Productivity Change of Surgeons in an Academic Year

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OBJECTIVE: The goal of this study was to calculate total factor productivity of surgeons in an academic year and to evaluate the effect of surgical trainees on their productivity.

STUDY DESIGN: We analyzed all the surgical procedures performed from April 1 through September 30, 2013 in the Teikyo University Hospital. The nonradial and nonoriented Malmquist model under the variable returns-to-scale assumptions was employed. A decision-making unit is defined as a surgeon with the highest academic rank in the surgery. Inputs were defined as the number of physicians who assisted in surgery, and the time of surgical operation from skin incision to skin closure. The output was defined as the surgical fee for each surgery. April is the beginning month of a new academic year in Japan, and we divided the study period into April to June and July to September 2013. We computed each surgeon's Malmquist index, efficiency change, and technical change.

RESULTS: We analyzed 2789 surgical procedures that were performed by 105 surgeons. The Malmquist index of all surgeons was significantly greater than 1 ($p = 0.0033$). The technical change was significantly greater than 1 ($p < 0.0001$). However, the efficiency change was not statistically significantly different from 1 ($p = 0.1817$).

CONCLUSIONS: The surgeons are less productive in the beginning months of a new academic year. The main factor of this productivity loss is considered to be surgical training. (J Surg 72:128-134. © 2014 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Malmquist index, efficiency change, technical change, surgical training

COMPETENCIES: Patient Care, Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

Operating room efficiency is an important concern in most hospitals today.[1] The most significant part of the operating room efficiency is considered to be surgical procedures because they usually occupy the longest time portion of the operating room time. When a new academic year starts, a number of new interns, residents, fellows, and attending physicians begin to work in a teaching hospital. It has been suggested that new trainees adversely affect the productivity in the operating rooms of a university hospital.[2] In fact, it is demonstrated that surgical trainees' participation in surgical procedures is associated with an increase in total operative time.[3] Although those studies may be clinically significant, they only represent partial productivity measures, which evaluate only 1 factor (input) and 1 product (output), while assuming other variables as constant. A partial productivity measure may impute productivity changes to 1 input (or 1 output) that are really attributable to some other input (or output).[4] However, there are no studies that have evaluated total factor productivity of surgeons that combines all inputs and all outputs.

The Malmquist productivity index (Malmquist index, MI) represents total factor productivity change of a decision-making unit (DMU) between 2 periods under dynamic situation and is an example of in comparative statics analysis.[4] It is based on data envelopment analysis (DEA), which evaluates relative efficiency of DMUs against the efficient frontier under static conditions in a single period. By comparing DEA results between 2 time periods, MI can divide productivity change into 2 components, one measuring efficiency change (EC) and the other measuring

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technical change (TC).[5] MI is defined as the product of EC and TC terms. The EC term relates to the degree to which a DMU improves or worsens its efficiency, whereas the TC term reflects the change in the efficient frontiers between the 2 time periods. If productivity change of a DMU is compared between period 1 and period 2, they are mathematically defined as follows[4]:

$$\begin{aligned}\text{EC} = {} & \{\text{Efficiency of a DMU in period 2} \\ & \text{with respect to period 2 frontier}\}/ \\ & \{\text{Efficiency of a DMU in period 1} \\ & \text{with respect to period 1 frontier}\}\end{aligned}$$

$$\begin{aligned}\text{TC} = {} & [\{\text{Efficiency of a DMU in period 1} \\ & \text{with respect to period 1 frontier}\}/ \\ & \{\text{Efficiency of a DMU in period 1} \\ & \text{with respect to period 2 frontier}\} \\ & \times\{\text{Efficiency of a DMU in period 2} \\ & \text{with respect to period 1 frontier}\}/ \\ & \{\text{Efficiency of a DMU in period 2} \\ & \text{with respect to period 2 frontier}\}]^{1/2}\end{aligned}$$

$$\text{MI} = \text{EC} \times \text{TC}$$

for example, we choose a 2-input, 1-output model that we will use in this study (Fig.). EC is defined as follows:

$$\text{EC} = \frac{OA/OB}{OE/OG}$$

TC is defined as follows:

$$\text{TC} = \left(\frac{OE/OG}{OF/OG} \times \frac{OC/OB}{OA/OB}\right)^{1/2} = \left(\frac{OE}{OF} \times \frac{OC}{OA}\right)^{1/2}$$

thus, combining EC with TC, we get

$$\text{MI} = \text{EC} \times \text{TC} = \left(\frac{OC/OB}{OE/OG} \times \frac{OA/OB}{OF/OG}\right)^{1/2}$$

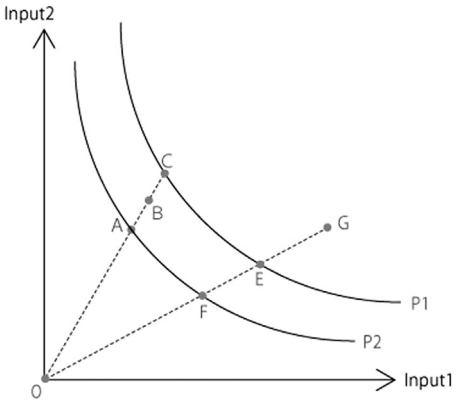

FIGURE. The Malmquist index in a 2-input, 1-output model. A DMU is in G in period 1 and moves to B in period 2. P1 indicates the efficient frontier in period 1. P2 indicates the efficient frontier in period 2.

TABLE 1. Technical Terminology for Productivity Study

Factor	The input used to produce goods and services
Input	Same as factor or resource
Product	The goods and services produced from the inputs
Output	Same as product or goods and services
Total factor productivity	Productivity that includes all the outputs produced and accounts for all of the inputs used to produce these outputs
Decision-making unit (DMU)	The entity that is regarded as responsible for converting inputs into outputs
Data envelopment analysis (DEA)	A frontier analysis method that evaluates relative efficiency of DMUs
Efficient frontier	A combination of minimum inputs that produces a certain amount of outputs, or a combination of maximum outputs that are produced from a certain amount of inputs
Nonradial, nonoriented Malmquist model	A variant of Malmquist model that takes account of all existing slacks (input excesses and output shortfalls)
Variable returns to scale	A production function that assumes that outputs increase variably when inputs increase proportionally
Comparative statics analysis	An analysis that compares 2 different economic outcomes, before and after a change

where *OA*, *OB*, *OC*, *OE*, *OF*, and *OG* are defined as the linear distances from the origin to the respective points.

There have been a number of studies that applied DEA to surgery, and they provided clinically significant results.[6-8] Although there has never been a study that applied a DEA-based MI model to surgery, it is considered appropriate to do so because MI is a nonparametric DEA model under time-dependent situations.[4] Moreover, the MIs have been used to assess productivity change in a variety of sectors, such as agriculture, airlines, banking, electric utilities, insurance companies, and public sectors.[5] Technical terminology used in efficiency and productivity study is summarized in Table 1.

The goal of this study was to compute total factor productivity of surgeons in an academic year and to evaluate the effect of surgical trainees on their productivity change.

METHODS

The Teikyo University institutional review board approved our study. Anonymity of the data was strictly maintained by de-identification by the research team.