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MEASURING THE IMPACT OF INNOVATIONS ON EFFICIENCY IN COMPLEX HOSPITAL SETTINGS

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Abstract

In this paper the authors propose an approach for measuring the impact of innovations on hospital efficiency. The suggested methodology can be applied to any type of innovation, including technology-based innovations, as well as consumer-focused and business model innovations. The authors apply the proposed approach to measure the impact of transcanalicular diode laser-assisted dacryocystorhinostomy (DCR), i.e. an innovation introduced in the surgical procedure for treating a tear duct blockage, on the efficiency of general hospitals in Slovenia. They demonstrate that the impact of an innovation on hospital efficiency depends not only on the features of the studied innovation but also on the characteristics of hospitals adopting the innovation and their external environment represented by a set of comparable hospitals.

Keywords: *healthcare, innovation, hospital processes, hospital efficiency, production-possibility frontier, Data Envelopment Analysis*

JEL: *I10, O30*

INTRODUCTION

This paper addresses the issues of adequately identifying the impacts of innovations in complex hospital settings and discusses how the impact of innovations on hospital efficiency should be measured. As shown by Vasileiou, Barnett and Young (2012) through interviews with 18 key informants in the United Kingdom who had won Health Service Journal awards for successfully implementing 15 service innovations, evidence of efficiency is one of the four concepts of evidence employed by health care innovators in pursuing service innovations and in demonstrating their success. In measuring the impact of innovations on hospital efficiency, technology-based innovations are those most commonly considered. However, there is increasing focus also on other types of innovations in health care, including consumer-focused innovation and business model innovation (Herzlinger 2006). The methodology proposed in this paper can be applied to any type of innovation.

The impacts of different types of innovations have been extensively studied in health care and existing empirical studies investigating the relationship between innovations and efficiency vary significantly in

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their key research questions. Kazley and Ozcan (2009), for example, employ DEA to study how the use of electronic medical records impacted the efficiency of US acute hospitals. Lee and Menon (2000) similarly investigate the relationship between efficiency and investments in IT and find that hospitals investing more in IT are technically more efficient. Ozcan, Watts, Harris and Wogen (1998) analyze technical efficiency and provider experience in the treatment of stroke patients. They show that inefficient providers can lower their costs if they improve their processes according to the practices of more efficient providers. Nickel and Schmidt (2009) conducted a case study in a German university hospital to study how organizational changes and process reengineering impact capacity utilization and waiting times in its radiology department. Leu and Huang (2011) similarly demonstrate how modelling, reengineering and the informatization of processes can lower, for example, the hospital's bed occupancy rate, the number of working hours of the nursing staff and the share of patients with unplanned hospital admission within 72 hours of discharge. Tsiachristas, Notenboom, Goudriaan and Groot (2009) develop case studies that confirm innovations play an important role in increasing labour productivity in health care. De Castro Lobo, Ozcan, da Silva, Estellita Lins and Fiszman (2010) also examine hospital efficiency and productivity but adopt a Malmquist approach to study how they are affected by innovation in the form of a financing reform. The relationship between changes in payment systems and efficiency were also examined by DesHarnais, Hogan, McMahon and Fleming (1991). Very often longitudinal data is also used for constructing Malmquist indices that can be used to identify shifts in the production possibility frontier of the studied health care providers that are usually attributed to innovation adoption (for detailed reviews see Jacobs, Smith, and Street 2006; Fried, Knox Lovell, and Schmidt 2008; Hollingsworth 2003; Hollingsworth and Peacock 2008).

Studies addressing the issue of efficiency in health care in Slovenia include, for example, the comparative study of the costs of selected groups of diagnoses in selected hospitals in Slovenia (Setnikar-Cenkar and Seljak, 2004). A recent study by Lichtenberg (2015) investigates the impact of pharmaceutical innovation on mortality and hospitalisation in Slovenia. According to this study, new chemical entities launched in Slovenia during 2003-2009 have reduced the number of hospital discharges in 2010 by 7 percent.

The authors of this paper propose a different approach to studying innovations as factors of efficiency. They extend the analysis of process-level effects of innovations to their hospital-level efficiency effects. In doing so, they build on two important notions.

First, every innovation initially impacts specific hospital processes. Every innovation affects some hospital processes directly by, for example, altering their flow and/or structure and may also indirectly affect the input-output ratios of other unaltered processes simply because available capacities and the hospital's organizational structure determine the relationships between various hospital processes. Because hospitals as process organizations are in essence a set of various processes, this implies that every innovation impacts hospital efficiency both directly and indirectly, and that it is crucial we capture overall effects to correctly assess the innovation's impact on hospital level efficiency. The authors show that this is particularly challenging, because internal characteristics and especially the existing inefficiencies of the innovation-adopting hospital can significantly influence both the type and the magnitude of the process-level effects of the innovation being studied.

Second, by definition a successful innovation adopted by an organization sets a new benchmark for other comparable organizations. This has important implications for assessing the impacts of innovations on hospital-level efficiency because it can only be measured relatively to other hospitals. In such a setting a specific innovation alters benchmarks only if it indeed translates into technological progress that is reflected in shifts of the production possibility frontier and the reduced technical efficiency of hospitals that lag behind in adopting the innovation in question. In this context, a change adopted by a specific hospital is considered an innovation if it creates technological progress, while other changes that affect the studied hospital but are not novel to other observed hospitals need to be treated differently. This is why in designing their approach the authors pay special attention to separating the effects of a studied innovation from the catch-up effects that may arise in hospitals due to the increased technical efficiency of existing techniques. If the innovation is to shift the production possibility frontier, its impacts have to be observed in an innovation-adopting hospital that comprises the production-possibility frontier. Such hospitals are by definition technically efficient. This implies that the impacts of innovations on hospital efficiency have to be investigated in technically efficient hospitals.

The authors use the proposed approach to measure the impact of transcanalicular diode laser-assisted dacryocystorhinostomy (DCR), i.e. an innovation introduced in the surgical procedure for treating a tear duct blockage, on the efficiency of general hospitals in Slovenia. Even though the studied case innovation is an example of technology-based innovation, this methodology can be applied to any type of innovation, such as consumer-focused and business model innovations, according to Herzlinger (2006).

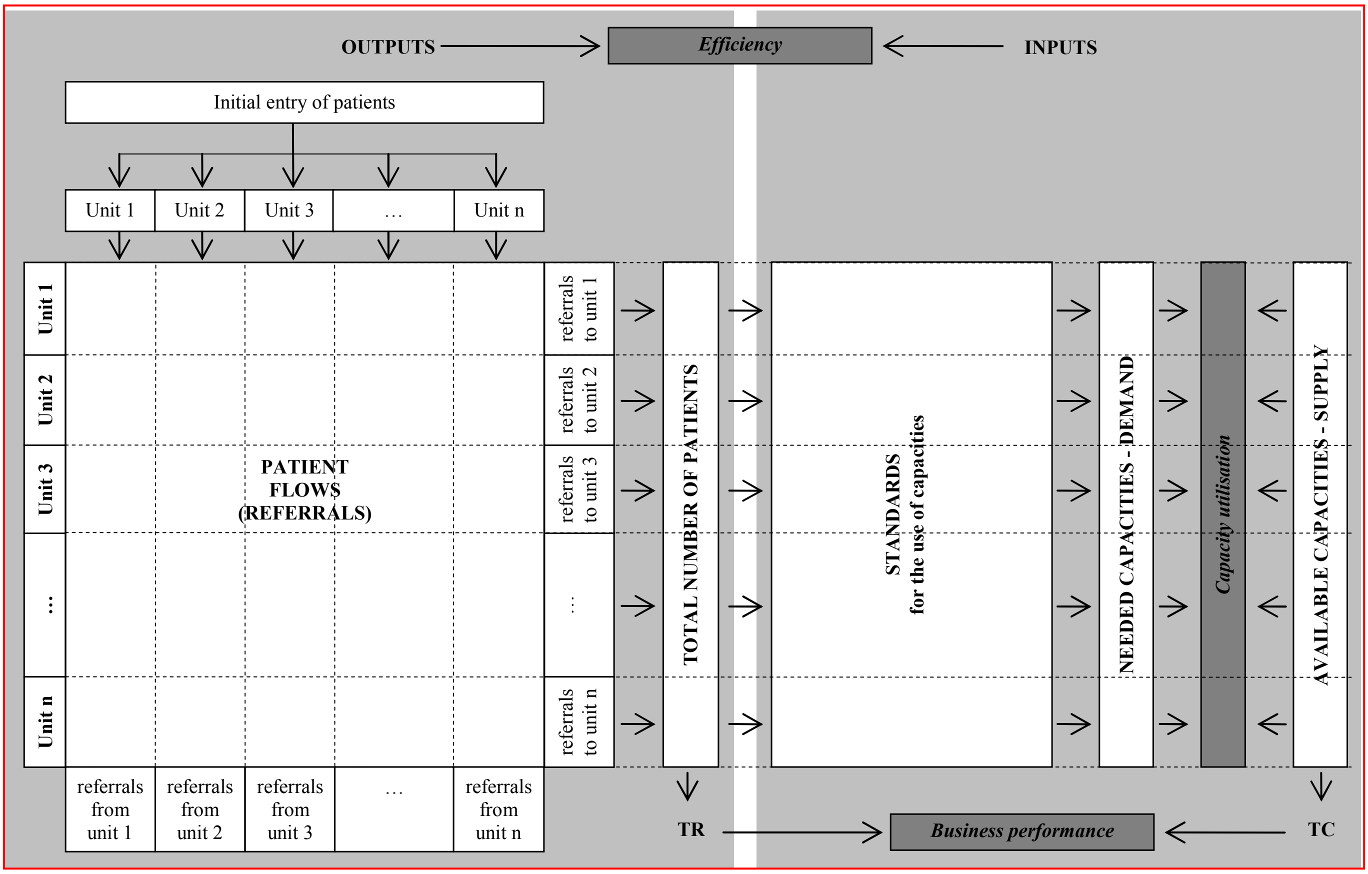
1 *PROCESS-LEVEL IMPACTS OF INNOVATIONS IN COMPLEX PROCESS ORGANIZATIONS*

Both the direct and indirect effects of innovations can be observed in a studied hospital. We may often find that a specific hospital process is altered by the studied innovation, and as a result the ratio of output to inputs of such a process increases. However, by observing also the innovation's indirect effects, i.e. the changes it provokes in other hospital processes, one might reveal the worsening of outputs-to-inputs ratios in other processes and consequently also on the level of the hospital as a whole. The impacts of a specific innovation must thus be observed not only at the level of individual processes, but also at the level of the individual organizational units of the innovation-adopting hospital so that its overall impact can be correctly identified and measured on the level of the hospital as a whole.

The process-level effects of the studied innovation can be translated into hospital level effects by using a model of the innovation-adopting hospital that represents it as a process organization (Ould 1995; Harmon 2007; Poulymenopoulou et al. 2003; Anyanwu et al. 2003; Lenz and Reichert 2007). In such a model, on the one hand, the structure and flow of individual core business processes form links between organizational units, while on the other, the available capacities and other resources of individual organizational units create a dependency between various core businesses. Figure 1 illustrates a simplified example of such a model of a hospital.

By controlling for both types of dependencies, the overall effects of an innovation can be determined on the level of individual processes, as well as on the level of individual organizational units and in the aggregate for the entire hospital. In identifying all direct and indirect innovation effects the authors pay special attention to the fact that the model of a hospital has to be designed so that it can measure the effects of innovations in terms of input and output categories that can then be used for estimating hospital efficiency. Input and output variables have to be designed to accommodate heterogeneous hospital inputs and outputs (O'Neill, Rauner, Heidenberger and Kraus 2008). In this way, the process-level direct and indirect effects of a specific innovation can be translated into hospital-level efficiency effects.

Figure 1: The model of a hospital



2 HOSPITAL-LEVEL EFFICIENCY IMPACTS OF INNOVATIONS

To assess the impacts of a studied innovation on hospital efficiency the authors include data envelopment analysis (DEA) in the proposed methodology. DEA has been widely used to assess hospital efficiency (Liu et al. 2013; Bouland et al. 2012). Even though other methods could also be used for the purpose of efficiency analysis (see, for example, Wagstaff 1989; Hollingsworth and Peacock 2008; Jacobs et al. 2006) DEA is employed in this paper because of the small size of Slovenia's public sector (Obadić and Aristovnik 2011; Zorić, Hrovatin and Scarsi, 2009).

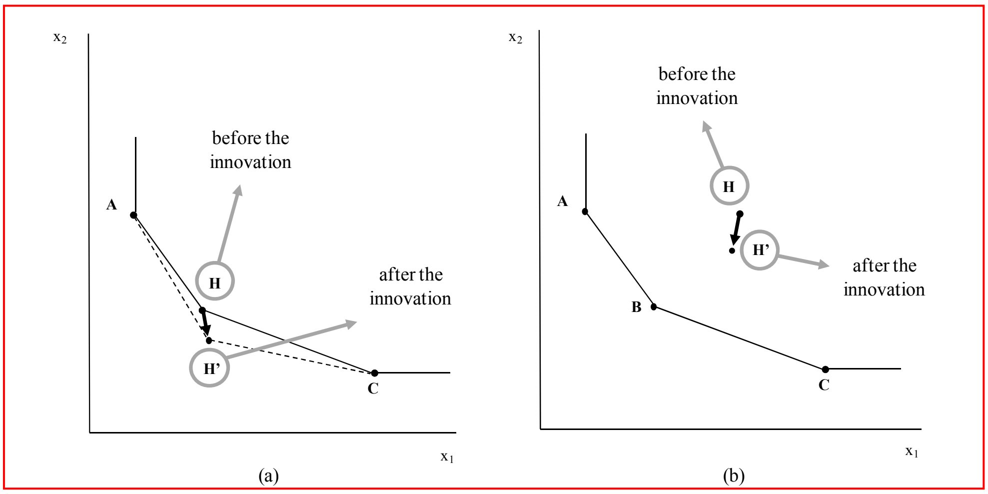
By using DEA the effects of a specific innovation on hospital efficiency can be measured by calculating the difference between the DEA efficiency scores that characterize the studied hospitals before the innovation was implemented by the innovation-adopting hospital and the DEA efficiency scores of the observed hospitals after the innovation was implemented by the innovation-adopting hospital.

For the purposes of this paper, however, the use of DEA is extended so that a theoretically consistent environment for identifying innovation effects is created. Namely, in studying innovations as factors of efficiency the authors build on the notion that innovations are new techniques or better solutions that organizations can apply to meet new requirements. As such, true innovations should translate into technological progress. In assessments of efficiency and productivity changes over time the latter is reflected in a desired shift of the production possibility frontier. This implies that the authors do not treat all changes hospitals adopt to increase their ratio of outputs to inputs, i.e. technical efficiency, as innovations. A novelty is treated as an innovation only if it represents a better solution for the whole set of studied hospitals. As such it has to be reflected in a shift of the production possibility frontier so that it can be clearly differentiated from the catch-up effect of inefficient hospitals (Zhu 2003, p. 279). Only in such a setting can benchmarking methods such as DEA set new targets and identify a reduction in the technical efficiency of those hospitals that lag behind in adopting the studied innovation.

2.1 Determining the Efficiency Impacts of Innovations in Inefficient Innovation-Adopting Hospitals

In observing and measuring the impact of innovations on hospital efficiency, one has to consider that the innovation-adopting hospital can be either an efficient or an inefficient hospital. In the first case, the innovation-adopting hospital comprises the production possibility frontier. In such a technically efficient hospital, a successful innovation will automatically be reflected in the shift of the observed production possibility frontier, thereby signifying technological progress for other hospitals and altering their benchmark. Figure 2a illustrates using an isoquant diagram for a single output-two inputs (x_1 and x_2) case that an innovation-adopting hospital H comprises a set of efficient hospitals (A, H and C). Because hospital H defines the production possibility frontier, any successful innovation that this hospital adopts automatically alters the frontier and shifts it closer to the origin. It is also possible that this hospital adopts a new technique that fails to improve its position and may even exclude the hospital from the set of efficient hospitals. Such an adopted novelty cannot be considered a successful innovation. This discussion raises an important issue of measuring output in health care organizations and the need to control for undesirable output in the form

Figure 2: The role of the efficiency status of innovation-adopting hospitals in observing the impact of innovations



of bad quality (Prior 2006).

If the innovation-adopting hospital exhibits inefficiency, meaning that it does not shape the production possibility frontier, the studied innovation will not necessarily translate into a shift of the production possibility frontier. In this case, as Figure 2b shows, the analysis of the innovation's impact on hospital efficiency may fail to interpret the studied innovation as technological progress and may thus set the benchmarks for other hospitals incorrectly. The inefficiency of the hospital in question measured by benchmarking methods such as DEA would decrease due to the innovation, but the innovation would not impact the measured efficiency levels of other comparable non-innovating hospitals. This is a direct consequence of an unaltered production possibility frontier that also implies unchanged benchmarks for the studied set of hospitals. As a result, there is no clear indication of what a specific innovation means for other non-innovating hospitals.

Another less obvious problem of studying the impacts of the studied innovation in an inefficient innovation-adopting hospital is that the innovation's process-level effects that depend on the structure and flow of business processes and the structure and distribution of capacities among hospital units may be influenced by existing inefficiencies. This is shown, for example, by Jakovljević et al. (2013), who show variability in the use of expensive high-tech services due to differences in the level of adherence to guidelines for the application of radiological methods in clinical practice. As a result of such existing inefficiencies, the measured effects of innovations can be influenced substantially by the characteristics of the innovation-adopting hospital.

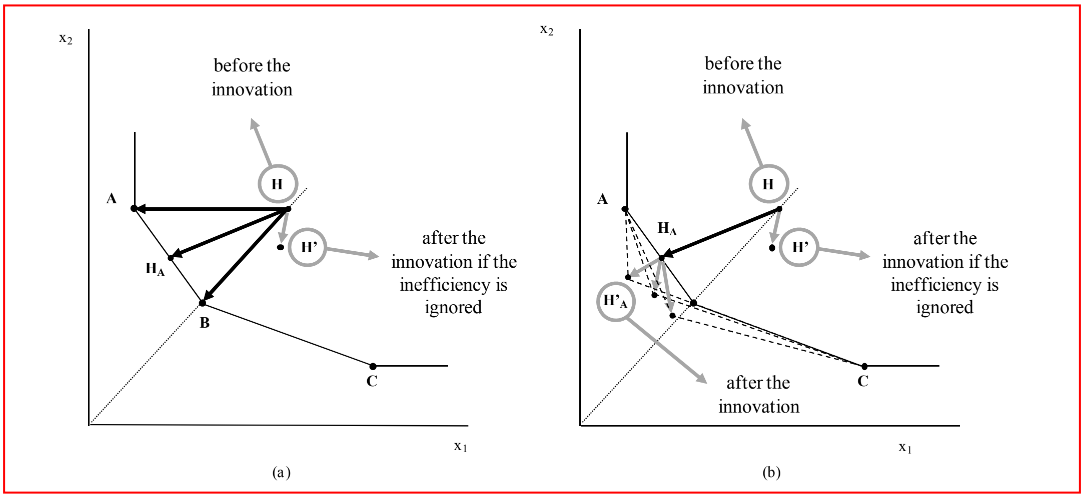
2.2 The Artificial Innovation-Adopting Hospital

If the innovation-adopting hospital proves to be inefficient, the authors suggest that the hospital be moved onto the frontier through the process of constructing an artificial hospital. In this way, the innovation-adopting hospital becomes efficient for the purpose of measuring the impact of a specific innovation on hospital efficiency.

An inefficient hospital can be moved onto the frontier in many different ways. One alternative refers to a proportional decrease of employed inputs, while other alternatives involve various disproportional reductions of employed inputs. These alternatives reflect the aggregate effects of the possible approaches an inefficient hospital could undertake to reengineer its processes. Figure 3a illustrates that the selected reengineering could move the inefficient innovation-adopting hospital H to, for example, points A, B or H_A. By moving the inefficient innovation-adopting hospital onto the frontier we construct an artificial hospital that eliminates the inefficiencies that characterize some of the innovation-adopting hospital's business processes.

By constructing the artificial hospital, the aggregate quantity of outputs and inputs of the innovation-adopting hospital are altered. Yet this move involves changes within the hospital on the level of its processes. A proportional decrease of the aggregate quantities of the hospital's inputs may be achieved with disproportional changes of inputs and outputs on the level of individual organizational units. Moreover, different input and output changes on the level of organizational units may result in the same aggregate changes on the level of the hospital. This implies, for example, that point H_A in Figure 3a does not depict a single artificial hospital. It can represent different

Figure 3: An artificial hospital as a tool for measuring the impact of innovations on hospital efficiency



artificial hospitals with the same aggregate quantities of inputs and outputs but with differing internal characteristics, i.e. differing structures, flows and features of business processes.

This means that the process of constructing an artificial hospital can create very different environments for measuring the impact of innovations on efficiency. In such environments the effects of innovations translate into shifts of the production possibility frontier. However, as Figure 3b illustrates, the shifts depend on the internal characteristics of the constructed artificial hospital. This implies that the same innovation may yield differing effects on hospital efficiency. This is due to the fact that its process-level effects depend strongly on the structure and flow of business processes and the structure and distribution of capacities within the hospital that are determined by the proposed or assumed form of reengineering. Regardless of the selected reengineering, a true innovation, if observed in the artificial hospital, alters the production possibility frontier. This may not be the case if the innovation is observed in the actual inefficient innovation-adopting hospital.

The construction of the artificial hospital thus enables us to measure the impact of innovations in a theoretically consistent way where a successful innovation shifts the production possibility frontier in line with the technological progress achieved. It also ensures that in the case of an inefficient innovation-adopting hospital the impacts of the studied innovation are not confounded with the hospital's catching up effect due to the increased efficiency of its existing techniques. Furthermore, the process-level effects of innovations are not mismeasured due to the innovation-adopting hospital's inefficiency. Yet the measured effects then depend not only on the characteristics of the innovation-adopting hospital and its external environment represented by a set of comparable hospitals in differing national health care systems (Jakovljević 2012), but also on the process of constructing the artificial hospital.

3 THE CASE INNOVATION: TRANSCANALICULAR DIODE LASER-ASSISTED DACRYOCYSTORHINOSTOMY

The authors apply the proposed approach to assess the hospital-level efficiency effects of an innovation introduced in the surgical procedure for treating a tear duct blockage in one hospital in Slovenia (Drnovšek-Olup et al. 2004; Drnovšek-Olup, Beltram, 2010; Olver 2002, pp. 115-126). They start their analysis by employing DEA to identify the production possibility frontier of general hospitals in Slovenia and to assess the efficiency status of the innovation-adopting hospital. For this purpose, they specify several input-oriented constant-returns-to scale (CRS) DEA models (Charnes et al. 1978; Zhu 2003) and employ pooled data on the inputs, outputs and input prices of 12 general hospitals in Slovenia for the period of 2005–2008. The studied hospitals represent the total population of general hospitals in the country.

Even though the authors examine different model specifications to check the consistency of the obtained results, only one specification can be used in the later stages of the analysis. Namely, the selected specification must include categories that are used to model those processes that are altered by the innovation in question and comprise the elements of the model of the innovation-adopting hospital that is used to translate the process-level effects of the case innovation to hospital-level effects.

In this paper, the number of inpatients and number of outpatients are used as outputs, while labour measured by the number of full-time equivalents (FTEs) and capital measured with the discounted cost value of property, plant and equipment represent the employed inputs. The price of labour is calculated as the ratio of real annual labour costs and the average number of FTEs. The price of capital is calculated as the ratio of the sum of depreciation cost and cost of financing on one hand, and the cost value of property, plant and equipment on the other. The selected output variables may not reflect output heterogeneity, but they are used in this paper because of the way the model of the innovation-adopting hospital was constructed. Both the model of the hospital and DEA analysis can of course be refined given available data. In this paper they are only used to illustrate the proposed methodology for assessing the impacts of innovations on hospital-level efficiency.

DEA applied in this paper reveals that the innovation-adopting hospital is both technically- and cost-inefficient. The radial measure of its technical efficiency equals 0.9821, and the radial measure of its cost efficiency is 0.9531.

3.1 Constructing an Artificial Hospital

Because the studied innovation-adopting hospital is both technically- and cost-inefficient, it was necessary to construct an artificial hospital that is an efficient twin of the inefficient innovation-adopting hospital. First, we need to identify the target aggregate values of the outputs and inputs that would render the innovation-adopting hospital efficient by moving it onto the production possibility frontier. Second, we need to identify which changes need to be implemented at the level of hospital processes and units so that the aggregate target values of inputs and outputs can indeed be attained. This second step first involves a clear identification of various hospital processes that are used to develop a model of the innovation-adopting hospital, which is illustrated in Figure 1, and then altering the model's elements so that the hospital's inefficiency is eliminated.

The authors have developed and quantified such a model for an innovation-adopting hospital by using data regularly collected and reported by the studied hospital and by collecting data on site by observing hospital operations and interviewing hospital staff over a period of a year and a half. The model is not shown here because of the large data set, but as illustrated by Figure 1, it allows us to identify capacity utilization rates for every organizational unit of the studied hospital. For the purpose of illustrating the proposed methodology for measuring the impact of innovations on hospital efficiency the authors used the results of the capacity utilization analysis at the level of individual organizational units of the studied innovation-adopting hospital. By altering utilization rates and eliminating large differences in utilization rates between various organizational units they achieved a reduction in the quantity of inputs, which allowed the hospital to move onto the production-possibility frontier. As previously mentioned, this is not the only possible approach to transform an inefficient hospital towards efficiency. In the studied case, however, this seemed most reasonable because of a generally low capacity utilization rate, as well as the large differences in capacity utilization between different organizational units.

The alterations described above enabled the authors to construct from an inefficient innovation-adopting hospital an efficient artificial hospital whose aggregate values of inputs and outputs equal the target values of the inputs and outputs of the innovation-adopting hospital.

3.2 Impacts of the Case Innovation

The process level effects of the studied innovation were identified by developing the "as was" and "as is" process models and comparing their structures, flows and the relating consumptions of hospital resources per patient treated. Process modelling revealed that process-level direct and indirect effects of the case innovation studied in this paper include alterations in the structure and length of DCR surgery, a shortening of how long patients stay in the ophthalmology department, and an increase in the number of patients referred to the department of otolaryngology for additional tests. The studied innovation also created changes in the type of equipment used to deliver the surgery and length of equipment use. The studied innovation correspondingly altered the prices of inputs employed during surgery.

The identified direct and indirect process-level effects of the studied innovation were translated to hospital-level input and output effects by using the elements of the model of the artificial hospital. In this paper the case innovation does not alter the studied hospital's output, as it is determined by a contract with the provider of compulsory health insurance. The studied innovation does, however, reduce the required inputs. If the model of the hospital is refined given available data on output quality, both input and output changes could possibly be observed for the studied innovation.

By using the model of the artificial hospital we find that the case innovation decreases the aggregate quantity of the human capacities of the studied hospital by 0.25 full-time equivalents and the total value of its material capacities by €18,932, leaving the output level unaltered. This relatively small decrease results from the fact that only 0.1 percent of patients of the ophthalmology department of the analyzed hospital are candidates for DCR. This illustrates that the impact of innovations on hospital efficiency depends on the hospital setting.

3.3 Measuring the Impact of the Case Innovation on Hospital Efficiency

By using the methodology described above, the impact of case innovation on efficiency cannot be assessed by comparing the efficiency measure of the artificial hospital prior to innovation to its efficiency measure after the innovation is adopted. This is because the artificial hospital was constructed to represent an efficient twin of the innovation-adopting hospital and its technical efficiency measures equal 1 both prior to and after implementing the innovation in question. Even though the innovation does not alter the efficiency measures of the artificial hospital, it does shift the production possibility frontier. Consequently, the innovation's impact is reflected in the efficiency measures of other non-innovating hospitals. This means that the impact of a specific innovation on hospital efficiency can be measured by identifying changes in the average efficiency of the observed set of hospitals.

The innovation's impact on efficiency is thus measured by observing the change in the average technical efficiency of the studied hospitals and the change in the average cost efficiency of those hospitals. The results show that the case innovation decreases statistically significantly both average technical and average cost efficiency (Tables 1-2). The results regarding technical efficiency demonstrate that the case innovation has indeed shifted the production possibility frontier towards increased efficiency, meaning that the case innovation can be considered a successful innovation.

In this paper the authors suggest determining the impact of the case innovation on hospital efficiency by comparing the average DEA hospital efficiency scores characteristic of Slovenian general hospitals before the selected innovation was implemented by the artificial hospital and the average DEA hospital efficiency scores after the innovation was implemented. However, other approaches could be used to measure the impact of the case innovation on the production possibility frontier.

One alternative involves observing the impact of the innovation on hospital efficiency by identifying the change in the super efficiency measure of the innovation-adopting hospital prior to and after implementing the innovation (Andersen and Petersen 1993; Zhu 2003, p. 198). Other alternatives include observing the change in the influence measures of the innovation-adopting hospital (Pastor et al. 1999) and identifying the changes in the stability region of the innovation-adopting hospital (Zhu 2003, pp. 237-239). Although the results of these other approaches are not reported here, they all confirm that the case innovation has indeed shifted the production possibility frontier towards increased efficiency.

4. CONCLUSIONS

The proposed methodology for measuring the impact of innovations on hospital efficiency provides two important conclusions for studying the impact of innovations.

First, even though the assessment of efficiency involves the use of fairly standard methods and techniques, one has to think carefully about the efficiency measurement process when the goal is to measure the impact of innovations on efficiency. By definition, a successful innovation represents technological progress. Accordingly, its effects cannot be reflected solely by the improved efficiency status of the innovation-adopting hospital. Its effects have to be translated into a shift of the production possibility frontier so that the innovation truly and in a correct way impacts the efficiency status of all non-innovating hospitals. Only in such circumstances does it make sense to measure the impact of a specific innovation on hospital efficiency by identifying changes in the average efficiency of the observed set of hospitals.

Second, analyzing innovations in relation to efficiency requires that we do not observe the impacts of a specific innovation by isolating the innovation in question from its hospital internal and environment, where the latter is represented by a set of comparable hospitals. Namely, one must keep in mind that innovations create both direct and indirect effects and that both types of effects can be observed both at the level of processes and at the level of organizational units, and thus the hospital as a whole. Further, isolating the innovation in question from its hospital environment is made impossible by the fact that the efficiency of a specific hospital can only be measured relative to the efficiency of other comparable hospitals. This

Table 1: Comparison of technical and cost efficiency scores prior to and after implementation of the case innovation

	TECHNICAL EFFICIENCY (TE)		COST EFFICIENCY (CE)	
	before the innovation	after the innovation	before the innovation	after the innovation
	$A\theta_0$	$A\theta_1$	$B\theta_0$	$B\theta_1$
Average	0.8740	0.8733	0.8605	0.8597
Std. dev.	0.1006	0.1005	0.0997	0.0996
Min	0.6033	0.6030	0.5969	0.5963
No. of efficient DMUs	3	2	2	1

Table 2: The Wilcoxon signed-rank test – a comparison of average technical efficiency scores

	Comparison of TE and CE measures before and after the innovation	
	$A\theta_1$ and $A\theta_0$	$B\theta_1$ and $B\theta_0$
Z statistic	-5.907	-6.030
P-value (two sided test)	0.000	0.000

again demonstrates that the impacts of innovations on hospital efficiency are conditional on the hospital's internal characteristics and competitive environment. This is why the impact of a specific innovation differs across hospitals adopting the innovation, and that the adoption of a particular innovation that is reasonable for some hospitals may not create the desired effects for certain other hospitals. For example, capital-intensive innovation may significantly increase efficiency in certain environments, whereas the same innovation could also lead to reduced efficiency in other environments. One might easily imagine an innovation that improves technical efficiency but reduces cost efficiency due to a big rise in input prices.

The impacts of a specific innovation might thus, for instance, be significant in developed health care systems, while in another less developed health care system its impact could be minor. It is important to again to note that the direct and indirect process- and unit-level impacts of a specific innovation depend on the characteristics of the innovation-adopting hospital. This implies that we will obtain different impacts from a specific innovation if we observe them in two different efficient innovation-adopting hospitals. Regardless of these limitations, the methodology proposed in this paper does allow us to investigate the impacts of specific innovations in specific environments on efficiency. This provides managers with the information they need about whether the innovation in question actually improves the efficiency of their hospital.

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