case mix–adjusted comparison would be warranted.

The case hospitals in this research were different in many other respects than scale and volume. One was public, the other private, and they functioned under different regulatory regimes and in different cultures. It can be assumed that while a world-class OT is similar in any cultural environment, patient preferences and other issues in the local environment may affect the operating policies associated with ward care and LOS. This assumption would need more scrutiny.

Finally, while a comparative case study can shed light on mechanisms, it does not yet allow generalizations. Therefore there is a need to develop mechanism-specific productivity models, and associated metrics, such as those listed in Tables 1 and 2. If such data could be collected is sufficient amount, it would be possible to develop various regression models to produce generalizable results.

Acknowledgements

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