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Data Envelopment Analysis and Efficiency Analysis of Higher Education Institutions: Example of Selçuk University

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Abstract

In this study, it was tried to determine how effective and efficient they work with input (number of academic staff, number of administrative staff, number of students,) and output (total expence, number of graduates, academic grade point average) values used by Selcuk University affiliated faculties and four year college. It is important to inform senior management about the current situation and to create insight in decisions to be taken under variable factors for the future. In this study, Selcuk University 2018 Administration Annual Report and 2018 Academic Incentive Score data were used. In this study, data envelopment analysis (DEA), which is a parameterless technique which uses linear programming principles, is used to perform relative efficiency analysis in order to enable comparison with each other. As a result of the study, relative efficiency analysis of the units were performed and evaluations were made regarding the ways in which the input and output values were not effective and the ways to be effective. If it is effective, in order to maintain the current level of activity, if the idle (unutilized capacity) capacity arose, the assessments regarding the idle capacity were made.

Keywords: *Activity Measurement, Universities, Data Envelopment Analysis, Lineer Programming.*

2010 Mathematics Subject Classification: *62R07, 65L03.*

1. Introduction

Universities are ”institutions that produce and disseminate knowledge and educate qualified work force needed in every field according to the objectives determined [14]. It is indicated that the most distinctive feature that distinguishes universities from others among higher education institutions is their concentration on the function of study [13], Therefore, the efficient assessment of the universities is very important for the efficient distribution and use of the resources used [5] The Ministry of National Education and the Council of Higher Education are authorized and responsible for studies on improving the educational quality of higher education institutions in our country, implementation of educational activities, balanced distribution of higher education services throughout the country, to take measures to ensure equality of opportunities and opportunities for candidates to access to higher education through effective and efficient use. The fact that universities are decision-makers, have independent legal entities, and act independently in decision-making and implementation; lack of a foresight mechanism for the decisions to be taken, with the usefulness of the actions taken, and the appropriateness of the decisions taken; act independently in decision-making raises the problem of lack of knowledge of the activities of universities and units. In this study, it was tried to determine how effectively and efficiently the input and output values used by the faculties of Selcuk University and four-year high schools compared to each other. Since more than one input and output will be used in this study, the nonparametric DEA method is used. When the literature is examined in the field of Higher Education Institutions regarding Data Envelopment Analysis, which is one of the efficiency analysis techniques, some academic studies are as follows; In his study, Rosenmayer [16] compared and evaluated five articles on the evaluation of the efficiency of universities using the data envelopment analysis method.In his study, Özel [7], aimed to determine the efficiency of state universities in Turkey and to rank them in terms of super-efficiency model and efficiency. In the study of Gündüz et al [12], Vocational Colleges of different universities were measured and it was concluded that the Vocational Schools increased the outputs instead of reducing the inputs to provide efficiency. Kuah and Wong [4] presented a data envelopment analysis (DEA) model to evaluate the relative teaching and research efficiency of universities together in their study. In the study, the model was tested using a hypothetical example and its use and effects in university performance measurement were explained. In the study of Çınar [19], teaching and research efficiencies of 45 public universities in Turkey have been measured for 2010. As a result of the study, it was seen that universities reached different scores

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in terms of teaching and research efficiencies and it is shown that each university can increase the total efficiency score by giving priority to the field in which it is more effective. In his study, Bal [18] aimed to investigate the efficiencies of 23 Foundation Universities, measured their efficiencies anconcluded that inefficient universities had amount of outputs required to be increased andamount of inputs required to be decreased in order to work more efficiently and prevent wastage.
In the study of Özden [17], relative total, technical and scale efficiencies of foundation universities in Turkey were analyzed by using DEA models. In their studies, Kutlar and Babacan [3], used DEA to measure the relative effectiveness of 53 public universities. It was concluded that universities did not make good use of scale efficiency in input and output- oriented models. In their study, Kempkes and Pohl [6] analyzed the productivity of 72 German universities between 1998-2003 with DEA technique. They concluded in the study that the relative productivity of West German universities is higher. In their studies, Baysal et al [9], It was aimed to measure the relative efficiencies of 50 state universities in Turkey by DEA. In the study of Gülcü et al. [2], the efficiency of Faculty of Dentistry, Cumhuriyet University, for the years 1999-2001 was measured. In their studies, Flegg et al. [15] used DEA technique to examine the technical efficiency of 45 British universities in the periods of 1880 / 1881-1992 / 1993. In their studies, Abott and Doucouliagos [8], used DEA technique, which is one of the nonparametric techniques, to determine the technical efficiency of universities in Austria. As a result of their studies, they came to the conclusion that Austrian universities recorded higher productivity levels compared to each other. In their studies, Mcmillan and Datta [10] used DEA technique to evaluate the relative efficiency of 45 Canadian universities and made use of nine input and output specifications. The study consists of two parts, theoretical and empirical. The obtained data were dissolved in the Linear-Interactive and Discrete Optimizer (LINDO) package program and the results were evaluated. The study consists of four parts including introduction. In the introduction; the purpose of the study, the method of the study, the organization of the study and the literature review are included. In the second part, the conceptual framework of the data envelopment analysis method has been mentioned and data envelopment analysis and efficiency analysis are included. The third section includes the findings of the analysis. In the conclusion part, the findings were interpreted and evaluated.

2. Efficiency Analysis With Data Envelopment Analysis

In order to improve the performance of decision-making units, the evaluation of the activities performed at the end of certain periods is made by using some efficiency measurement methods. Data Envelopment Analysis (DEA) method is used in non-parametric efficiency measurement analyzes [11], This method; It is a linear programming (LP) based approach that allows to measure the relative total factor efficiency of DMUs in cases where there are many input and output variables with different measurement units and they cannot be reduced to a common criterion basis. Charnes-Cooper Rhodes (CCR) and Banker, Charnes-Cooper (BCC) models used in DEA; It can be set up in two different ways, input oriented and output oriented. CCR models are used in the calculation of relative total activities under the assumption of constant returns to scale, that is, based on the assumption that all Decision Making Units (DMU) operate at an optimal scale. However, in real life, there are systems that have returns that vary according to scale. Banker, Charnes and Cooper developed the BCC model, which is referred to by the initials of their names, in 1984 in order to determine the efficiency of systems with varying returns on scale. For this, they added the constraint called convexity constraint to the dual of CCR models. Primal and dual forms of input oriented CCR and BCC models are given in table 1 [17].

Tablo I: Input Oriented CCR And BCC Models

Input Oriented CCR Models			
Primal		**Dual**	
$Enb \sum_{r=1}^{s} u_r y_{rk}$	(1)	$Enkq_k$	(6)
$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij}$	(2)	$\sum_{j=1}^{n} \lambda_{rj} X_{ij} \leq q_k X_{ik}$	(7)
$\sum_{i=1}^{k} v_i x_{ik} - \sum_{i=1}^{m} v_i x_{ij} = 1$	(3)	$\sum_{j=1}^{n} \lambda_{jk} Y_{rj} \geq Y_{rk}$	(8)
$u_{rk} \geq 0, \quad r = 1,2,\ldots,s$	(4)	$\lambda_{kj} \geq 0$	(8)
$v_{ik} \geq 0, \quad i = 1,2,\ldots,m$	(5)	$\lambda_{kj} \geq 0$	(9)
Input Oriented BCC Models			
Primal		**Dual**	
$Enkq_k$	(10)	$Enb \sum_{r=1}^{s} u_r y_{rk} - u_k$	(15)
$q_k X_{ik} - \sum_{j=1}^{n} \lambda_{rj} X_{ij} \geq 0$	(11)	$\sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_k \leq 0$	(16)
$\sum_{j=1}^{n} \lambda_{rj} X_{ij} \leq q_k X_{ik}$	(12)	$\sum_{i=1}^{m} v_i x_{ij} = 1$	(17)
$\sum_{j=1}^{n} \lambda_{jk} = 1$	(13)	$u_r, v_i \geq \varepsilon > 0$ random	(18)
$\lambda_{kj} \geq 0$	(14)		(19)

On the model;
Enb :maximization
Enk :minimization
u_r : the weight given to the r'th output by k decision units,
v_i: the weight given to the i'th input by k decision units
Y_{rk} : r'th output produced by k decision units,
X_{ik} : i'th input used by k decision units
Y_{rj}: r'th output produced by the j'th decision-making unit

X_{ij} : i'th input used by the j'th decision-making body
ε : positive very small value, it is expressed as [17].
Data Envelopment Analysis (DEA) models were formed for all decision-making units, solved in LINDO package program and the results were evaluated. As a result of the CCR-DEA results, Dual CCR-DEA models were formed for inefficient decision-making units and solved in Lindo package program, reference sets were created. According to the reference set data, rate of change for new input values have emerged for inefficient decision-making units. BCC-DEA models were formed to see the value of returns which increases or decreases according to the scale and the results were evaluated by solving them in the LINDO package program [1].

3. Scope of the Study and Data

In the study, the faculties, colleges and conservatories affiliated to Selcuk University as Decision Making Units (DMU) will be examined according to inputs and outputs. In this study, three inputs (number of academic staff, number of administrative staff, number of students) and three outputs (total expenditure, number of grad students, academic incentive average score) of 2018 for 20 decision-making units shown in table 2 have been discussed and shown in table 3 below. The faculties and four-year colleges selected as the decision-making units in Selcuk University have been discussed.

Tablo 2: Decision-Making Units That Are The Study Subject

Faculty/School/Conservatory			
A1	Akşehir Economic And Administrative Sciences Faculty	A11	Faculty of Health Sciences
A2	Beyşehir Ali Akkanat Faculty of Business	A12	Faculty of Art and Design
A3	Beyşehir Ali Akkanat Faculty of Tourizm	A13	Faculty of Sport Sciences
A4	Faculty of Dentistry	A14	Faculty of Technology
A5	Faculty of Letters	A15	Faculty of Medicine
A6	Faculty of Sciences	A16	Faculty of Tourizm
A7	Faculty of Fine Arts	A17	Faculty of Veterinary Medicine
A8	Faculty of Law	A18	Faculty of Agriculture
A9	Economic And Administrative Sciences Faculty	A19	Akşehir Kadir Yallagöz School of Health
A10	Faculty of Communication	A20	Dilek Sabancı State Conservatory

Table 3: Input and Output Table

Input Oriented CCR Models			
	Entries	**Outcomes**	
X1	Number of Academic Staff	Y1	Total Expense
X2	Number of Administrative Staff	Y2	Number of Graduates
X3	Number of Students	Y3	Academic Grade Point Average

The data set is based on Selçuk University's 2018 Administrative Activity Report and 2018 academic incentive application data, and the data set is shown in table 4.

Table 4: Data Set

		ENTRIES			OUTCOMES		
lUnit Codes	Decision Units	Number of Academic Staff	Number of Administrative Staff	Number of Students	Total Expense	Number of Graduates	Academic Grade Point Average
		X1	X2	X3	Y1	Y2	Y3
A1	Aksehir Faculty of Economic And Administrative Sciences	9	10	674	1.771	134	25
A2	Beysehir Ali Akkanat Faculty of Business	9	10	654	1.785	121	21
A3	Beyşehir Ali Akkanat Faculty of Tourizm	11	9	243	1.667	47	26
A4	Faculty of Dentistry	123	23	678	11.419	113	8
A5	Faculty of Letters	174	20	7149	18.695	1103	14
A6	Faculty of Sciences	156	26	1475	19.302	132	19
A7	Faculty of Fine Arts	54	10	1120	6.475	220	12
A8	Faculty of Law	45	15	3144	4.847	732	10
A9	Faculty of Economic And Administrative Sciences	104	15	6188	13.207	1482	19
A10	Faculty of Communication	75	12	2936	9.281	584	10
A11	Faculty of Health Sciences	84	17	2580	8.636	591	14
A12	Faculty of Art and Design	47	8	222	4.275	36	5
A13	Faculty of Sport Sciences	67	7	1295	7.663	190	15
A14	Faculty of Technology	62	11	2213	7.658	210	19
A15	Faculty of Medicine	492	11	1299	41.284	157	9
A16	Faculty of Tourizm	21	8	1336	2.825	224	25
A17	Faculty of Veterinary Medicine	134	23	1090	18.789	193	19
A18	Faculty of Agriculture	144	25	2216	18.020	375	21
A19	Akşehir Kadir Yallagöz School of Health	15	6	576	1.724	129	3
A20	Dilek Sabancı State Conservatory	28	5	157	3.225	30	3

- Aksehir Faculty of Engineering and Architecture, Faculty of Education, Faculty of Nursing, Faculty of Pharmacy, Faculty of Islamic Sciences, School of Civil Aviation, Beyşehir Ali Akkanat School of Applied Sciences and Çumra School of Applied Sciences are not included in the data set since they did not produce any graduates yet.
- Thousands digits of total expenses have been rounded off. Actual expenses are approximately X 1000.
- The academic incentive average score has been obtained by dividing the total score of the staff who benefit from the academic incentive allowance by the total number of academic staff.
- In the number of administrative staff, only 657 civil servants have been included in the data set of the number of employees working according to the law.

4. Findings

Using the data in Table 4, input-oriented CCR-DEA models were created according to total expenditure, number of graduate students and academic incentive point average and analyzed in LINDO package program. Then, dual CCR-DEA models were created and analyzed in the LINDO package program in order to activate the ineffective DMUs in the input-oriented CCR-DEA models created according to the total expenditure, the number of graduates and the academic incentive point average. As a result of the solution of the Dual CCR-DEA models, firstly, efficiency and reference values were found for each DMU, then new input ratios and values for ineffective DMUs were found according to the reference values of the ineffective DMUs in the solution of dual CCR-DEA models. Finally, input oriented BCC-DEA models were created and analyzed in LINDO package program to determine the decreasing, fixed and increasing return values.

4.1. CCR-DEA Model Solution

By using the data in table 4 and by modelling the data of 20 units within the framework of CCR-DEA's objective functions and constraints, it has been analysed in the LINDO package program, and the values indicated in table 5 and table 6 emerged.

Table 5: CCR-DEA Detailed Result Table

Unit Codes	**X1**	**X2**	**X3**	**Y1**	**Y2**	**Y3**	**Efficiency**
A1	0,012622	-	0,001315	-	0,006297	0,006249	1
A2	0,060225	-	0,000700	0,00454	0,001566	-	1
A3	-	-	0,004115	-	-	0,0038462	1
A4	-	-	0,001475	0,000016	0,006017	-	0,860
A5	0,003710	0,018891	-0,000003	0,000049	-	-	0,918
A6	0,003536	0,017396	-0,000003	0,000046	-	-	0,894
A7	0,006126	0,039716	0,000243	0,000085	0,000940	0,011450	0,895
A8	0,003554	-	0,000267	-	0,001349	0,001252	1
A9	-	-	0,000162	-	0,000675	-	1
A10	0,012225	0,006927	-	0,000095	0,000083	-	0,928
A11	-	-	0,000388	0,000004	0,001579	0,000532	0,972
A12	-	-	0,004505	0,000092	0,012291	0,013986	0,905
A13	0,006108	0,039598	0,000242	0,000085	0,000937	0,011416	1
A14	0,010569	0,032366	-0,000005	0,000108	-	0,006775	0,954
A15	-	-	0,000770	0,000024	-	-	1
A16	0,008754	0,053872	0,000288	-	0,002091	0,021267	1
A17	0,002747	0,001634	0,000545	0,000050	-	0,003648	1
A18	0,005643	0,007495	-	0,000048	0,000028	0,001505	0,900
A19	-	-	0,001736	0,000017	0,007071	0,002384	0,947
A20	-	-	0,006369	0,000130	0,017380	0,019777	1

Tablo 6: CCR-DEA Result Table

Unit Codes	Efficiency	Unit Codes	Efficiency
A1	1	A11	0,972
A2	1	A12	0,905
A3	1	A13	1
A4	0,860	A14	0,954
A5	0,918	A15	1
A6	0,894	A16	1
A7	0,895	A17	1
A8	1	A18	0,900
A9	1	A19	0,947
A10	0,928	A20	1

When examining the result of values as a result of analysis, it can be said that the decision-making units of A1, A2, A3, A8, A9, A13, A15, A16, A17, A20 were efficient and decision-making units of A4, A5, A6, A7, A10, A11, A12, A14, A18 and A19 were inefficient. In this case, we can determine the reference sets and shadow prices by analysing the dual models in order to enable the decision-making units of A4, A5, A6, A7, A10, A11, A12, A14, A18 and A19. Accordingly, when examining the table given above, it is seen that 10 of 20 decision-making units have reached the efficiency value and 10 of them are not completely efficient. In the light of the data obtained, by forming a reference set for efficient units and inefficient units, in other words, by taking efficient decision-making units as reference for inefficient decision-making units, input and output values will be prepared again. Dual CCR-DEA model shall be installed in order to find and enable reference set for inefficient unit. This model installed has been solved in the LINDO package program and the reference set table specified in table 7 below has been created.

4.2. Dual CCR-DEA Model Solution

In order to enable the decision–making units of the A4, A5, A6, A7, A10, A11, A12, A14, A18 and A19 decision units which are not completely efficient in the CCR-DEA model, the reference sets are obtained by analysing them in the Dual CCR-DEA model, as seen on table 7.

Table 7: Efficiency Value and Reference Set for Decision-making Units in Dual CCR-DEA Model

Unit Codes	Efficiency	Reference Set	Decision Variable
A1	1	K1	-
A2	1	K2	-
A3	1	K3	-
A4	0,860	K9,K20	0,004986-3,520356
A5	0,914	K9,K13,K15	0,566437-1,373219-0,016740
A6	0,894	K15,K17	0,009451-1,006537
A7	0,895	K3,K9,K13,K15,K17	0,203523-0,109781-0,010571-0,005880-0,232162
A8	1	K8	-
A9	1	K9	-
A10	0,928	K2,K9,K17	0,025831-0,360990-0,237762
A11	0,972	K3,K9,K20	0,141754-0,372441-1,079339
A12	0,905	K3,K15,K20	0,074184-0,026884-0,943084
A13	1	K13	-
A14	0,950	K9,K13,K16,K17	0,013515-0,309846-0,403420-0,211054
A15	1	K15	-
A16	1	K16	-
A17	1	K17	-
A18	0,900	K1,K9,K16,K17	0,058875-0,131614-0,030180-0,856472
A19	0,947	K3,K9,K20	0,034504-0,082314-0,179648
A20	1	K20	-

After the determination of reference sets by analysing the Dual CCR-DEA model, it is provided to increase the outputs of the inefficient decision-making unit, whether its inputs are used as idle, or to reduce it within the determined ratios and to make this decision-making unit efficient. After the calculations using the decision variables in the reference set, the percentage change with the positive value indicated in Table 8 means that the same performance will be delivered even if it is at a lower level where idle capacity is existing. The percentage change with the negative value means to increase the amount of input in order to be efficient.

Table 8: Table of New Input Change Rates for Inefficient Decision-making Units

Unit Codes	X1(%)	X2(%)	X3(%)
A4	0,19	0,23	0,14
A5	0,09	0,09	0,26
A6	0,11	0,11	0,25
A7	0,10	0,10	0,10
A10	0,07	0,07	0,15
A11	0,16	0,28	0,03
A12	0,14	0,29	0,09
A14	0,05	0,05	0,43
A18	0,10	0,10	0,18
A19	0,07	0,59	0,05

4.3. BCC-DEA Model Solution

In the CCR-DEA model, it is acted with the assumption that decision-making units are subject to a constant return scale. And in the BCC-DEA model, because the efficiency limits are more flexible and because the decreasing and increasing income scale situations are taken into account, the values might be different. However, CCR-DEA and BCC-DEA results were the same in our result table. Because it is U0 = 0 in all decision-making units, it is possible to talk about a constant return for all decision-making units, according to the scale. This situation shows us that any changes which may occur in inputs for all decision-making units may affect the outputs at the same rate. In line with the BCC-DEA objective functions and constraints, BCC-DEA modeling was performed for all DMUs (Decision-making units) and the efficiency results indicated in Table 9 were obtained.

Table 9: BCC-DEA Efficiency Results for All Decision-making Units

Unit Codes	Efficiency	U0
A1	1	0
A2	1	0
A3	1	0
A4	0,860	0
A5	0,918	0

Continuation Of Table 9: BCC-DEA Efficiency Results for All Decision-making Units

Unit Codes	Efficiency	U0
A6	0,894	0
A7	0,895	0
A8	1	0
A9	1	0
A10	0,928	0
A11	0,972	0
A12	0,905	0
A13	1	0
A14	0,954	0
A15	1	0
A16	1	0
A17	1	0
A18	0,900	0
A19	0,947	0
A20	1	0

5. Conclusion

The distribution of resources between Faculties and Schools in different amounts can be shown as one of the main reasons for developmental differences. As a result of this study performed, some important findings were found. These can be expressed as follows; As a result of the application of the input-oriented CCR-DEA model, 10 out of 20 Faculties and Schools were found completely effecient. Faculty of Dentistry, Faculty of Literature, Faculty of Science, Faculty of Fine Arts, Faculty of Communication, Faculty of Health Sciences, Faculty of Art and Design, Faculty of Technology, Faculty of Agriculture, Aksehir Kadir Yallagoz School of Health, which were 10 out of 20 Faculties and Schools, could not be able to reach complete efficiency. Dual CCR-DEA model was formed to create a reference set for these regions which did not reach complete efficiency and the same regions also did not reach complete efficiency in this model. As a result of the calculation made by using the reference set, it is concluded that there was an idle capacity as much as positive values as specified Table 7 in the input amounts of the regions that cannot achieve complete efficiency (number of academic staff, number of administrative staff, number of students), in other words, input amounts can be reduced in order to remain at the same efficiency level. Although not included in the results, the amount of input should be increased as well as changes with negative value. If these changes can be realized, the efficiency value, which characterizes the most efficient use of the resources available, shall appear to be 1. BCC-DEA models have been formed to examine increasing returns, fixed returns and decreasing returns, and as a result of obtaining the value of U0 = 0 for all units, it is possible to talk about constant returns for all regions.In other words, the change that it will create in the input amounts of all regions will be at equal rate in output value. Aksehir Faculty of Economics and Administrative Sciences, Beysehir Ali Akkanat Faculty of Management, Beysehir Ali Akkanat Faculty of Tourism, Faculty of Law, Faculty of Economics and Administrative Sciences, Faculty of Sport Sciences, Faculty of Medicine, Faculty of Tourism, Veterinary Faculty, Dilek Sabancı State Conservatory have reached complete efficiency. The Faculty of Dentistry, which is expected to be at the top level, has the lowest efficiency rate. The other faculties have reached an efficiency rate above the medium level. Based on the results emerged as a result of said study, it is seen that there is an idle capacity in input values in comparison with output values. However, considering the fact that the output values are generally low, situations such as ranging the academic incentive average scoren from 3 to 26, non-use of those below 30 score in the application pursuant to the regulation and taking maximum 30 from the activity included in the same category, are among the negative issues. . Because the number of faculty members per grad student in the education units with application education is high and it occurred the reverse situation in other units, it affects the high efficiency in schools where there is no applied education, but where more theoretical education is given. It could be considered as disadvantages not to include permanent personnel in the expenditure items, although they are included within the scope of administrative personnel, not to involve them in the number of administrative personnel and to have complex job descriptions. The results revealing that the policies carried out to reduce the development differences were successful, even partially. However, it can be said that the efficiency levels of the developed units were found to be lower than expected. Another factor, that needs to be considered as much as the efficient use of resources, is the relative distribution intensity of resources. Significant differences were observed between some units in the amount of input. Therefore, inefficient units should increase their efficiencies or take measures to reduce input amounts.

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