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Comparative Analysis of the Public Funding for Greek Universities: An Ordinal DEA/MCDM Approach

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***Abstract*—**This study performs a comparative analysis of the 21 Greek Universities in terms of their public funding, awarded for covering their operating expenditure. First it introduces a DEA/MCDM model that allocates the fund into four expenditure factors in the most favorable way for each university. Then, it presents a common, consensual assessment model to reallocate the amounts, remaining in the same level of total public budget. From the analysis it derives that a number of universities cannot justify the public funding in terms of their size and operational workload. For them, the sufficient reduction of their public funding amount is estimated as a future target. Due to the lack of precise data for a number of expenditure criteria, the analysis is based on a mixed crisp-ordinal data set.

***Keywords*—**Data envelopment analysis, Greek universities, operating expenditures, ordinal data.

I. Introduction

THE 21 Greek Universities operate as public organizations, accepting annual funding from the Ministry of Education. This funding covers their operational expenditure spent only for the support of the educational and social activities as well as the operation and maintenance of facilities and infrastructure. It does not include expenses for the payroll, for the members of faculty / administrative staff, the development of new infrastructure, the undertaking of scientific and research projects etc., which are financially supported by other sources. The particular amount assigned to the universities is formed so far independently for each university, following an empirical estimation, more or less proportional to the number of the enrolled students. Regarding this assignment, the question that rises is whether it is fair and if the particular amount given to a university reflects its operational needs.

This paper performs the comparative assessment all the Greek universities using Data Envelopment Analysis (DEA) / Multi Criteria Decision Making (MCDM) models. DEA, first introduced in [1], is a non-parametric linear programming method for measuring the relative efficiency of homogeneous organizational units on the basis of multiple inputs and outputs. The relative efficiency is measured by a fraction of "weighted outputs" to "weighted inputs". The weights are variables, estimated in favor of each evaluating unit in order to maximize its relative efficiency score. DEA, due to its formal analogies with MCDM (DMUs to alternatives, inputs-outputs to criteria to be minimized and maximized, DEA efficiency to convex efficiency etc.), has been proposed as a tool for multicriteria analysis [2].

Universities as individual entities have been on the focus of a number of DEA assessment studies. Especially for the Greek Universities, recently, [3] studied the degree of utilization of operating expenditures using ratio analysis, DEA and econometrics on two sets of performance indicators. At European and international level, DEA has been used to assess universities in terms of their cost, operating and research efficiency. Related studies are those in [4]-[9].

In this paper we first introduce a DEA-like linear programming model that, for every university, analyses relatively to the others, the amount of its public funding in terms of four criteria: the number of students (full time equivalent), the number of faculty members, the type and extent of premises and the variety of faculties and departments. This model is able to identify the best performing universities, i.e. those that receive lower level of funds while they have high operating needs due to their size and educational workload. For the rest, the non-best performing universities, the sufficient funding reduction is estimated as a future a target for them. In a second level of analysis, a DEA common weight approach is proposed in order to reallocate the total available budget, ensuring a consensus between the universities. The above models are implemented by using data for year 2011, mainly provided by the Hellenic Quality Assurance and Accreditation Agency.

The rest of this paper is organized into the following sections: Section II presents the data model for the assessment, Section III provides a DEA/MCDM model that allocates the amount of public funding to the criteria used to describe the universities' operating demands, Section IV presents a new, common assessment model to reallocate the total available budget and Section V shows the results and discuss the outcomes; the last section provides the concluding remarks.

II. The Data Model

Every university allocates the amount of the annual public funding for its operations, activities, and works. These impose expenses for both the operation of premises and facilities (rents, cost for power supply and telecommunication, cleaning-security services, heating, maintenance of electromechanical equipment, maintenance of gardens and open spaces, etc.), and the support of academic and

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supplementary activities (library operation, consumables and laboratory equipment, maintenance for software and hardware, organization of scientific conferences and events, educational excursions, transportation of students and staff in cases when university premises are located in different areas, health and medical services, etc.).

Due to the different budget allocation plans followed by the Greek universities and the lack of precise data for most of the types of expenditure, the whole schema of universities' operating costs in this paper is expressed in terms of four factors that consist the basic reference criteria for the analysis. These are

s : the number of students (full time equivalent),
t : the number of faculty members,
p : the type and extent of premises
q : the variety of faculties and departments that a university covers.

The last two criteria p and q, due to their qualitative nature are expressed with ordinal variables. Their ordinal levels categorize the universities under assessment in different classes of increasing expenditure as follows :

For *Variety of schools and divisions* (criterion q), ordinal value 1 is assigned to those universities that provide education in theoretical (humanities, law, art, business administration, economics etc.), polytechnic, agricultural and science directions and value 2 to those that additionally include medical schools, and university hospitals.

For *Type and extent of premises* (criterion p), ordinal value 1 is assigned to universities that operate in independent buildings (even if these are located in different cities and/or islands), value 2 is for universities that possess a campus including a number of buildings and facilities for administration, sports, restaurants, hostels etc. and value 3 is for universities that possess more than one campus and/or additional premises for the operation of research institutions, hospitals etc.

The data for this study have been collected from a working document of the Hellenic Quality Assurance and Accreditation Agency, authority responsible for the quality assurance in Greek universities, and refer to year 2011. The qualitative factors have been estimated by field research. The data are presented in Table I.

III. Allocating Public Funding into Expenditure Factors

Let n be the number of the universities under evaluation. The total amount of operating expenditure of the jth university (j=1,..,n) is expressed by the value function

$$H_j = w_1 s_j + w_2 t_j + v_1 q_j + v_2 p_j$$

which summarizes the worth that it estimates for its operational demands. Following the fundamental concept of DEA, every university j is let free to allocate its public funding to all four expenditure factors so as to reach the maximum possible value of claimed amount. This is achieved by estimating the unknown weights w_1, w_2, v_1, v_2 in the most favorable way. If by C_j we denote the amount of public fund assigned to the jth university, since this amount is fixed and predetermined, the inequality $H_j \le C_j$ expresses the condition that the claimed amount for the operating expenses H_j has to stay within the budget.

TABLE I
THE DATA SET OF THE 21 GREEK UNIVERSITIES

University	Public funding (in '000 s €) C	Variety of schools and divisions q	Type of premises p	Number of students - full time equivalent s	Number of faculty members t
AUTH	29500	2	3	25315	2131
UP	11150	2	3	14465	704
UT	6250	2	2	6470	430
DUT	10300	2	3	15275	383
UOA	48600	2	3	24360	1926
UI	8600	2	2	11610	537
UC	6350	2	3	10830	496
AUEB	4150	1	1	5200	198
PUSPS	3100	1	1	6170	226
UNIPI	4000	1	1	6270	186
UM	3900	1	1	4465	215
UA	5800	1	1	10480	298
IU	2600	1	1	2285	106
HU	1150	1	1	655	64
UP	1650	1	1	4115	128
UWM	1600	1	1	2905	44
UCC	600	1	1	610	11
NTUA	6150	1	2	5490	541
AOA	3100	1	2	2020	153
ASFA	2250	1	1	570	35
TUC	2650	1	2	2325	103

The factors $v_1 q_j, v_2 p_j$, due to the ordinal nature of the criteria q and p, have to be transformed into quantitative measurements. Techniques for incorporating ordinal data in the measurement of performance indicators have been extensively presented in past publications, for example in [10]. They either assume that the ordinal levels correspond to unknown, under estimation, real numbers that comply with the ordinal increasing/decreasing scale worth ([11]) or use binary variables for each one of the ordinal level ([12], [13]). In this study we implement the second approach. The ordinal criteria q and p are replaced by the L-dimensional unit vectors $q_j(l), l = 1,2$ $(L = 2)$ and $p_j(l), l = 1,2,3$ $(L = 3)$ defined as follows

$$q_j(l) = \begin{cases} 1 & \text{if university } j \text{ is assigned the } l\text{th level on factor } q \\ 0 & \text{otherwise,} \end{cases}$$

$$p_j(l) = \begin{cases} 1 & \text{if university } j \text{ is assigned the } l\text{th level on factor } p \\ 0 & \text{otherwise.} \end{cases}$$

For example, if the 4th university (j=4) is assigned the 2nd ordinal level in criterion q and the 3rd level in criterion p, then the corresponding vectors will be $q_4 = (0,1)$ and $p_4 = (0,0,1)$ respectively or equivalently $q_4(1) = 0, q_4(2) = 1$ and $p_4(1) = 0, p_4(2) = 0, p_4(3) = 1$.

Based on the above notation for the ordinal criteria, the total amount of operational expenditure H_j takes the form

$$H_j = w_1 s_j + w_2 y_j + u_1 q_j(1) + u_2 q_j(2) + u_3 p_j(1) + u_4 p_j(2) + u_5 p_j(3),$$
$$j = 1,..,n.$$

The following DEA/MCDM model (1), executed n times, estimates for all universities their maximum possible amount H_j^* that they can claim for their operational expenses.

$$\max\ H_j$$
$$s.t. \qquad (1)$$
$$H_j = w_1 s_j + w_2 t_j + u_1 q_j(1) + u_2 q_j(2) + u_3 p_j(1) + u_4 p_j(2) + u_5 p_j(3), \quad j = 1,..,n$$
$$d_j = C_j - H_j,\ j = 1,..,n$$
$$d_j \geq 0,\ j = 1,..,n$$
$$w_1, w_2, u_1,..,u_5 \in \Omega$$

The weights $w_1, w_2, u_1,..,u_5$ are under estimation and they are imposed to restrictions described by the set Ω which is discussed in the next paragraphs.

Model (1), using appropriate variable transformations, is equivalent to a typical DEA setting with single input the funding amount and multiple outputs the four criteria of the operating expenditure factors. Following the concept of DEA, model (1) is able to discriminate universities into two classes: the best performers, i.e. those that achieved to fully justify their funding by estimating their total expenditure up to the limit of C_j ($H_j^* = C_j$) and the rest, the non-best performers, those that could not reach that level ($H_j^* < C_j$).

The variable $d_j = C_j - H_j$ denotes the deviation of the estimated expenditure from the amount of public funding. The restriction $d_j \geq 0$ ensures that the estimated expenditure stays within the budget of public funding. After solving model (1), the quantity $d_j^* = C_j - H_j^*$ indicates the excess amount that university j has not been able to justify due to the comparative assessment with the rest of the universities and serves as a target for its expenditure. Furthermore, the sum of all such unallocated amounts $\sum_{j=1}^{n} d_j^* = \sum_{j=1}^{n} (C_j - H_j^*)$ represents an estimation of the reduction of total public budget that the Greek educational system could benefit. The values of the weights estimated from the solution of model (1) may not unique and in general cannot be used for further analysis and exploitation. However, the particular definition of H_j as a value function, enables the interpretation of the weights w_1, w_2 as the amount per student and per member of faculty respectively, that university j assigned so to achieve its maximum possible score. In the same manner $u_1,..,u_5$, express the expenditure estimated for the distinctive ordinal classes for the two qualitative criteria. Such a meaning of the weights w_1, w_2 and $u_1,..,u_5$ impose certain restrictions to both ensure that they will not be assigned unrealistic values and to express the strict ordinal levels setting. First, the minimum amount per student and per member of faculty ε_1 and ε_2 respectively, may serve as a lower bound for the weights w_1, w_2 ($w_1 \geq \varepsilon_1, w_2 \geq \varepsilon_2$). Next, the strict ordinal restrictions $u_1 < u_2$ and $u_3 < u_4 < u_5$, expressing the increasing level of expenditure for the classes of divisions and types of premises, can be reformulated in terms of positive discrimination parameters $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5$, as follows

$$u_1 \geq \delta_1,\ u_2 - u_1 \geq \delta_2 \ \text{ and } \ u_3 \geq \delta_3, u_4 - u_3 \geq \delta_4, u_5 - u_4 \geq \delta_5.$$

The values of $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5$ denote the minimum expenditure that universities attitude to difference between the ordinal classes. The so formed restrictions define the set Ω of model (1) as

$$\Omega = \begin{Bmatrix} w_1 \geq \varepsilon_1, w_2 \geq \varepsilon_2, u_1 \geq \delta_1, u_2 - u_1 \geq \delta_2, \\ u_3 \geq \delta_3, u_4 - u_3 \geq \delta_4, u_5 - u_4 \geq \delta_5 \end{Bmatrix}.$$

IV. Budget Reallocation through the Estimation of Common Weights

In model (1), different sets of weight values have been assigned as the universities were placed in their most advantageous position and the amount H_j^* is estimated as the maximum possible solution for the jth university to achieve. The common weight approach estimates the same weight values for all universities by solving only one linear program, forcing all to be placed as close as possible to their best amount H_j^*. Typical references for the different aspects of the common weight concept are [14]-[16].

The following model (2) is a DEALP model that derives from model (1) by minimizing the deviation variables for all universities.

$$\min \sum_{j=1}^{n} d_j$$

$s.t.$ (2)

$$H_j = w_1 s_j + w_2 t_j + u_1 q_j(1) + u_2 q_j(2) + u_3 p_j(1) + u_4 p_j(2) + u_5 p_j(3), \quad j = 1,..,n$$

$$d_j = C_j - H_j,\ j = 1,..,n$$

$$d_j \geq 0,\ j = 1,..,n$$

$$w_1, w_2, u_1,.., u_5 \in \Omega$$

Model (2) imposes a strict framework of evaluation that requires a consensus between the universities in order to achieve common solution. This implies that under the common weights assessment, the values of the performance indicator H_j will be lower than those obtained by model (1) so a number of universities may no longer become best performers.

The common assessment framework expressed by model (2) enables to further extent the public funding analysis by examining the reallocation of the universities funding, keeping fixed the total budget available for all the universities. In such a case, a number of universities, through the estimated amount H_j^*, may claim more funding than the predetermined C_j and for others that level might be surplus. The problem of allocation of fixed resources allocation within the DEA framework has been first addressed in [17]-[20]. The following model (3) is the extension of model (2) that implements a common assessment and reallocation of the universities' funding.

$$\min \sum_{j=1}^{n} d_j$$

$s.t.$ (3)

$$H_j = w_1 s_j + w_2 t_j + u_1 q_j(1) + u_2 q_j(2) + u_3 p_j(1) + u_4 p_j(2) + u_5 p_j(3), \quad j = 1,..,n$$

$$d_j = C_j - H_j,\ j = 1,..,n$$

$$\sum_{j=1}^{n} H_j = Q$$

$$w_1, w_2, u_1,.., u_5 \in \Omega$$

TABLE II
RESULTS OF MODELS (1), (2) AND (3)

University	Model (1) H_j^*	Model (1) d_j^*	Model (2) - Common weights H_j^*	Model (2) - Common weights d_j^*	Model (3) – Common weights and funding reallocation H_j^*	Model (3) – Common weights and funding reallocation d_j^*
AUTH	24936350	4563650	24581611	4918389	25510385	3989615
UP	8819650	2330350	8791238	2358762	14597559	-3447559
UT	6250000	0	5307345	942655	6547043	-297043
DUT	8131850	2168150	5460264	4839736	15411822	-5111822
UOA	22603860	25996140	22354245	26245755	24549776	24050224
UI	6841300	1758700	6785522	1814478	11716236	-3116236
UC	6350000	0	6350000	0	10941781	-4591781
AUEB	2471740	1678260	2462166	1687834	5249624	-1099624
PUSPS	2837430	262570	2823477	276523	6225141	-3125141
UNIPI	2514000	1486000	2408339	1591661	6325667	-2325667
UM	2602080	1297920	2591513	1308487	4510482	-610482
UA	4202100	1597900	3876023	1923977	10559603	-4759603
IU	1452620	1147380	1293503	1306497	2318037	281963
HU	1075595	74405	739637	410363	678771	471229
UP	1650000	0	1650000	0	4158414	-2508414
UWM	1287520	312480	681657	918343	2941483	-1341483
UCC	600000	0	177510	422490	633463	-33463
NTUA	6150000	0	6150000	0	5551608	598392
AOA	3049470	50530	1821262	1278738	2061584	1038416
ASFA	815400	1434600	427953	1822047	593261	1656739
TUC	2650000	0	1314578	1335422	2368260	281740

In the case of model (3), the funding reallocation is achieved first by letting the universities free to bind their funding amount even higher than the predetermined level C_j and then by keeping constant the total amount available from the part of the Ministry of Education. The first condition is achieved by eliminating the constraint $d_j \geq 0$ from model (2) and the second by introducing the new constraint $\sum_{j=1}^{n} H_j = Q$ where Q is the fixed total public budget available to be shared by all universities. Note that in model (3) the deviation variable d_j is unbounded so may accept negative values. In such a case, from the restriction $d_j = C_j - H_j < 0$ derives that $H_j > C_j$, condition interpreted as an extra funding requirement from the part of university j.

V. Implementation and Results

For the implementation of models (1)-(3), the discriminating parameters $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5$ and ε_1, ε_2 have been assigned the minimum values of 10000€ and 1€ respectively, so to allow full flexibility for the universities to be placed in their most benevolent position. The results obtained from models (1), (2) and (3) on the data set of Table I are presented in Table II.

Furthermore, additional weight restrictions may be employed to express certain viewpoints of assessment. For example the restrictions

$$p_j(1) \geq w_1 s_j,\ p_j(1) \geq w_2 t_j,\ j = 1,..,n$$

illustrate the condition that for all universities, the expenses for the premises, even at their minimum level, are greater than the operating expenses for students and members of academic staff.

From Table II derives the universities UT, UC, UP, UCC, NTUA and TUC are the best performers. Through the comparative evaluation they justified their public funding by properly weighting the expenditure factors. The rest did not achieve to do so. For the first group, the excess amount d_j^* (column 3 of Table II) is equal to zero and for the second has a significant positive value that indicates the sufficient reduction of the public funding for the university j in order to become best performer. For example, university AOA may reduce the funding of 3100000€ by d_j^*=50530€ up to the level of H_j^*= 3049470€. The total amount of reduction expressed by the sum $\sum_{j=1}^{n} d_j^*$ is estimated to 46,159,035€ which is the 28% of the initial total funding for the year 2011.

Fig. 1 presents graphically the amount of public funding of all 21 universities, distinguishing the estimated value H_j^* (white part of the bar) and the amount of reduction (grey part of the bar).

Columns 4 and 5 of Table II derive from model (2). Under the common weight assessment, the estimated amount for the expenditure is less than the value obtained by model (1) and therefore, the universities UT, UCC and TUC are no longer best performers. In this case, the amount of total reduction is greater and is estimated to 55,402,158€, being the 34% of the initial available total budget. Finally the last two columns of Table II derive from to the reallocation process of model (3). As mentioned in the last paragraph of Section 4, the negative values of the column d_j^* denote the additional funding that the universities may claim by weighting the expenditure factors and the positive values show the excess amount that is not justified by their performance. The last column of Table II shows this estimation. The graph of Fig. 2 presents the estimated claimed amounts H_j^*. The white part of the bar shows the initial funding amount C_j and the grey part indicates either the extra amounts that they claim (positive axe) or the excess amounts estimated during the process of reallocation (negative axe). University UOA has the most significant contribution to the reallocated total budget while UP demands, proportionally to its initial funding, the greater amount.

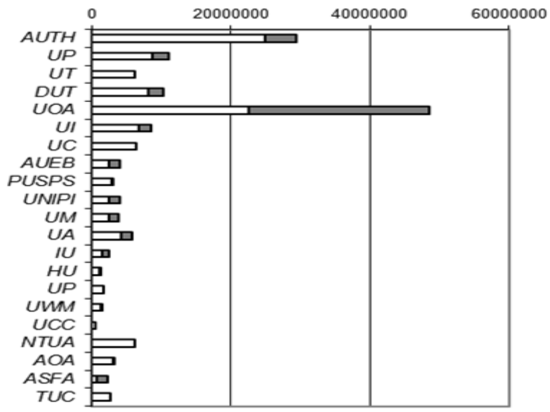

Fig. 1 Allocation of initial funding (Model (1))

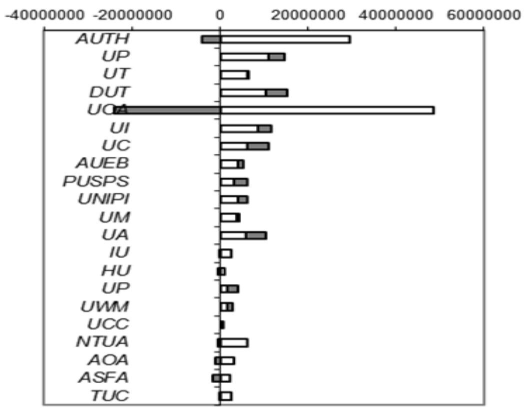

Fig. 2 Allocation of initial funding (Model (3))

VI. Conclusion

This paper presented three DEA/MCDM models for the comparative analysis of public funding for the Greek universities in terms of four expenditures factors, two of them expressed by ordinal data. The analysis reveal that a number of universities were best performers, able to justify their public funding with the operating demands. For the rest, the sufficient amount of reduction has been estimated, acting as a future target for them. In a second level of analysis, the total available public funding was kept fixed and the universities were left free to claim their share.

The use of qualitative data instead of crisp for the premises, infrastructure and operating demands in divisions and schools, deprived from a number of universities the opportunity to promote the actual level of their operating expenditure as the same amount was estimated for every ordinal level. If analytical data were available, the assessment could be more fair. In such a case, extra weight restrictions could be added so to approach the funding allocation problem in a more realistic way.

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