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DEPARTMENTAL EFFICIENCY ANALYSIS IN THE UNIVERSITY: A DEA APPROACH

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Abstract

Assessing the efficiency of university is vital for effective allocation and utilization of educational resources. This study attempts to examine the efficiency of the selected academic Departments of Mawlana Bhashani Science and Technology University in Bangladesh by applying Data Envelopment Analysis (DEA). The study conducts the Correlation Coefficient Analysis, Technical Efficiency Analysis, and Partial Productivity Analysis. Then it ranks the Departments on the basis of their average technical efficiency score. The results show that seven Departments exist below the efficiency level, while five Departments succeed to obtain full efficiency score as per CRS approach. As per VRS approach, eight Departments are identified as fully efficient and rest of the Departments fail to attain satisfactory efficiency scores. The study found that the average technical efficiency under input-oriented CRS and VRS approaches were 88.17% and 92.97% respectively. The study revealed that the average scale efficiency was 95.14%. Also, in the Partial Productivity Analysis, the study found a positive correlation of each input and technical efficiency score. The study recommends providing all the amenities and training to the academic and non-academic staff to improve the level of efficiency so that the students are served better.

Keywords: University, Department, DEA, efficiency, CRS, VRS

Introduction

Universities are considered as the center of generating and transferring knowledge. University functions influence the economic development of a country and the quality life of its citizens (Aziz *et al.*, 2012). Today, the number of higher education institutions is increasing rapidly all over the world. Universities became much bigger than ever before and more universities are established in recent days. On the other hand, universities are asked to be self-sufficient and accountable to the stakeholders. The quest of accountability with less financial supports from government has caused university authorities sufferings from managerial control. Therefore, authorities might need to rely more on performance analysis mechanisms to obtain the control over the institutions.

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Thus, universities can facilitate the planning course of operation and pay attention to the aspects where improvements are needed. Since, the country's strategic planning is involved with the efficiency of university, there is a need to measure efficiency of this institutions. Also with the ever-increasing enrolments of students and limited funding into the public universities, it is no longer an option for these institutions to operate at a higher degree of efficiency. The question of how efficiently the resources should be utilized in a public university has become an important issue. Hence, a performance measurement tool is required to measure the performance across the departments of a university. It is a challenging task to analyze the efficiency of a university at the department-level, because university is a complex organization that utilizes multiple inputs to produce multiple outputs. The efficiency has been studied by many researchers in different contexts, including research units and university departments (Koksal and Nalcaci, 2006).

A variety of methods have been used to evaluate the performance of universities, and Data Envelopment Analysis (DEA) is one of the most common methods (Kuah and Wong, 2011). DEA is a non-parametric technique that is widely applied by researchers and practitioners to evaluate the relative efficiencies of a set of homogeneous organizational units that use multiple inputs to produce multiple outputs. It is the optimization method of mathematical programming and aim of DEA is to divide production units, into efficient and inefficient, by comparing each production unit with its peer units (Mikusova, 2015). DEA has the advantage over alternative (parametric) methods that it can be applied in a multiple input multiple output production context (Johnes, 2006). In past years, increasing interest in performance measurement in higher education was generated (Broadbent, 2007) and various multi-dimensional frameworks have been applied in higher education. But the practice of performance measurement and efficiency analysis is not popular in Bangladesh. Recently, few frameworks of efficiency analysis in universities have been developed. This study chooses MawlanaBhashani Science and Technology University (MBSTU) for analyzing its efficiency by using DEA. The study considers the golden rule that an academic department's performance has several dimensions. There is no positive correlation of each of the partial productivity of inputs with efficiency scores obtained by DEA. The issue of Departmental efficiency analysis of university, as a control device, has got huge attention in last few decades. It has been extensively used in efficiency measurement of university departments. Tomkins and Green (1988) studied the overall efficiency of UK accounting departments; Beasley (1995) compared chemistry and physics departments; Johnes and Johnes (1995) studied UK economics departments; Stern *et al.* (1994) compared efficiencies of all departments in one US university; and Taylor and Harris (2004) compared the relative efficiency of ten South African universities.

McMillan and Datta (1998) used DEA to measure the efficiency of Canadian universities and obtained outcomes from nine different specifications of inputs and outputs. Results

showed that average university is about 94 percent efficient. Despite the limitations of DEA, they believed that this method is useful. They also recommended DEA can be useful to analyze more homogeneous units, like faculties or departments, across university. Avkiran (2001) applied DEA to measure relative efficiency of Australian universities based on three models - overall performance (model 1), performance on delivery educational services (model 2) and performance on fee-paying enrolments (model 3). He found out the average efficiency score of universities is 0.9553 for model 1, 0.9667 for model 2, 0.6339 for model 3. Martin (2003) conducted a DEA analysis to assess the performance of departments of a university in Spain. The study revealed the existence of differences among departments of different areas. Johnes (2006) conducted a study to examine the possibility of measuring efficiency in the context of higher education. She applied DEA with bootstrapping methods, which suggested that there is a significant difference between best and worst performing English universities. Koksal and Nalcaci (2006) employed DEA to measure efficiency of academic departments of an engineering college in Turkey. They developed the measurement model in such a way that other engineering colleges can easily adapt it to their needs. Multiple criteria decision making was integrated in the study to improve the discrimination power. Kempkes and Pohl (2007) examined the efficiency of 72 public universities in German. They used the number of graduates and the amount of research grants as outputs; and the technical staff, the research staff and current expenditure as inputs. They also compared the East German universities to the West German universities. They concluded that East German universities are less efficient than the West German counterparts and the size of the university is not necessarily associated with its efficiency.

Kao and Hung (2008) applied DEA to assess the relative efficiency of academic departments at National Cheng Kung University in Taiwan. They applied cluster analysis to categorize the academic departments into groups that have similar features. They also restricted the flexibility in selecting the weights by constructing assurance region for the weight based on the prior information given by the top administrators. Kuah and Wong (2011) stated that assessing the efficiency of universities is vital for effective allocation and utilization of educational resources. They used DEA to measure efficiency because it can provide information on how much universities should improve in their performance. Ramirez-Correa *et al.* (2012) adopted DEA to assess efficiency of universities in Chile. The findings revealed that there were no significant statistical differences between public and private universities. Aziz *et al.* (2013) mentioned that in case of multiple inputs and multiple outputs, it is useful to apply DEA to measure efficiency of higher learning institutions. The studies mentioned above utilize very few input and output criteria because of the limitation in the total number of input and output criteria that can be handled by DEA. However, no such studies of university efficiency analysis have been conducted in the Bangladeshi Universities by using DEA approach. In addition, no studies have been found which mentioned the relationship between efficiency scores and partial productivity.

By considering this research gap, this research is aimed to measure efficiency of Bangladeshi universities by using DEA approach. The major objective of the study is to examine the efficiency and effectiveness of selected Departments of Mawlana Bhashani Science and Technology University. The specific objectives of the study are: i) to investigate the efficiencies of the selected Departments of MBSTU; ii) to determine the inputs that are required to targeted outputs of these Departments; and iii) to find out the effective and efficient use of inputs to achieve better outputs in the selected Departments.

Materials and Methods

From among the 15 Departments of MBSTU, the study selected 12 Departments that had given the graduation degree by the year 2014. The selected Departments are Textile Engineering (TE), Criminology and Police Science (CPS), Environmental Science and Resource Management (ESRM), Food Technology and Nutritional Science (FTNS), Computer Science and Engineering (CSE), Biotechnology and Genetic Engineering (BGE), Information and Communication Technology (ICT), Physics (PHY), Chemistry (CHEM), Business Administration (BA), Mathematics (MATH) and Statistics (STAT). The study covers only one academic year, i.e. 2014.

Data were collected from the selected Departments and concerned offices of the university of the year 2014. The study applied DEA (non-parametric technique) to measure the technical and scale efficiency of the Departments under input oriented Constant Return to Scale (CRS) and Variable Return to Scale (VRS) approach. The study has taken two types of variables - input and output - after considering the correlation among the input and the output variables. Result (X_1) and No. of Graduates (X_2) – are the *output variables*; and Budget (Y_1), No. of Students Admitted (Y_2), No. of Academic Staff (Y_3) and No. of Non-academic Staff (Y_4) - are the *input variables.* The variables used in this study are those contributing to teaching/learning and research performance.

The study ranked the Departments on the basis of average technical efficiency scores. In case of same scores, total numbers of peers are considered for ranking the Departments. Data were initially fed into SPSS-20 software and transformation of variables was done to make them usable. For testing the hypotheses, data were analyzed and interpreted through Technical Efficiency Analysis (in CRS and VRS approach), and Partial Productivity Analysis (in CRS and VRS approach). In this regard, the study used Correlation Co-efficient of Variance (Parametric Techniques) for better understanding.

Distribution of Data Variables

Table 1 shows the descriptive statistics of input and output variables of the selected departments for the year 2014. Here, the output variables are Results (X_1), and No. of Graduates (X_2). The input variables are Budget (in lac) (Y_1), No. of Students Admitted (Y_2), No. of Academic Staff (Y_3) and No. of Non-academic Staff (Y_4).

Table 1. Descriptive Statistics: Outputs and Inputs of the Selected Departments

Particulars	Output Variables		Input Variables			
Departments	Results (X_1)	No. of Graduates (X_2)	Budget (in Lac) (Y_1)	No. of Students Admitted (Y_2)	No. of Academic Staff (Y_3)	No. of Non-academic Staff (Y_4)
TE	3.39	49	70.38	51	6	10
CPS	3.35	34	73.67	51	8	8
ESRM	3.47	40	74.08	50	9	10
FTNS	3.54	30	65.46	54	9	9
CSE	3.21	41	91.88	48	6	12
BGE	3.22	33	83.2	53	8	9
ICT	3.25	42	85.85	55	8	11
PHY	3.27	19	32.95	25	6	8
CHEM	3.21	21	38.97	25	5	11
BA	3.38	44	28.09	54	5	4
STAT	3.35	24	36.11	25	6	5
MATH	3.34	18	31.15	25	5	7
Average	3.33	32.92	59.32	43	6.75	8.67
Maximum	3.54	49	91.88	54	9	12
Minimum	3.21	18	28.09	25	5	4

Source: Computed from the original data of the selected Departments for the year 2014

DEA: Concepts

Data Envelopment Analysis (DEA) is a non-parametric mathematical programming approach to frontier estimation and is a powerful service management technique. Charnes, Cooper and Rhodes (1978) developed the approach to evaluate non-profit and public sector organizations. The technique can be applied in banks, supermarkets, hospitals, schools, public universities, public libraries and so forth.DEA is awell-established framework for conducting efficiency measurement in multi-dimensional system perspective (Lu and Hung, 2011). It involves the use of linear programming methods to construct a non-parametric piecewise surface (or frontier) over the data so as to be able to calculate efficiencies relative to this surface (Coelli, 2005).

DEA is used to measure the technical efficiency of homogenous production units termed as Decision Making Units (DMU) and the technical efficiency is the ratio of weighted sum of outputs to the weighted sum of inputs (Flegg *et al.*, 2003). DEA approach helps to design a virtual (Hypothetical) unit of each inefficient unit and virtual units are a part of efficient frontier and are calculated as a combination of selected efficient units called as peer units or peer. CCR (Charnes, Cooper and Rhodes) Model and BCC (Banker, Charnes and Cooper) Model are two basic models of DEA. CCR Model assumes constant

returns to scale and BCC Model assumes variable returns to scale and all of the method can be input and output-oriented (Mikosova, 2015). The input and output oriented measures will only provide equivalent measures of technical efficiency when constant returns to scale exist, but will be unequal when variable returns to scale are present (Fare and Lovell, 1978).

In DEA analysis, some units are regarded as efficient and some are considered as non-efficient. A DMU will be called efficient only when the optimal value of efficiency is equal to 1 and the inefficient units have value of efficiency less than 1. This study utilizes input oriented CRS and VRS approach where DMUs deemed to produce optimum amount of output with a proportional reduction on inputs usage and their proper utilization.

Results and Discussions

Analysis of Correlation Coefficient

Table 2. Correlation Coefficient among the Output and Input Variables

Variables	Output variables		Input variables			
	Results (X_1)	No. of Graduates (X_2)	Budget (in Lac) (Y_1)	No. of Students Admitted (Y_2)	No. of Academic Staff (Y_3)	No. of Non-academic Staff (Y_4)
Results (X_1)	1					
No. of Graduates (X_2)	0.376181	1				
Budget (in Lac) (Y_1)	0.39488	0.601426*	1			
No. of Students Admitted (Y_2)	0.291045	0.84669**	0.709784**	1		
No. of Academic Staff (Y_3)	0.422644	0.271645	0.66702*	0.609087*	1	
No. of Non-academic Staff (Y_4)	0.30792	0.229579	0.708053**	0.226138	0.315528	1

Source: Computed from the original data of the selected Departments for the year 2014
**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 2 depicts the correlation coefficient among the output and input variables. It shows that the output variable X_1 has insignificant correlation with output variable X_2 and input variables Y_1, Y_2, Y_3 and Y_4. On the other hand, the output variable X_2 has significant correlation with input variable Y_2 at the 1% level and with Y_1 at the 5% level. X_2 also has insignificant correlation with input variables Y_3 and Y_4. Similarly, Table 2 shows that input variable Y_1 has significant correlation with input variable Y_2 and Y_4 at the 1% level and with Y_3 at the 5% level. In the same way, input variable Y_2 has significant correlation with the input variable Y_3 at the 5% level. Y_2 also has insignificant correlation with input variable Y_4. Table 2 also displays that input variable Y_3 has insignificant correlation with input variable Y_4.

Measurement of Technical Efficiency

Table 3. Technical Efficiency under Input Oriented CRS Approach

Department	Technical Efficiency	Working Percentage (%)	Total Peers	Rank
TE	1.000	100	5	1(5)
CPS	0.731	73.1	0	6(0)
ESRM	0.833	83.3	0	4(0)
FTNS	0.646	64.6	0	8(0)
CSE	0.913	91.3	0	3(0)
BGE	0.685	68.5	0	7(0)
ICT	0.795	79.5	0	5(0)
PHY	0.978	97.8	0	2(0)
CHEM	1.000	100	3	1(3)
BA	1.000	100	4	1(4)
STAT	1.000	100	6	1(6)
MATH	1.000	100	2	1(2)
Average	.88175	88.17		

Source: Computed from the data of the selected departments for the year 2014

Table 3 represents the measurement of technical efficiency scores of selected Departments as per DEA; the input-oriented constant return to scale (CRS) approach is applied during the period. The input-oriented measures state that how many inputs can be proportionally reduced without changing the output quantities produced. It is found that the decision making units (DMUs) of TE, CHEM, BA, STAT and MATH have full efficiency score (1) for the study year 2014. Similarly, the DMUs of CPS, ESRM, FTNS, CSE, BGE, ICT and PHY have efficiency score (.73), (.83), (.65), (.91), (.69), (.80) and (.98) respectively that indicates their operational inefficiencies. On the basis of the set criteria, STAT has gained the 1st position. Although TE, BA, CHEM and MATH have the equal efficiency score, but they have smaller total peers; that is why, these Departments stood in the next positions - 2nd, 3rd, 4th and 5th respectively. Similarly, PHY, CSE, ESRM, ICT, CPS, BGE and FTNS stood at the 6th, 7th, 8th, 9th, 10th, 11th and 12th position respectively, as per their efficiency score.

Table 4 describes the technical efficiency scores of the selected Departments as per DEA; the input-oriented variable return to scale (VRS) approach is applied during the period. It is noticeable that the DMUs of TE, ESRM, FTNS, PHY, CHEM, BA, STAT and MATH have the same efficiency score (1). That means the Departments are technically efficient. In the same way, the DMUs of CPS, CSE, BGE and ICT have efficiency score (.73), (.93), (.70) and (.80) respectively. On the basis of set criteria, TE and STAT stood at the 1st position. Although, ESRM, FTNS, PHY, CHEM, BA and MATH have the same efficiency score, but it has smaller total peers; thus, BA, CHEM and MATH stood at 2nd, 3rd and 4th position respectively and ESRM, FTNS and PHY stood at 5th position. Similarly, CSE, ICT, CPS and BGE got 6th, 7th, 8th and 9th position respectively.

Table 4. Technical Efficiency under Input Oriented VRS Approach

Department	Technical Efficiency (TE)		Working Percentage (%)		Total Peers	Rank
	VRS TE	Scale	VRS TE	Scale		
TE	1.000	1.000	100	100	4	1(4)
CPS	0.731	1.000	73.1	100	0	4(0)
ESRM	1.000	0.833	100	83.3	0	1(0)
FTNS	1.000	0.646	100	64.6	0	1(0)
CSE	0.932	0.980	93.2	98.0	0	2(0)
BGE	0.699	0.980	69.9	98.0	0	5(0)
ICT	0.795	1.000	79.5	100	0	3(0)
PHY	1.000	0.978	100	97.8	0	1(0)
CHEM	1.000	1.000	100	100	2	1(2)
BA	1.000	1.000	100	100	3	1(3)
STAT	1.000	1.000	100	100	4	1(4)
MATH	1.000	1.000	100	100	1	1(1)
Average	.92975	.951417	92.97	95.14		

Source: Computed from the original data of the selected Departments for the year 2014

It is proved that the overall efficiency score of TE and STAT is better than other Departments under the DEA, input-oriented variable return to scale (VRS) approach. The DMUs of TE, CPS, ICT, CHEM, BA, STAT and MATH have the efficiency score 1, that means, these Departments are technically efficient. In the same way, the DMUs of ESRM, FTNS, CSE, BGE and PHY have efficiency score (.83), (.93), (.65), (.98), (.98) and (.98) respectively.

Analysis of Partial Productivity

Partial productivity measures are simple and operational measures as it may contribute to a set of performance indicators (Rushdi, 2009). For analyzing the partial productivity, all the input variables and the technical efficiency are taken for calculation. Here, PP-Y_1 denotes Partial Productivity of Budget, PP-Y_2 denotes Partial Productivity of No. of Student Admitted, PP-Y_3 denotes Partial Productivity of No. of Academic Staff, and PP-Y_4 denotes Partial Productivity of No. of Non-academic Staff.

Table 5. Partial Productivity (PP) by CRS Approach

	Average Technical Efficiency	PP-Y_1	PP-Y_2	PP-Y_3	PP-Y_4
Average Technical Efficiency	1				
PP-Y_1	0.613922	1			
PP-Y_2	0.783389	0.339844	1		
PP-Y_3	0.62441	0.599234	0.054606	1	
PP-Y_4	0.245599	0.811992	0.09127	0.603637	1

Source: Calculated by using the selected variables

Table 5 displays the correlation of partial productivity and efficiency scores, according to the input-oriented CRS approach. There is a positive correlation of each variable with technical efficiency score by the degree of 0.61, 0.78, 0.62 and 0.24, respectively. Hence, the hypothesis (Hypothesis 1) is rejected in case of each variable, as per the CRS approach.

Table 6. Partial Productivity (PP) by VRS Approach

	Mean Technical Efficiency	PP-Y_1	PP-Y_2	PP-Y_3	PP-Y_4
Mean Technical Efficiency	1				
PP-Y_1	0.505814	1			
PP-Y_2	0.560517	0.339844	1		
PP-Y_3	0.321214	0.599234	0.054606	1	
PP-Y_4	0.158933	0.811992	0.09127	0.603637	1

Source: Calculated by using the selected variables

Table 6 describes the correlation of partial productivity and efficiency scores, according to the input-oriented VRS approach. There is a positive correlation of each variable with technical efficiency score by the degree of 0.50, 0.56, 0.32 and 0.15, respectively. Hence, the hypothesis (Hypothesis 1) is rejected in case of each variable, as per the VRS approach.

Conclusions

Organizational efficiency analysis is one of the fundamental managerial functions for effective planning and controlling. This study has analyzed and evaluated the relative efficiency of the selected Departments of MBSTU by using Data Envelopment Analysis. The results revealed that under input-oriented CRS approach, Textile Engineering, Chemistry, Business Administration, Statistics, and Mathematics Departments were technically efficient. However, Criminology and Police Science, Environmental Science and Resource Management, Food Technology and Nutritional Science, Computer Science and Engineering, Biotechnology and Genetic Engineering, Information and Communication Technology, and Physics were technically inefficient due to the insufficient budget and the proportionately smaller number of academic and non-academic staff. Under input-oriented VRS approach, the DMUs of Textile Engineering, Environmental Science and Resource Management, Food Technology and Nutritional Science, Physics, Chemistry, Business Administration, Statistics, and Mathematics were found technically efficient. But the DMUs of Criminology and Police Science, Computer Science and Engineering, Biotechnology and Genetic Engineering and Information and Communication Technology were technically inefficient¸ because of the smaller number of academic staff in relation to the number of students. Interestingly, in both CRS and

VRS approach, Textile Engineering, Chemistry, Business Administration, Statistics, and Mathematics Departments showed technical efficiency. That means these Departments utilized their resources efficiently for producing graduates. The results also show that there is a positive relation between efficiency scores and partial productivity. This finding is useful for the university administrators and policy makers for making better decisions and for allocating resources efficiently. University authority can use this analysis to distinguish efficient and inefficient departments and can set the efficient departments as benchmark as if the efficient departments are the model department in the university. It will help the follower departments to know how efficiently those departments utilized their resources. To improve the level of efficiency across the Departments, firstly both the academic and the non-academic staffs should be provided training. Universities have to provide all the amenities to the Departments so that the students are served and they can have an environment where they can stay up to the completion of the degree. Government has to allocate more budgets and even provide more subsidies, if necessary, to the universities for academic and research works. Departments need to properly utilize the allocated budget by following their strategic plan. In addition, Departments can arrange workshop, seminar etc. to improve the efficiency of staff, teachers and students. Teachers should play the role of senior researcher whereas students will act as junior researcher. In consequence, a research-based culture will be developed where students will get motivation to study and to acquire good manners. In a word, aim of the efficiency analysis is not only to know the current performance but also to open up the way of efficiency practice in the university setting.

References

Avkiran, N.K. 2001. Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. *Socio- Economic Planning Sciences*, **35**(1): 57-80.

Aziz, N.A.A., R.M. Janor and R. Mahadi. 2013. *Comparative Departmental Efficiency Analysis within a University: A DEA Approach*, Faculty of Computer Science and Mathematics, University Teknologi, Malaysia.

Beasley, J. 1990. Comparing university departments' Omega International, *Journal of Management Science*, **18**: 171-183

Broadbent, J. 2007. *Performance measurement system in and of Higher education institutions in England: Professionalism, managerialism and management*, Roehampton Research Paper. *(*Retrieved from http:/rrp.roehampton.ac.uk/bsspapers/3)

Charnes, A., W. Cooper and E. Rhodes. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research*, ***2***: 429-444.

Coelli, T.J. and Rao, D.S.P. 2005. Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980-2000, *Agricultural Economics*, **32**: 115-134.

Fare, R. and C.A.K. Lovell 1978. Measuring the Technical Efficiency of Production, *Journal of Economic Theory*, **19**: 150-162.

Flegg, A.T., D.O. Allen, K. Field and T.W. Thurlow. 2003. Measuring the Efficiency and Productivity of British Universities: An Application of DEA and the Malmquist Approach, University of the West of England, Department of Economics, Series Discussion Paper No. 304.

Johnes, J. and G. Johnes. 1995. Research funding and performance in UK university departments of economics: a frontier analysis, *European Economics Review*, **14**: 301-314

Johnes, J. 2006. Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review,* **25**(3), 273-288.

Kao, C. and H.T. Hung. 2008. Efficiency analysis of university departments: An empirical study. *Omega*, **36**(4), 653-664.

Kempkes, G. and C. Pohl. 2007. *The Efficiency of German Universities- Some Evidence from Non-Parametric and Parametric Methods.*CESifo Venice Summer Institute 2007, 18-19.

Köksal, G. and B. Nalçaci. 2006. The relative efficiency of departments at a Turkish engineering college: a data envelopment analysis. *Higher Education*, **51**(2), 173-189.

Kuah, C.T. and K.Y. Wong. 2011. *Efficiency assessment of universities through data envelopment Analysis*, UniversitiTeknologi Malaysia, Malaysia. (Retrieved from www.elsevier.com/ locate/procedia)

Martín, E. 2003. An application of the Data Envelopment Analysis Methodology in the performance assessment of the Zaragoza University Departments. *Documentos de trabajo (Universidad de Zaragoza. Facultad de CienciasEconómicas y Empresariales)*, (6), 1.

McMillan, M.L. and D. Datta. 1998. The Relative Efficiencies of Canadian Universities: A DEA Perspective. *Canadian Public Policy*, **24**(4), 485-511.

Mikusova, A. 2015. *An application of DEA methodology in efficiency measurement of the Czech public universities*, Department of Public Finance, University of Economics, Prague.

Ramírez-Correa, P., J.C. Peña-Vinces and J. Alfaro-Pérez. 2012. Evaluating the efficiency of the higher education system in emerging economies: Empirical evidences from Chilean universities. *African Journal of Business Management*, **6**(4), 1441-1448.

Rushdi, A.A. 2009. Performance Measure for the Commercial Banks in Bangladesh: An Application of Total Factor Productivity, *AIUB Business Economics Working Paper Series*, **1**: 1-16.

Stern, Z.S., A. Mehrez and A. Barboy. 1994. Academic departments efficiency via DEA, *Computers and Operations Research*, **21**: 543-556

Taylor, B. and G. Harris. 2004. Relative efficiency among South African Universities: a data envelopment analysis, *Higher Education*, **47**: 73-89

Tomkins, C. and R. Green. 1988. An experiment in the use of data envelopment analysis for evaluating the efficiency of UK university departments of accounting, *Financial Accountability Management*, **4**: 147-164