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INNOVATIONS AND ITS IMPACT ON THE PERFORMANCE OF ACUTE CARE HOSPITALS IN GERMANY – AN INVESTIGATION CONTAINING EMPIRICAL RESEARCH AND SOFTWARE DEVELOPMENT

ABSTRACT. *Objectives*: Innovations are the basis for economic progress and development in every society. Nevertheless, not many scientific studies exist about the influence of innovations on the hospital performance in the German health care sector. The purpose of this paper is to evaluate the impact of innovations on the performance of acute care hospitals in Germany. Based on this scientific foundation a software programme shall be developed to give hospitals, researchers, consultancies and other stakeholders the possibility to evaluate their innovative activity, to benchmark their hospitals against their peer group and to give individualized suggestions for improving the performance. The software programme is to be developed in cooperation with the software start-up company BinDoc as a web-based tool. Accordingly, this paper follows an approach of combining scientific work with practical software application.
Methods: The paper offers a short literature review of the influence of innovations on the performance of hospitals and demonstrates the relevance of software applications in health care business. In addition an introduction to data base development and web-based software is provided. Thereafter, key figures for measuring the influence of innovations on the performance of hospitals are evaluated. For the empirical part a sample of 30 acute care hospitals was analysed. For each hospital of the sample a number of approx. 240 variables was gathered to create a sufficiently sized database for the investigation.
Results: Hospitals in private ownership show a significantly higher performance in the financial key figures as well as a higher performance in patient satisfaction than hospitals in public ownership. On the other hand there is a slightly higher performance in the innovative key figures among public hospitals, however most of them not at statistically significant level. Some significant correlations between innovations and performance were identified, but not all indicators suggest that the performance is positively influenced by innovations.

Conclusion: The results of the investigation can be interpreted as follows: Due to some significant correlations between innovations and financial and quality performance it is not possible to provide a clear statement about the impact of innovations on the performance of acute care hospitals so far. Because of this further research is needed to validate the findings and expand the investigation. Follow-up research should also investigate whether there are enough incentives for hospitals to be innovative or whether regulation has to be changed.

JEL Classification: M21, I11, L86, C88

Keywords: Hospitals, Innovations, Performance, Software development, Germany.

Introduction

Innovations are the basis for economic progress and development in every society. Nevertheless, not many scientific studies exist about the influence of innovations on the hospital performance in the German health care sector. Several studies put hospital efficiency in the focus without investigating correlations and causation to the innovative activity. This paper takes a relational and causal research approach (Trochim, 2006) with the research question weather innovations has an impact on the performance of acute care hospitals in Germany. Therefore a post-positivist approach of research philosophy is adopted. The post-positivism thinking is characterized by a critical realism. However, in contrast to the naive realism of the positivism approach, the post-positivists accept that not everything "real" is readily perceivable for humans (Skinner, Tagg, Holloway, 2004, p. 389). For this kind of research the post-positivism is a coherence approach to consider both statistical hard facts with quantitative research methods and soft facts.

Furthermore, a software application has been developed to offer practitioners the possibility of analysing their own hospital, comparing it to their peer group and to support them in finding appropriate strategies for improving the performance of their hospitals. The objective is to combine scientific research with practical software development in order to generate a platform, which can be used by scientists as well as practitioners.

1. Literature Review

Only a few studies and scientific works exist in the field of innovations in hospitals and the influence thereof on the performance of hospitals in Germany. There are several studies that deal with the performance of hospitals (Röhmel, 2009, p. 94). Many of them use frontier analysis such as data envelopment analysis (DEA) or stochastic frontier analysis (SFA) as the main tool for assessing efficiency (Nunamaker, 1983; Hollingsworth, 2003, p. 204).

The importance of innovations for companies and for social development was impressively characterized by Joseph A. Schumpeter an Austrian economist. Schumpeter defines innovation simply as the existence of a new production function which leads to the creation of new products as well as the development of new markets (Schumpeter, 1939, p. 95). He characterizes the appearance of innovations as a process of creative destruction (Schumpeter, 1942, p. 143). Taking up the theory of Schumpeter Fueglistaller *et al*. define the creative destruction "…as a simultaneous process of appearing and disappearing of technology, products and companies on the market as a result of innovation" (Fueglistaller *et al.*, 2008, p. 1). In business administration innovation is characterized as targeted planning and organization to control the process of researching and developing new products. According to Schneck the

power of innovation is defined as the ratio between the revenue generated from new products, equipment or services and the overall revenue (Schneck, 2005, p. 504).

Von Bandemer *et al.* argue that innovations in the German health care market is needed for increased productivity, new products and services, to develop the field of prevention, for internationalization strategy and, last but not least, to create attractive jobs (von Bandemer *et al.*, 2014, p. 276 f). Research conducted by Basu *et al.* in 2012 (*Figure 1*) shows that the German health care market is very slow at adapting innovation in comparison to the United States and other European countries (Basu, 2012, p. 486).

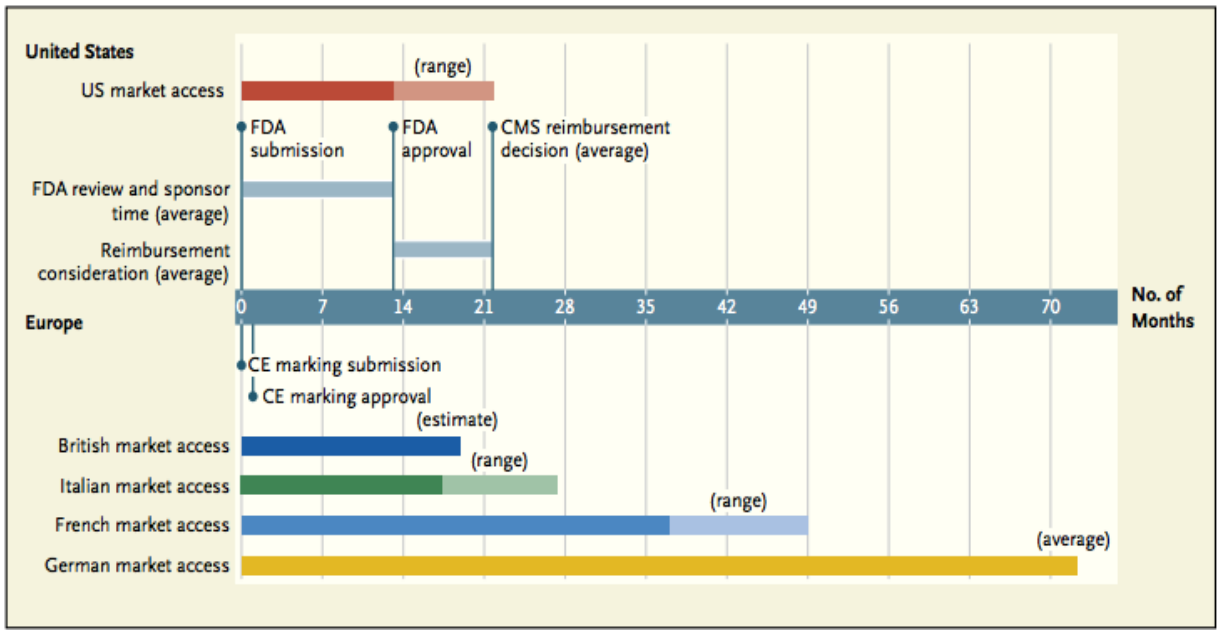

Figure 1. Comparison of Time to Market in Premarket Approval and Reimbursement Processes
Source: Basu, S., Hassenplug, J., 2012, p. 486.

Aside from the time required for the development and approval of innovations in the health care market in Germany the main challenge consists of getting the innovations financed. Due to German regulations a hospital, for example, is not allowed to introduce new methods without formal permission from the health insurances or the Institute for Hospital Reimbursement (InEK). In view thereof we first have to classify the means of innovations in order to be able to identify the different possibilities and processes of implementing innovations in the acute care hospital market. *Figure 2* categorizes the different kind of innovations (*Figure 2*). The two general modes by which innovations can be implemented in German hospitals and possibilities of improving performance through the innovations are illustrated. According to von Bandemer *et al.* new examination and treatment methods (NUB) as well as new operation and procedure codes (OPS), shown on the left-hand side of *Figure 2*, can lead to new products and services and thereby increase revenue.

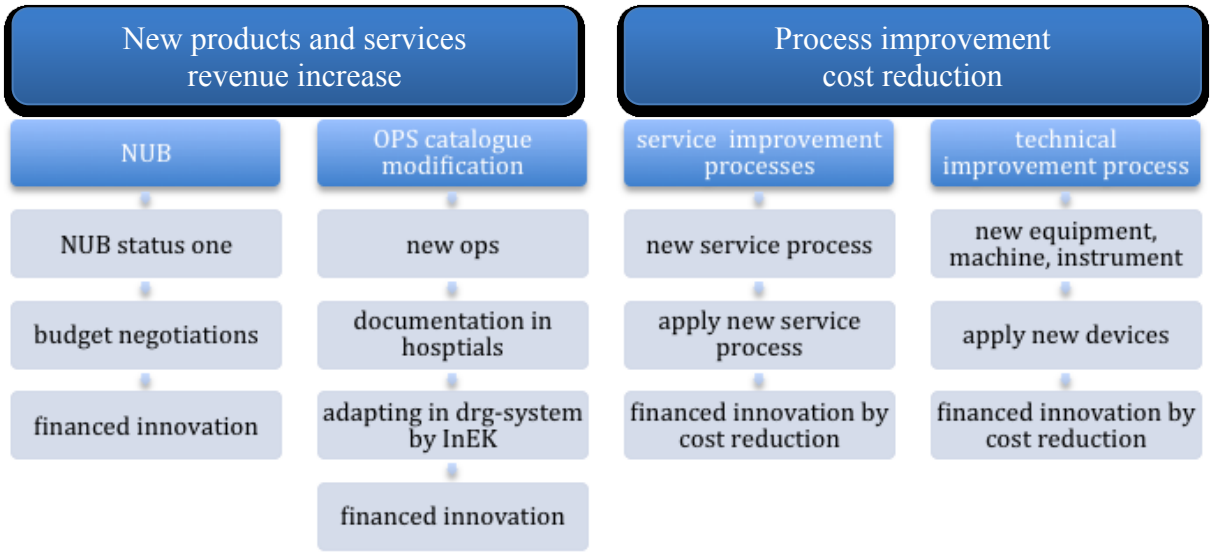

Figure 2. Different means of improvement by innovations in hospitals
Source: Own illustration according to von Bademer *et al.*, 2014, p. 279.

The problem with NUB and OPS often is the long time required for their implementation due to formal requirements and negotiations with the health insurances and the InEK. Cost reductions by process improvements on the other hand are much easier and especially faster to realise for a hospital. Whether attained through innovative service methods or through new equipment, cost reduction, just like revenue increase, leads to better financial and occasionally to better quality performance.

However innovation is responsible for the progress of companies as well as social prosperity as a whole, there is one basic requirement whose presence can be put in question: A functioning competitive market or at least a regulated market with simulated market mechanisms. This is the only way how innovations can be activated (Eiff, 2000, p. 8).

2. Methodology

There are different kinds of research purposes with different research designs and various frameworks for analysing and collecting data (Bryman, Bell, 2007, p. 39). This paper uses description and exploration as typologies of research purposes in order to do both examining the past and generating new ideas (Newman, Ridenour, Newman, DeMarco, 2003, p. 175).

For measuring the performance and evaluating the impact of innovations on the performance of hospitals several types of research designs can be used (Bryman, Bell, 2011, p. 40). Since the objective of this study is to identify the performance, innovative activity and its correlation, a cross-sectional research design is outlined.

2.1. Population, data set and sampling

All in all in 2012, which is the year of investigation, there were 2.017 hospitals in Germany. These hospitals can be divided into for-profit hospitals (in private ownership), non-profit hospitals and hospitals in public ownership such as cities and counties. This study restricts its investigation to for-profit and public hospitals, because the access to data of non-

profit hospitals, especially financial data, is very limited. Therefore the population investigated in this study is reduced to 1.298 hospitals as shown in *Figure 3*.

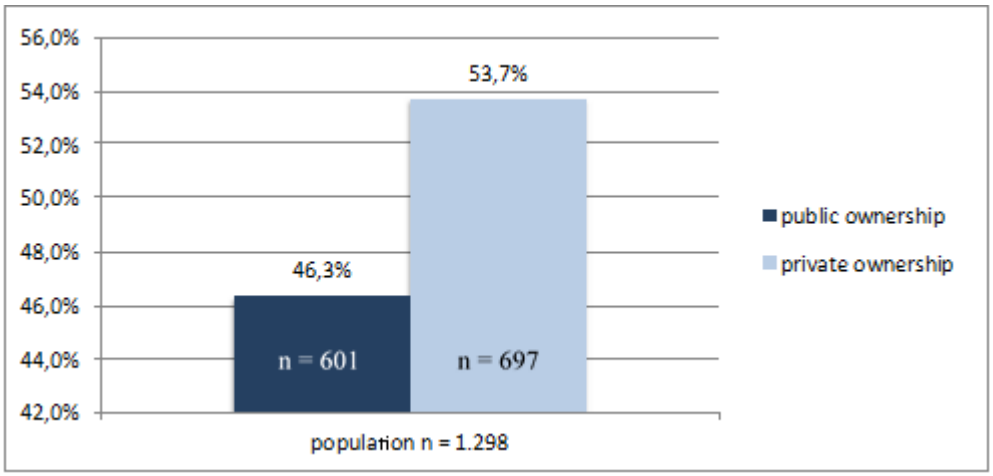

Figure 3. Defined Population
Source: Own illustration.

The investigation is based on two data sets; one built by the investigator on his own and the other being the official data set of the federal statistical office. The data set of the federal statistical office covers the entire population. Therefore, sampling is not necessary for this data set. For the generation of the data set built by the investigator it was necessary to draw a sample in order to be able to manage the amount of data. Deming makes the limited availability of resources responsible for the need to carry out sampling by saying that "…we lack the resources to study more than a fragment of the phenomena that might advance our knowledge" (Deming, 1990, p. 23). In research sampling is the process of selecting parts from a population in order to generalize the results back to this population (Trochim, 2006). For the present study a simple random sample of 30 hospitals was taken from the accessible population of 1.298 hospitals as defined above. Simple random samples are on the one hand not too difficult to draw and on the other hand allow external validity to be generated.

After drawing the sample of hospitals the data has to be collected, which often is the most difficult part of a study (Witt, 2001, p. 1). For the present study the data collection was based on publicly accessible data, such as the legal quality reports of hospitals 2012, annual reports of the hospitals and the hospital report 2012 published by the health insurance AOK. All in all, data for 240 different variables for the 30 hospitals was collected so that in sum 7.200 variables were collected and analysed by the investigator.

Key figures were calculated from the data set as illustrated in *Table 1*.

Table 1. Key innovation indicators

Innovation Indicator	Analysis method	Significant test
invest rate of the hospital	location parameters	yes
special innovative equipment	location parameters	yes
new methods	Frequency distribution	yes
specialization (gini-coefficient)	location parameters	yes

Source: Own illustration.

Table 2. Performance key figures

Performance Indicator	Analysis method	Significant test
EBIT	location parameters	yes
EBITDA	location parameters	yes
net profit	location parameters	yes
revenue	location parameters	yes
casemix	location parameters	yes
full patient cases	location parameters	yes
patient satisfaction	location parameters	yes

Source: Own illustration.

2.2. Analytics

According to Trochim data analytics usually contains three major steps (Trochim, 2006): First of all the collected data has to be prepared. Data preparation includes the cleaning and organizing of the data, such as entering the data into the database, conducting plausibility checks, as well as transforming and transposing the data until they are in an adequate format for statistical evaluation. In this research the data were prepared and analysed with the software packages Microsoft Excel XLSTAT and STATA.

The second step of data analytics is descriptive statistics. For the defined key figures (*Tables 1* and *2*) the distribution, the central tendency and the dispersion were evaluated. Distribution is drawn with frequency distribution tables. Mode, arithmetic mean, median and quantiles were evaluated for the central tendency. Boxplot charts and simple tables were used to make the central tendency visible. Range and standard deviation were calculated in the field of dispersion.

In addition to investigating the differences among the dataset, the existence of correlations between two or more variables was also evaluated. Therefore correlation analysis after Pearson and Spearman was used.

After determining the location parameters, the differences and the correlations among the data using descriptive statistics, inferential statistics was used for inferring from the sample to the population by testing the significance. Depending on the property and condition of the data different tests were used to assess the significance of the results. A significance level of $\alpha = 0.05$ was used for the significance tests. A further differentiation of the significance levels for this study was defined as followed:

Table 3. Levels of significance

$\mathbf{0.01 < p \leq 0.05}$	low significant
$\mathbf{0.001 < p \leq 0.01}$	significant
$\boldsymbol{p \leq 0,001}$	highly significant

Source: Own illustration.

The sample contained 30 hospitals, 17 hospitals being in private and 13 hospitals being in public ownership. The random sample corresponds to the population in terms of composition of private and public owned hospitals.

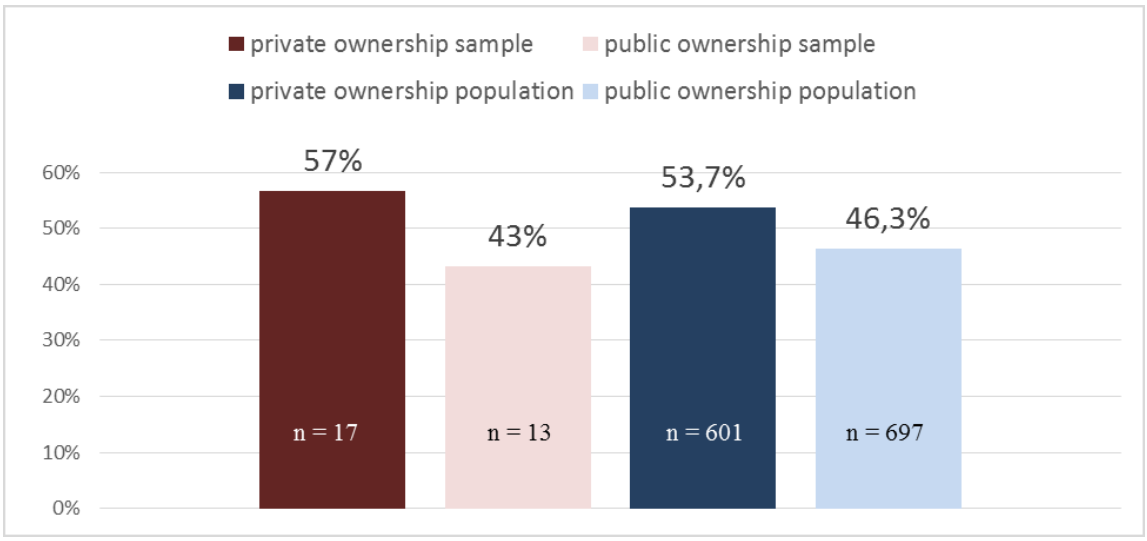

Figure 4. Sample and population
Source: Own illustration.

The boxplots in *Figure 5* show that hospitals in private ownership have a smaller median and mean number of beds than public owned hospitals. Nevertheless, the standard deviation is very high, thus showing that both, public and private hospital owners, have large and small clinics in their portfolio.

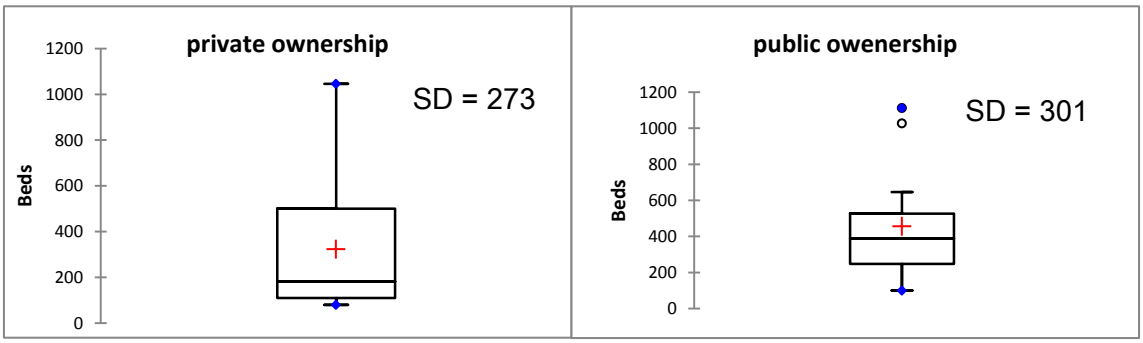

Figure 5. Boxplots of the distribution of beds
Source: Own illustration.

3. Results and interpretation

In order to evaluate the comparability of the samples a Mann-Whitney U test was conducted for the variables beds, case-mix-index and fully inpatient cases. The case-mix is the product of all fully inpatient cases of one year of a hospital and the valuation ratio for the cases according to the DRG-System. The case-mix-index describes the average economic effort that is required for the treatment of all cases in a hospital and can be calculated dividing the case-mix by fully inpatient cases. The significance level was set at $\alpha = 0{,}05$.

Table 4. Comparability of private and public owned hospitals

		Public	Private	p-value	significant
Beds	Mean	457	324	0,131	no
	SD	313	282		
Fully inpatient cases	Mean	19.283	12.677	0,065	no
	SD	13.378	12.815		
Case-Mix-Index	Mean	0,97	1,20	0,067	no
	SD	0,11	0,38		

Source: Own illustration.

As can be gathered from *Table 4* there are no significant differences in the variables beds, fully inpatient cases and case-mix-index between private and public owned hospitals. Therefore, there is no reason to not compare the private and public hospitals of these sample.

3.1. Analysis of differences

As was already mentioned, the first step of the analysis is the evaluation of differences in the variables that express the innovative activity as well as in the variables that represent the financial and quality performance of the hospitals.

We will first analyse the location parameters of the variables shown in *Tables 1* and *2* and then use the Mann-Whitney U test to figure out whether the differences in the variables between public and private owned hospitals are significant. The complete results of the analysis of the location parameters can be found in *Appendix 1*.

Summarising some of the major points it can be stated that the innovation activity in the selected key figures is slightly higher among public hospitals, but for many of the parameters not at statistically significant levels.

The Gini coefficient of specialisation describes the level of specialisation in relation to the provided diagnosis related group services. The German reimbursement system is based on diagnosis related groups (DRGs). DRGs represent an economically-medical patient classification system in which the hospital cases based on their diagnoses and treatments are classified into categories which are valued according to the economic effort required for the treatment (Augurzky, 2013, p. 203). The more cases a hospital can distribute on few DRGs in relation to all cases, the higher is the level of Gini coefficient. The boxplots in *Figure 6* show the difference in the level of specialisation (Gini-coefficient) for public and private owned hospitals. It can be seen that private hospitals have a significantly higher level of specialisation than public hospitals, which is an indicator for higher innovative activity. The other key figures for innovation are listed in *Table 5*. Public owned hospitals show more special equipment in mean and median as well as higher investment rates. However, both not at statistically significant levels.

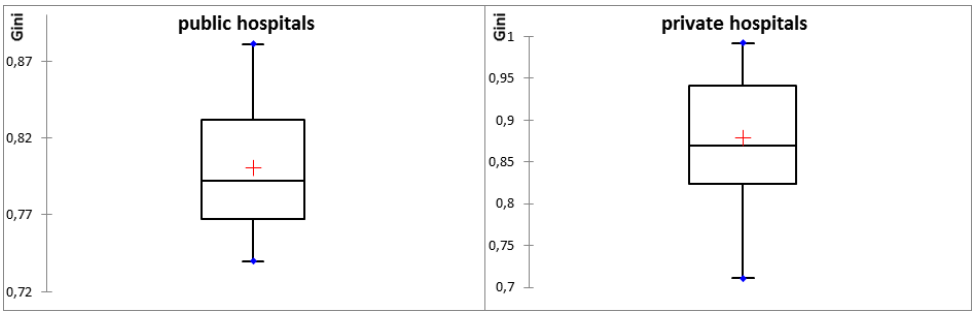

Figure 6. Boxplots of Gini coefficient of specialisation
Source: Own illustration.

On the other hand, public hospitals provide highly significantly more new methods than private hospitals. According to these key figures (even though not all of them are significant) it can be stated that hospitals in public ownership are slightly more innovative than hospitals in private ownership; however only in one variable (number of new methods) significantly.

Table 5. Key innovation figures

	Gini coefficient		special equipment		invest rate of the hospital		number of new methods	
	private	public	private	public	private	public	private	public
observations	17	13	17	13	17	13	17	13
mean	0,879	0,801	4,294	5,692	5,91%	6,68%	0,588	0,615
median	0,869	0,792	5,00	6,00	2,79%	3,99%	-	-
p-value	0,01**		0,131		0,335		< 0,0001***	

** low significant, ** significant, *** highly significant*

Source: Own illustration.

After evaluating the innovative activity of the hospitals the performance of the investigated hospitals, both financially and in terms of quality, has to be reviewed. *Table 6* shows the results of the performance analysis. These show that private hospitals demonstrate higher performance for each of the defined key figures. Patient satisfaction as well as financial performance, such as EBIT or EBITDA, is higher in hospitals in private ownership. For two of the three figures the results are significant, even highly significant.

Table 6. Key performance figures

	EBIT		EBITDA		patient satisfaction	
	private	public	private	public	private	public
observations	17	13	17	13	17	13
mean	4.733.675 €	- 2.484.454 €	7.037.147 €	- 248.942 €	84%	83%
median	2.060.080 €	- 2.268.690 €	3.389.631 €	- 1.127.195 €	85%	83%
p-value	< 0,0001***		0,006**		0,483	

** low significant, ** significant, *** highly significant*

Source: Own illustration.

So far, it can be stated that hospitals in public ownership are more innovative than hospitals in private ownership, whereas private hospitals show significantly higher performance than their public competitors.

3.2. Correlation analysis

After identifying and comparing the differences in performance and innovation activity the next step is to examine the correlation between innovation activity and performance. The complete results of the correlation analysis can be found in *Appendix 2* and *Appendix 3*. *Appendix 2* shows the correlation matrix, p-values and the coefficient of determination for the variables that were analysed with Pearson's correlation. *Appendix 3* shows the correlation for variables with an ordinal scale level after Spearman.

Summarizing some highlights, it can be said that there is a significant degree of correlation between special equipment and EBITDA both, for private and for public owned hospitals. However, public owned hospitals show a generally poor financial performance in EBIT and EBITDA, hospitals with a high degree of application of special equipment perform better than hospitals with little special equipment. The latter also holds true for private hospitals, which improve their already very good financial performance by using a high amount of special equipment.

Table 7. Correlations after Pearson

		EBITDA			patient satisfaction		
		r	p-value	R^2	r	p-value	R^2
Special equipment	privat	0,495*	0,043	0,245			
	public	0,603*	0,029	0,364			
Specialization (Gini-Coefficient)	privat	-0,574*	0,016	0,260	0,623*	0,008	0,388
	public	-0,679*	0,011	0,461	0,682*	0,010	0,465

* low significant, ** significant, *** highly significant

Source: Own illustration.

Another significant correlation can be found between the level of specialization and patient satisfaction, for private as well as for public hospitals. Therefore, it can be stated that the more specialized a hospital is, the higher the patient satisfaction is. On the other hand there is a significant negative correlation between specialization and EBITDA.

Unfortunately there are no more significant correlations between innovation activity and financial and quality performance than the ones that have been pointed out in *Table 7*. Consequently, it is not possible to provide a clear statement about the impact of innovations on the performance of acute care hospitals, both for public and private hospitals. Further interpretations of these results and possibilities for further research which can follow up on this point are provided in the conclusion.

4. Software Development

4.1. Importance of IT, IS and IM for business and science

In order to provide a wide range of scientists and practitioners with access to the results of this study and to encourage them to carry out further research, an analysing software tool was developed. Software development and the large field of information systems,

-technology and -management is very important, but also very complex in theory and practice.

It is important to first define the strategic alignment of the application. To meet the demands of both, scientists, for getting free access for further investigations, and practitioners, who can use the application for their business, it is important to focus on an alignment at the process level of each consumer (Tallon, 2007, p. 227). The importance of IT and Business alignment can also be identified by the evolution of the top management concerns during the last two decades. While in 1980 the main concern was IT strategic planning, top management now focusses on the IT and business alignment (Luftman *et al.*, 2009, p. 152). Not only information systems and information technology are playing an increasingly important role, but the integration of information management (IM) strategy is just as important (Pai, Lee, 2005, p. 149). This applies to both, enterprises as well as science processes, in making the next step towards higher digitalization.

Especially in the field of innovations IT plays an important role. In Harvard Business Review November 2008 Cash, Earl and Morison coined the term DIG (distributed innovation group). "A distributed innovation group (DIG) combines a company's own innovation efforts with the best of external technology to create new business variations" (Cash *et al.*, 2008, p. 92). In applying these ideas to the scientific field instead of companies it can be said that a web based software as developed in this study is important for both, scientists, for investigating the interaction of innovation and performance of hospitals, and companies, for evaluating their business and for finding inspirations for possible strategies.

4.2. Software architecture and development process

In order to create the basis for the application it was necessary to build a database with the relevant information of the hospitals. Because the information was acquired from different data sources the extract, transform and load (ETL) process was used. This process is applied to integrate data from different sources into a single form of data (Inmon, Linstedt, 2014, p. 104). The Pentaho Data Integration (a graphical ETL-Tool) was used to complete this step.

Further information about the software architecture, the development process, the procedure of data collection and data matching process can be viewed online (www.bindoc-analytics.de). The application can also been viewed online to get an impression about the functionality, design and usability.

Conclusion

Investigating the impact of innovations on the performance of hospitals and developing a software tool to make the results accessible to a wide range of scientists and practitioners were the two objectives of this study.

After confirming that the built sample of public and private owned hospitals was suitable for comparing the two types of hospitals against each other the investigation started with a comparison of innovative and performance key figures. The first finding was a significantly higher performance of private hospitals in the financial key figures as well as a higher performance in patient satisfaction. The results for the innovative key figures were not as clear as the financial ones, but can be summarized as showing slightly higher performance among public hospitals, however most of them not at statistically significant levels.

Afterwards correlations between the innovative activity and the performance key figures were investigated to find out whether there is an impact of innovations on the performance of hospitals. On the one hand some significant correlation between innovations

and performance was identified, but on the other hand not all indicators suggest that the performance is positively influenced by innovations.

In view of the known fact that innovations definitely has a positive influence on the performance of enterprises, at least in competitive markets, the results of the study have to be interpreted as follows:

First it has to be affirmed that there is a need for further research. In particular, further research should take the existing key figures and expand them in order to obtain more information about the influence of innovations on performance. For example, at the process level such parameters as the use of electronic patient records, process flows and so forth can be investigated. Furthermore, follow-up research should also investigate whether there are enough incentives for hospitals to be innovative or whether regulation has to be changed. In a cost-based reimbursement system as it currently exists in the German hospital market cost effectiveness, efficiency and the quantity of service represents the given incentive for the hospitals. There might be too little incentive for hospitals to be innovative not only in terms of process innovation, but also in creating new products, methods or services. As is shown in *Figure 2* the time that passes from the creation of new products, methods or services until these innovations are accepted by the health insurances and the Institute for Hospital Reimbursement (InEK) can be long and may be too long time. This aspect should be investigated when doing further research based on the findings in this paper.

The development of the software should help researchers as well as practitioners in doing their daily work. The innovation key figures which can be evaluated in different ways should only represent the beginning with many more key figures in different relevant fields for hospitals, such as value-based key figures, performance indicators, quality key figures, process key figures and so forth to follow. The software, which is intuitive to handle, is definitely able to simplify practitioners´ everyday business life.

The next development stage of the software will be an addition tool for scientists to give them the opportunity to not only evaluate key figures, but to put their own databases into the cloud and have them analyzed.

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