

Measuring the Efficiency of University Libraries Using Data Envelopment Analysis

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Abstract

Data envelopment analysis is a non-parametric linear programming-based technique used for measuring the relative performance of organizational units where the presence of multiple inputs and outputs makes comparisons difficult. The aim of this paper is to apply Data envelopment analysis in order to measure the efficiency of University Libraries. The panel data of five University Libraries for years 2002 and 2003 has been estimated. We identified six inputs and three outputs. The input variables are staff, print edition expenses, electronic edition expenses, building space, wages, library technical equipment. As output variables we estimated: number of registered readers, number of customers served, number of borrowed items. We found that three libraries form the efficiency frontier and the other two are inefficient for 2002 and 2003. A benchmark model is recommended for inefficient units.

1. Introduction

Because of their specific organization, University Libraries present certain difficulties in their efficiency evaluation. One recent approach to the evaluation of library efficiency is Data envelopment analysis (DEA). There have been a number of studies that applied DEA technique in order to assess the efficiency of different types of libraries. The most recent and accomplished is the paper of Shim³, where a comparison of DEA applications in libraries is put forward. Chen, Vitaliano and Shim examine academic libraries and Hammond, Sharma et al., and Worthington study the efficiency of public libraries. Easun is one of the firsts to apply DEA approach to evaluate school libraries. The aim of the present paper is to apply DEA to measure the efficiency of University Libraries, in the town of Varna, Bulgaria.

2. Background of Data envelopment analysis (DEA)

Data envelopment analysis (DEA), occasionally called frontier analysis, was first put forward by Charnes, Cooper and Rhodes in 1978. It is a linear programming-based technique for evaluating the performance of administrative units. Examples of such decision making units (DMUs) to which DEA has been applied are: banks, mutual funds, police stations, hospitals, tax offices, defense bases, insurance companies,

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³ Shim, W., *Applying DEA Technique to Library Evaluation in Academic Research Libraries*, Library Trends, Vol. 51, No 3, 2003, p312-332

schools, libraries and university departments. The method can successfully be applied to profit and non-profit making organizations, as well. DEA can handle multiple inputs and multiple outputs as opposed to other techniques such as ratio analysis or regression. The performance of a unit is evaluated by comparing its performance with the best performing units of the sample. Best performing units form the efficiency frontier. If the unit is not on the efficiency frontier it is considered to be inefficient. Hence, DEA is called frontier analysis. The aim of DEA is to quantify the distance to the efficient frontier for every DMU. The measure of performance is expressed in the form of efficiency score. After the evaluation of the relative efficiency of the present set of units, the analysis shows how inputs and outputs have to be changed in order to maximize the efficiency of the target DMU. DEA suggest the benchmark for each inefficient DMU at the level of its individual mix of inputs and outputs. The basic mathematical formulation of DEA has the following form:

Maximize

$$E_b = \left(\sum_{r=1}^R u_r y_{rj} \right) / \left(\sum_{i=1}^I v_i x_{ij} \right)$$

subject to:

$$\left(\sum_{r=1}^R u_r y_{rj} \right) / \left(\sum_{i=1}^I v_i x_{ij} \right) \leq 1, \forall j, j = 1, 2, \dots, N$$

And $u_{rb}, v_{ib} \geq e$ for all r, i (where $r = 1, 2, \dots, R$ and $i = 1, 2, \dots, N$)

Where

E_b is the efficiency of any unit b ;

y_{rj} is observed quantity of output r produced by unit $j = 1, 2, \dots, N$

x_{ij} is observed quantity of input I used by unit $j = 1, 2, \dots, N$

u_{rb} is the weight (to be determined) given to output r by base unit b

v_{ib} is the weight (to be determined) given to input i by base unit b

e is a very small positive number.

The u 's and v 's are the variables of the problem and are constrained to be greater than or equal to some small positive quantity e in order to avoid any input or output being totally ignored in determining efficiency. Charnes, Cooper and Rhodes proposed that each unit should be allowed to adopt the most favorable set of weights. The linear program solution technique will attempt to make the efficiency of the unit as large as possible. This search procedure will terminate when some of the efficiencies hit 1.

DEA gives the weights of inputs and outputs leading to the calculated efficiency. The unit is efficient if the efficiency is equal to 1 and inefficient if it is less than 1. If represented graphically, for a given set of units, the efficient DMUs form the frontier that encloses the inefficient ones (the whole data set). Hence the name of analysis - data envelopment analysis. So, the efficient units use its mix of inputs better than inefficient ones or the efficient units manage to produce more outputs using a given mix of inputs. An input-oriented measure quantifies the input reduction, which is necessary for a DMU to become efficient, holding the output constant. Similarly, an output-oriented measure quantifies the necessary output expansion, holding the input constant. A non-oriented measure quantifies the improvements when both inputs and outputs can be modified simultaneously. DEA suggest the creation of virtual unit B'

for the inefficient unit B. B' lies on the efficient frontier and is the best practice for unit B, if it aims to be efficient. The outputs and inputs of such a virtual unit are linear combinations of corresponding outputs and inputs of all other units. Thus DEA gives inputs/outputs targets for inefficient units – a benchmarks. The benchmark represents the peer group for the inefficient DMU.

Since the technique was first proposed much theoretical and empirical work has been done. Many studies have been published dealing with applying DEA in real-world situations. The most important task is to determine the proper set of inputs and outputs for the observed units. Having reviewed literature on economics of hospitals, we concluded that the authors use three categories of inputs: labour, supplies and capital. Labour is number of physicians, surgeons, nurses, technical staff; the suppliers are pharmaceutical and others; capital includes equipment, vehicles and building space. There are four types of outputs: inpatient days, outpatient visits, surgical operations, and live births. When DEA is undertaken to evaluate bank branch efficiency inputs are: staff, interest costs, non-interest costs – expenses for rent, electricity, printing, advertising, post and telephone, repair and maintenance, etc. and the outputs are: number of transactions – deposits, loans, advances, mortgages etc. One of the strengths of DEA is the fact that inputs and outputs can be measured in different units for example dollars, square meters, number of staff, etc. The analysis can be run using one input and several outputs or vice versa estimating one output produced by multiple inputs. DEA can be run with a very small data set, as is the case in this paper.

The first and probably most difficult step in efficiency evaluation is to decide which inputs and outputs data should be included.

The literature on applying the DEA technique to library evaluation shows various schemes of inputs and outputs sets. The inputs usually are library staff (Chen 1997; Sharma, Leung and Zane 1999), weekly hours (Vitaliano 1998), volumes held (Shim 2000), book collection (Sharma, Leung and Zane 1999), material resources (Easun 1992). The most frequently used outputs are total circulation, reference transactions, library visits, interlibrary lending, online search and provision of information. The inputs or outputs that can be controlled by the DMUs are called “standard” or “discretionary” variables. “Nondiscretionary” variables are beyond the control of library administration, like population density, area size, resident population, nonresidential borrowers, and socioeconomic indices.

2. Research Framework and Data Set

We have estimated the following six inputs: number of staff (Staff), printed edition expenses (ExPrIss), expenses on electronic databases and software (ExDB), building space (Scale), wages (Wages), technical equipment (MTB). We have defined three outputs: registered readers (Reg), customers served (Serv), books borrowed (Borr). Nondiscretionary inputs and outputs are not included, because the Libraries are situated in the same town. Number of staff includes director, bibliographers and technical personnel of the library. Printed edition expenses are textbooks, dictionaries, periodicals (newspapers and journals) purchased by the University plus all printed editions given as a grant by foundations or projects; expenses on electronic databases and software include electronic editions, software packages and all Internet resources paid for by the University. Building space is the area used for reading-rooms, checking out service and the information sector. Wages are the gross sum for twelve months. Technical equipment includes computers, furniture, electric devices etc. The wages, technical equipment and expenses are measured in Bulgarian leva

(1BGL=0,5EUR approximately). The building space is measured in square meters. All outputs are measured in numbers. DEA can handle inputs and outputs measured in different units.

The data was analyzed using a program called EMS - Efficiency Measurement System version 1.3. The type of analysis is input oriented, with radial distance and constant returns of scale.

We have collected the data by conducting an inquiry into five University Libraries in Varna, Bulgaria. As mentioned this fact minimizes the deviations caused by the environmental factors if the analysis is undertaken for DMUs located in different places. The estimated units are the Libraries in F1-Naval Academy, F2-Medical Academy, F3-Technical University, F4-University of Economics and F5-Free University. It is important to notice that the Universities are different types, but the Libraries' reports have similar structure.

Data for 2002

DMU	Staff{I}	ExPriss{I}	ExDB{I}	Scale{I}	Wages{I}	MTB{I}	Serv{O}	Reg{O}	Borr{O}
F1naval	4	13170	2700	2000	17900	14052	14120	1700	25520
F2med	8	73520	12656	1700	29700	94682	14600	2850	30260
F3techn	11	20883	2700	2000	41367	15404	83065	5638	142250
F4ec	14	102009	2228	2000	77280	84568	82250	6533	304584
F5free	8	6450	1700	800	46080	17200	33818	5202	48701

Results for 2002

DMU	Score	Benchmarks	ExPriss-	ExDB-	MTB-	Wages-	Borr+	Serv+
F1naval	75,66%	3 (0,18) 5 (0,14)	5399,74	1335,56	5582,86	0	6214,79	5138,22
F2med	70,41%	3 (0,51)	41207,09	7545,9	58876,3	0	41647,15	27389,22
F3techn	100,00%	2						
F4ec	100,00%	0						
F5free	100,00%	1						

Data for 2003

DMU	Staff{I}	ExPriss{I}	ExDB{I}	Scale{I}	Wages{I}	MTB{I}	Serv{O}	Reg{O}	Borr{O}
F1naval	4	39511	2440	2000	18480	16702	12170	1406	35217
F2med	8	77788	9520	1700	30791	94682	14930	2395	38690
F3techn	10	23165	3500	2000	42917	45942	73250	5139	131005
F4ec	13	76444	2837	2000	74234	121859	86474	6702	308276
F5free	8	70230	2225	2000	46900	120400	35095	5612	50147

Results for 2003

DMU	Score	Benchmarks	ExPriss-	ExDB-	MTB-	Wages-	Borr+	Serv+
F1naval	75,26%	3 (0,27)	23397,07	878,7	0	2165,7	625,19	7870,77
F2med	64,96%	3 (0,47)	39733,59	4552,85	40092,5	0	22364,08	19207,72
F3techn	100,00%	2						
F4ec	100,00%	0						
F5free	100,00%	0						

3. Results

As can be seen from the table above, the Libraries in the Technical University, in the University of Economics and in the Free University form the efficiency frontier for the two observed periods. The Libraries in the Medical Academy and in the Naval Academy work less efficiently during the period. The Library in Naval Academy efficiency is 75,66% in year 2002 and 75,26% in year 2003. The efficiency of the Library in the Medical Academy decreases from 70,41% in year 2002 to 64,96% in year 2003. DEA recommend benchmarks for the inefficient Libraries. For the Library in Naval Academy it is advisable to follow the model of DMU F3 - the Technical University or that of F5 - the Free University in the year 2002. Numbers in brackets show the corresponding intensities. The Library in Technical University is pointed as a benchmark twice – for the Library in the Naval Academy and for the Library in the Medical Academy. The Library in the Free University is referenced once – in 2002 to be an additional benchmark for the Library in the Naval Academy.

In order to improve their efficiency, the Libraries in the Naval Academy and in the Medical Academy can choose from the following variants or some mix of those:

1. Year 2002 the Library in the Naval Academy could reduce its expenses on printed editions by 5399,74 BGL, or reduce its electronic edition expenses by 1335,56 BGL.
2. The Library in the Naval Academy could make some efforts to increase its outputs – the borrowed literature approximately by 6214 or customers served by 5138.
3. The Library in the Naval Academy uses technical equipment, which could be decreased by 5582,85 BGL.
4. For year 2003 the Library in the Medical Academy could decrease its expenses on printed books and journals by 39733,59 BGL or it could reduce its expenses, made for electronic issues by 4552,85 BGL.
5. The expenses on technical equipment of the Library in the Medical Academy exceed with 40092,5 BGL.
6. If the Library in the Medical Academy aims to improve its relative efficiency, it has to increase the borrowed items by 22364 or to increase the number of served readers by approximately 19207.

The analyses of 2002 for the Library in the Medical Academy and of 2003 for the Library in the Naval Academy are made in the same way.

4. Conclusions

Data envelopment analysis seems to be a useful tool for small data sets estimation. When the DEA was undertaken in a group of University Libraries in the same town, the problem with population density, area size, resident population and others environment details was overcome. The method identifies best practices for the purpose of benchmarking. The analysis provides the precise corrective figure for every output and input in order to improve the efficiency of an inefficient University Library. The library administration might choose a new strategy, based on the results of DEA, in order to operate in a more efficient mode. However, this does not mean

that the results are directly transformed into attainable recommendations. In our case we apply Data envelopment analysis, using nine variables, which are not related to internal service quality. This analysis estimates the relative operating efficiency of University Libraries irrespective of quality comparisons. The Libraries of the Medical Academy and the Naval Academy tend to have lower efficiency score due to special features and resources needed. Further research - focusing on quality and specific characteristics of the different Libraries - might provide interesting insights.

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