“Explaining the efficiency of anaesthesiology and intensive care wards in the Slovak Republic”

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EXPLAINING THE EFFICIENCY OF ANAESTHESIOLOGY AND INTENSIVE CARE WARDS IN THE SLOVAK REPUBLIC

Abstract

In this article, the authors measure and evaluate the efficiency of anesthesiology and intensive care wards in the Slovak Republic using the suitable methods and check suitability of methods and variables used in the Slovak healthcare environment. Nowadays, trends are towards modification of basic data envelopment analysis (DEA) incorporating other quantitative methods. In this study, the authors examined the influence of contextual variables on CCR DEA efficiency scores. Variables Ageing index and Unemployment rate had unexpected sign/effect on efficiency. Variables Average length of stay and Bed occupancy rate seem to be adequate to be used and checked for significance in terms of selected wards of the Slovak Republic healthcare. Such types of articles are completely missing in the Slovak Republic. Methods and variables the authors have used could be modificated to needs of individual wards. These findings could be used to build information system of efficiency in the Slovak healthcare within cooperation with National Health Information Center.

Keywords two-step, data envelopment analysis, truncated regression, Slovak Republic, healthcare

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INTRODUCTION

Data envelopment analysis (DEA) is a well-known method which is used to evaluate the efficiency of decision making units. This method is based on the use of linear programming. It was founded in the 70s and originally was used to measure the efficiency of non-profit organizations (hospitals, schools, public administration, etc.). Thereafter the field of its use spread to the area of enterprises, national economies, different sectors or sport. Nowadays we know many models of this analysis, which finds application in measurement of efficiency. We can also mention the CCR, BCC or two-stage DEA as best known and the most used models of DEA. In this study, we focus on evaluation of efficiency in selected wards of Slovak hospitals using two-step DEA approach.

1. LITERATURE REVIEW

Based on our study of literature, we have found that the most commonly used regressions in health sector used in the second step of two-step DEA are truncated regression and Tobit regression.

Araújo et al. (2013), using truncated regression, analyzed profit hospitals in Brazil. They used number of beds as an input and inpatients as an output. Kounetas and Papathanassopoulos (2013) used similar

input (beds) and output (inpatient days). They evaluated one hundred and fourteen hospitals in Greece. Mitropoulos et al. (2012) also dealt with the evaluation of hospitals in Greece using truncated regression. They analyzed ninety-six public hospitals. Salaries were used as an input, introduction pathologic as an output. Same regression and sample of hospitals in Tunisia were used in the study of Chaabouni and Abednnadher (2012). Also, Blank and Valdmanis (2010) and Blank and Hulst (2010) used this type of regression in their studies focused on health sector in the Netherlands. Two-step DEA using truncated regression in combination with SFA were used in the study of Varabyova and Shreyogg (2013). Number of beds as an input and number of discharges as an output were used in their work.

Regarding Tobit regression, Matranga et al. (2014) analyzed four hundred eighty-one hospitals by ownership in Italy. They used medical staff as an input and number of discharges as an output. Also, Jehu-Appiah et al. (2014) evaluated efficiency of Ghanaian hospitals using the sample of hospitals by ownership with number of beds as an input and number of inpatients as an output. Twenty-six non-profit hospitals were analyzed in the study of Kalogeropoulou et al. (2012) using Tobit regression. There exist studies dealing with the evaluation of the efficiency in some Asian countries. Rahman and Capitman (2012) analyzed one hundred eighty-five profit hospitals in Bangladesh, Hu et al. (2012) dealt with hospitals in China, and Foo et al. (2015) analyzed ophthalmology wards in Malaysia.

The combination of both the abovementioned regressions were used in study of Gholami et al. (2015). They used salaries as an input and net patient revenues as on output in one hundred and eighty-seven hospitals in the USA. We can find another combination of regressions in Kaya Samut and Cafri (2015) study – they used Malmquist Index regression with Tobit regression.

In addition to these two regressions, there exist also other types methods used in second step of two-step DEA. First, ordinary least squares (OLS) regression was used in the studies of Castelli et al. (2015), Hadad et al. (2011) and Valdmanis et al. (2008). We can also find multiple regression as a part of second step. Harrison et al. (2010) used this regression when evaluating university hospitals in the USA. Same regression with Malmquist regression served for evaluation of public hospitals in Turkey (Gok & Sezen, 2013). Number of beds as an input and number of days of bed occupancy as an output were used. Seemingly unrelated regressions (SUR) and partial least squares (PLS) regression belong to the less widely used regressions. Karagiannis (2013) used SUR for evaluation of public hospitals in Greece. PLS regressions were used in the study of Djema and Djerdjouri (2012) who analyzed one hundred and seventy-four hospitals in Algeria.

2. METHODOLOGY

In the first step of two-step DEA, we have to calculate the efficiency scores using CCR output-oriented DEA model according to Cooper et al's. (2007) input-oriented model of linear programming often called as "Farell efficiency" as a reciprocal value $1/\theta$.

In the second step, we need to use regression to check the influence of explanatory variables on efficiency. For this purpose, truncated regression and Tobit regression are often used. To get consistent estimates of regression model, we need to use the method/algorithm proposed by Simar and Wilson (2007) which by using the double bootstrap mechanism provides bias corrected DEA efficiencies suitable for using in regression models. We will use truncated regression model which has the following form:

$$\delta_i = z_i\beta + \varepsilon_i, \tag{1}$$

$i = 1, \ldots, n,$

where δ_i is DEA efficiency score of selected DMU, z_i is set of explanatory variables, β are regression coefficients and ε_i is standard error. If we use the algorithm proposed by Simar and Wilson (2007) truncated regression model will have the following form:

$$\widehat{\delta}_i^{\,BC} \approx z_i\beta + \varepsilon_i, \tag{2}$$

$i = 1, \ldots, n,\ \varepsilon_i \geq 1 - z_i\beta,\ \varepsilon_i \sim N\left(0, \sigma_\varepsilon^2\right),$

Table 1. Descriptive statistics of input variables

Source: Own processing according to data provided by NHIC.

Statistic	Number of beds	Number of doctors	Number of nurses	Material costs	Operational costs
N	48	48	48	48	48
Mean	59.104	78.551	199.521	2776132.000	411253.600
St. Dev.	24.227	32.236	76.572	2045627.000	305053.500
Min	32.000	44.440	107.370	860763.000	152375.000
Max	109.000	158.590	371.670	8316696.000	1217190.000

where $\widehat{\delta}_i^{BC}$ is bias corrected efficiency using the second algorithm proposed by Simar and Wilson (2007).

Data will be truncated left to point 1, because output efficiencies are in interval 1 to infinity. The main point of this regression is that explanatory and dependent variables under this boundary are latent. Tobit regression assumes that only explanatory variable is latent one.

General form of Tobit regression is expressed as follows:

$$\delta_i^* = z_i\beta + \varepsilon_i, \quad (3)$$

$i = 1, \ldots, n.$

3. DATA

We chose as the object of research anaesthesiology and intensive care wards of secondary health care providers. According to the data provided by the National Health Information Center (NHIC), we chose to evaluate the efficiency between 8 regions in Slovakia according to NUTS 3 classification. Data were provided for 6 years (from 2009 till 2014). We selected DEA window analysis, which means that ward in the selected year will be taken as unique DMU.

As input variables for DEA CCR model we chose, according to the most used variables presented in Hadji et al. (2014) and according to the section Introduction and availability of variables provided by NHIC, the following variables: Number of beds, Number of doctors, Number of nurses, Material costs and Operational costs. Variables Number of doctors and Number of nurses were considered as fixed. As output variables, we chose Number of inpatients, Number of inpatient days and Total revenues. As explanatory variables, we selected following variables: Average length of stay, Bed occupancy rate divided by 100, Citizens in age 15 to 64 divided by 100, Ageing index divided by 100 (rate of citizens in age 0-14 to citizens in age 65 and more), Mortality of new-borns to 1000 inhabitants divided by 10 and Unemployment rate divided by 10. These data were provided by NCHI and Eurostat. Then we constructed panel with 48 DMUs.

4. RESULTS

Table 1 shows selected descriptive statistics of input variables, which were used for DEA efficiencies computation.

The average number of beds was at value of almost 60 beds. The minimum level of the number of beds was recorded in the Zilina region, on the contrary, the highest in Bratislava. The lowest number of doctors and nurses was reported in the Trnava region. The highest operating costs were recorded in Bratislava and Kosice. It is similar in the case of material costs. The next Table 2 shows the output characteristics of DEA models.

Table 2. Descriptive statistics of output variables

Source: Own processing according to data provided by NHIC.

Statistic	Number of inpatients	Number of inpatient days	Total revenues
N	48	48	48
Mean	2287.958	12092.270	7720145.000
St. Dev.	1316.909	5007.014	5461431.000
Min	841.000	5987.000	2450419.000
Max	5031.000	20807.000	19344061.000

Table 3. Descriptive statistics of explanatory variables

Source: Own processing according to data provided by NHIC and Eurostat.

Statistic	ALOS	Bed occupancy	15-64	Ageing index	Mortality of New-borns	Unemployment rate
N	48	48	48	48	48	48
Mean	5.767	0.57948	0.7189	0.86577	0.3049	1.3017
St. Dev.	0.942	0.04181	0.0098	0.16597	0.1314	0.4845
Min	3.900	0.48700	0.7018	0.56520	0.0900	0.4360
Max	7.300	0.67900	0.7376	1.11410	0.6300	2.0810

The average number of hospitalizations in the different regions for the period was nearly 2,300 patients. Most patients were hospitalized in the Kosice region, least in Trnava. Top revenues were reached in Bratislava and Kosice, on the contrary, Trnava and Trencin were the regions with lowest values of this variable. Table 3 shows the descriptive statistics of explanatory variables.

The average of ALOS (Average length of stay) was approximately 5.8 days. The highest values were recorded in the Trencin and Trnava region and the lowest in the Kosice region. Bed occupancy level fluctuated at around 60%. The following table shows the test results of DEA CCR model and BCC for wards of anaesthesiology and intensive care. Table 4 shows the computed efficiency scores of individual wards.

In the case of wards of A&IC, it can be argued that according to results of model CCR, only Banska Bystrica region is efficient. In the model BCC, Banska Bystrica region was joined by the region of Trnava, which was by CCR, on the con-

Table 4. Efficiency scores and slacks

Source: Own processing.

DMU	CCR out ef.	N. of beds	Material costs	Operational costs	BCC out ef.	N. of beds	Material costs	Operational costs
BA14	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BA13	1.03	0.00	0.00	162485.93	1.02	0.00	5146.79	164533.72
BA12	1.03	0.00	0.00	136921.93	1.03	0.00	182049.14	0.00
BA11	1.02	0.00	595531.37	113555.41	1.02	0.00	573419.64	116718.92
BA10	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BA09	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
TT14	1.17	0.00	51978.63	0.00	1.00	0.00	0.00	0.00
TT13	1.18	0.00	49521.67	0.00	1.00	0.00	0.00	0.00
TT12	1.24	0.00	92678.76	0.00	1.00	0.00	0.00	0.00
TT11	1.18	0.00	37623.51	0.00	1.00	0.00	0.00	0.00
TT10	1.19	0.00	30539.87	0.00	1.00	0.00	0.00	0.00
TT09	1.22	0.00	77537.31	0.00	1.00	0.00	0.00	0.00
TN14	1.12	0.00	0.00	0.00	1.03	1.46	0.00	0.00
TN13	1.03	0.00	0.00	0.00	1.00	0.00	0.00	0.00
TN12	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
TN11	1.09	1.17	0.00	0.00	1.00	0.00	0.00	0.00
TN10	1.01	4.62	0.00	0.00	1.00	0.00	0.00	0.00
TN09	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
NR14	1.07	3.46	0.00	0.00	1.06	2.19	0.00	0.00
NR13	1.06	4.86	56754.76	0.00	1.06	2.15	45997.25	0.00
NR12	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
NR11	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
NR10	1.07	5.80	32605.41	0.00	1.03	2.83	476047.35	0.00
NR09	1.08	1.30	0.00	0.00	1.06	0.00	73643.06	0.00
ZA14	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
ZA13	1.01	0.00	0.00	41723.98	1.00	0.00	0.00	27761.88
ZA12	1.07	0.00	0.00	117180.73	1.00	0.00	0.00	0.00
ZA11	1.09	0.00	0.00	46668.29	1.00	0.00	0.00	0.00
ZA10	1.12	0.00	0.00	11214.89	1.01	0.00	0.00	35219.45
ZA09	1.17	0.00	0.00	70629.57	1.06	0.00	0.00	60073.34

Table 4 (cont.). Efficiency scores and slacks

DMU	CCR out ef.	N. of beds	Material costs	Operational costs	BCC out ef.	N. of beds	Material costs	Operational costs
BB14	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BB13	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BB12	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BB11	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BB10	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
BB09	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
PO14	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
PO13	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
PO12	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
PO11	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
PO10	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
PO09	1.01	1.45	0.00	4496.95	1.01	1.22	0.00	1796.63
KE14	1.01	0.00	0.00	323714.43	1.00	0.00	0.00	0.00
KE13	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
KE12	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
KE11	1.03	0.00	0.00	73855.66	1.02	0.57	0.00	36526.81
KE10	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
KE09	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00

Note: BA – Bratislava region, TT – Trnava region, TN – Trencin region, NR – Nitra region, ZA – Zilina region, BB – Banska Bystrica region, PO – Presov region, KE – Kosice region, number after abbreviation is the year in which DMUs were evaluated.

trary, the most inefficient region. Distinct need for a reduction in material costs occurred by CCR only in Trnava and Bratislava. Operating costs were higher in Bratislava, Kosice and Zilina regions. Table 5 shows the results of regressions for A&IC wards. We should note, that output efficiency scores were used. It means that lower value of efficiency is better score of efficiency, since the values are ranging from 1 (which means efficient DMU) to infinity.

One could argue that the variables Average length of stay, Bed occupancy rate, Ageing index and Unemployment rate were statistically significant for both models. Unexpected element was the influence of the variables Ageing index and Unemployment rate, which had a negative/unexpected effect. It means that by improving these variables to better levels, efficiency rate is worsening. Variable Mortality of new-borns for these models is not appropriate at all, so is the variable of the population aged 15-64 years. It should be noted the fact that the dependent variable of regression models was CCR efficiency, since the efficiency of BCC for those wards is not appropriate, models were insignificant.

Table 5. Regression models results

Source: Own processing.

Explanation variables	Dependent variable:	
	CCR output efficiency	
	Tobit	Truncated regression
ALOS	0.041***	0.069***
	(0.007)	(0.014)
Bed occupancy	–0.877***	–1.485***
	(0.176)	(0.359)
15-64	–0.844	–3.316
	(1.143)	(2.045)
Ageing index	–0.152***	–0.258***
	(0.054)	(0.087)
Mortality of new-borns	–0.015	–0.107
	(0.066)	(0.128)
Unemployment rate	–0.062***	–0.152***
	(0.016)	(0.042)

Table 5 (cont.). Regression models results

Explanation variables	Dependent variable: CCR output efficiency	
	Tobit	Truncated regression
Intercept	2.159**	4.320***
	(0.900)	(1.661)
Log (scale)	–3.317***	–
	0.102	–
Sigma	–	0.043***
	–	(0.006)
Observations	48	48
Log likelihood	91.092	115.04
Wald test (df = 8)	117.841***	–
R-squared	0.7106	0.6855

Note: *$p < 0.1$. **$p < 0.05$. *** $p < 0.01$.

CONCLUSION

The aim of this work is to use a slight modification of modern approach for assessment of the impact of explanatory variables with respect to efficiency. Integration of scientific research areas with medical practice is necessary for the potential application of the recommendations of the various models, because one side of the issue is recommendations of models and the second is incorporating the changes in the hospitals and organizational processes. In accordance with the objectives and tasks of the European Union in the field of healthcare, the Slovak Republic should establish a way to substantial changes in health care and as a framework for these changes, there should be utilized strategies and objectives of common European area, which include an emphasis on the integration of science and research not only into health management, but also at specific hospitals. Such types of articles are completely missing in the Slovak Republic. Methods and variables we have used could be changed to needs of individual wards. These findings could be used to build information system of efficiency in Slovak healthcare within cooperation with National Healthcare Information Center. Options for further research are obvious. Results also showed that differences between regions should be considered. So, we strongly recommend to research if there are possibilities to include these differences into health policies.

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