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RANKING OF GLOBAL EFFICIENCY OF THE BEST UNIVERSITIES IN EUROPE

In any economic organization, the existing relationship between its inputs and its outputs must be established in such a way that the management of its tangible and intangible human resources allows producing the maximum amount of useful products with the least amount of resources. In this article, we have analyzed this relation of efficiency applied to the university environment. In particular, the best universities in Europe have been studied. Previously, a rigorous study of the existing bibliography has been carried out. As a result, it has been seen that these studies include specific results analysis, without taking into account the three basic functions of 21st century universities, such as those related to improving the employability of their graduates, transmitting and expanding their scientific knowledge, and the modernization of the national economic system through the introduction of improvements in business activity. The methodology used in is data envelopment analysis (DEA). This model has allowed determining the relative position of each university in relation to the distance it maintains with respect to an ideal efficiency frontier. It also shows that aspects must be improved to be in a position of maximum efficiency. Four types of analysis have been applied. DEA 1 "Analysis of labor efficiency" in which the improvement of the degree of employability of university graduates has been analyzed, DEA 2 "Analysis of academic efficiency" that has allowed us to measure the efficiency in publications, the DEA 3 "Analysis of technological efficiency "that has allowed identifying the universities that are more efficient in terms of patents and finally DEA 4" Global efficiency analysis "that encompasses all the previous ones. Likewise, a correlation analysis was carried out among the results obtained. Among the main conclusions highlight how there is a high degree of correlation between the universities that achieve the best results in academic efficiency and technological efficiency. The comparisons in the level of global university efficiency made in this research work are the result of applying the DEA methodology on a production function that has been constructed using four variables inputs - undergraduate and graduate students and national and foreign teachers - and three output variables - levels of employment, publications and patents.

Keywords**:** ranking, university, employability, data envelopment analysis, patents, publications.

Formulation of the problem generally. Efficiency is a business concept that defines the relationship between inputs and outputs. In their management, organizations must make decisions that involve producing the maximum amount of products using the minimum possible amount of inputs. To do this, they have to take three types of decisions (Arcos et al., 1993 [1], Alvarez, 2001 [2]):

- Choose the output that maximizes the benefit of all possible production levels (scale efficiency);
- Choose the optimal combination of inputs that minimizes production costs among all possible combinations of inputs necessary to obtain the product (allocative efficiency);
- Produce the product using the minimum possible quantity of inputs (technical efficiency).

For the study of these three types of efficiency, it is usual to resort to the border model. This model implies defining a production, benefit or cost function through techniques that can be parametric or non-parametric.

The production function must allow determining the theoretical maximum product that can be reached from a given combination of inputs (Farrell, 1957 [3]). Once defined, comparisons can be made between a set of organizations or Decision Making Units (DMU) based on their greater or lesser proximity to the production frontier. Thus, by using this type of efficiency analysis, one can compare the actual situation of an organization with respect to an optimum and conclude whether or not an organizational unit is effective in relation to its location on the production, benefits or costs frontier. If it falls below this function or is above the cost frontier, the entity is inefficient (Buchelli and Marín Restrepo, 2012 [4]).

One of the main advantages of this model lies in the amount of information it provides starting from a moderate level of data since it works mainly by comparing decision units (Chirinos and Urdaneta, 2007 [5], Camilli, Vargas, Ryan, & Barnett, W., 2010 [6]).

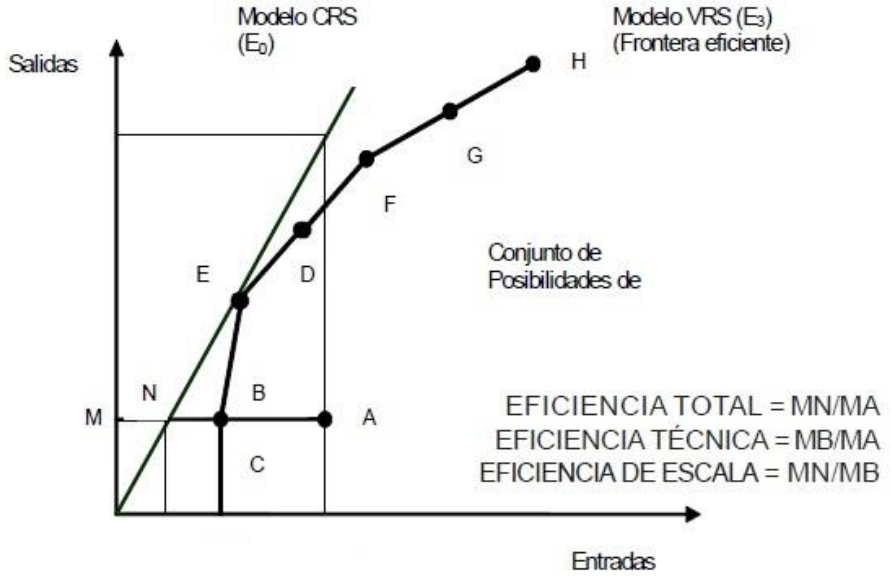

Figure 1 – **Set of production possibilities and the different efficiencies**

The overall efficiency is determined by the following equation (Model CCR):

$$Global\ efficiency\ =\ MN/MA \tag{1}$$

On the other hand, technical efficiency would be defined by (BBC Model):

$$Technical\ efficiency\ =\ MB/MA \tag{2}$$

Finally, the scale efficiency would be calculated as follows:

$$Scale\ efficiency\ =\ MN/MB \tag{3}$$

The relationship between them is determined by the following equation:

$$Global\ efficiency\ =\ Technical\ efficiency\ \times\ Scale\ efficiency \quad (4)$$

In practice, it is interesting to know the efficiency of organizations since it is essential to increase their output without absorbing more than the resources necessary for it (Farrell, 1957 [3]). For this, the authors usually use different models, both parametric and non-parametric.

The determination of the efficient frontier, through the application of a non-parametric methodology, has some advantages over parametric models, fundamentally those derived from the need to determine a specific function that explains a certain behaviour through the definition of a set of variables dependent and independent. Using a non-parametric methodology, what is being determined is the relative efficiency of an organization in relation to others taken from a representative and homogeneous group (Maza, Vergara and Navarro, 2011 [7]).

One of the most widely used nonparametric models is the data envelopment analysis (DEA) proposed by Charnes, Cooper and Rhodes in 1978 [8]. Subsequently, Banker, Charnes and Cooper (1984) [9] developed a model that is known by the initials of its authors (BCC) similar to the previous one, but which includes a more flexible border. This fact made it quickly used by different authors in their efficiency analysis both in the purely business field and in the field of social organizations, among which are those related to teaching and research activity (Johnes and Li, 2008 [19], Bessent & Bessent, 1980 [10] and Emrouznejad and Yang, 2017 [11]). The main reason lies in the fact that it allows the inclusion of multiple input and output variables, a situation that adapts to the reality of social organizations since they pursue multiple objectives that must be taken into account in the analysis of the determination of their levels of performance (Worthington and Dollery, 2000 [12], Zhonghua and Ye, 2012 [13]). In these cases, the efficiency of each decision unit (DMU) is obtained as:

$$Efficiency = \frac{Y}{X} = Output/Input \quad (5)$$

When more inputs are used, the equation would be the following:

$$Effiency = \frac{a_i Y_i}{b_i X_i} \quad (6)$$

Analysis of recent researches and publications. The use of this model implies, in the first place, to define a series of variables inputs/outputs. To this end, an exhaustive analysis of the available literature on DEA analysis in higher education has been carried out (Table 1).

Table 1 – **Analysis of inputs/outputs by authors in DEA analysis applied to higher education**

Author	Inputs	Outputs
1	2	3
Abbott & Doucouliagos [14]	Total number of academic staff (full-time equivalent) The number of non-academic staff (full-time equivalent) Expenditure on all other inputs other than labour inputs Non-current assets	Teaching output includes the number of equivalent full-time students, the number of post-graduate and under-graduate degrees enrolled as well as the number of post-graduate degrees conferred and the number of undergraduate degrees conferred EFTS is arguably the better measure
Avkiran [15]	Academic staff FTE Non-academic staff, FTE	Overseas fee-paying enrolments, EFTSU Non-overseas fee-paying postgraduate enrolments, EFTSU

table 1

1	2	3
Bessent & Bessent [16]	Pupil inputs measured by the California Achievement Test in May 1976. X1 median percentile reading achievement for only those pupils who attend school during the full year; X2 median percentile mathematics achievement test score for only those pupils who attend school during the full year. Proxy measures for the neighbourhood and home conditions (obtained from school district records) X3 per cent of Anglo-American students; X4 per cent of students that are not from low-income families;X5 per cent in average daily attendance; X6 mobility index: (total enrollment – the number of entered late or withdrawn)/total enrollment Proxy measures for within school conditions (obtained from school district records) X7 number of professional staff per 100 pupils; X8 total per-pupil expenditure for instruction School organizational climate indicators obtained from the Organizational Climate Description Questionnaire [10]; a high score on each dimension indicates the following: X9 esprit--an indicator of job satisfaction; X10 intimacy--an indicator of how much social interaction exists among teachers;X11 thrust--principal motivates teachers by personal example of work orientation; X12 consideration-- a measure of' the principal's friendliness and cooperativeness with teachers A measure of classroom instructional processes (obtained from Individualization of Instruction Inventory [10]; a higher score indicates a greater degree of individual rather than group-oriented teaching methods) X13 total individualized instruction index	Median percentile reading achievement for only those pupils in attendance at the school for a full year Median percentile mathematics achievement test score for only those pupils in attendance for a full year
Chu Ng & Li [17]	**Full sample inputs:** Number of researchers; Number of research supporting staff; Budget funds (in thousand RMB); (a) In-budget; (b)Out-budget **East region inputs:** Number of researchers; Number of research-supporting staff; Budget funds (in thousand RMB); (a) In-budget; (b) Out-budget **Central region inputs:** Number of researchers; Number of research-supporting staff; Budget funds (in thousand RMB); (a) In-budget; (b) Out-budget **West region inputs:** Number of researchers; Number of research-supporting staff; Budget funds (in thousand RMB); (a) In-budget; (b) Out-budget	**Full sample outputs:** Number of manuscripts; Number of articles; Number of recognized research outputs; Number of contracts; Number of prizes **East region outputs:** Number of manuscripts; Number of articles; Number of recognized research outputs; Number of contracts; Number of prizes **Central region outputs:** Number of manuscripts; Number of articles; Number of recognized research outputs; Number of contracts; Number of prizes **West region outputs:** Number of manuscripts; Number of articles; Number of recognized research outputs; Number of contracts; Number of prizesN
Correas and Jorge [18]	Personal expenses Current expenses in goods and services Lecturers' expenses Other expenses	No. of students enrolled No. of graduate students No. of the Ph.D. thesis No. of publications No. of scientific documents in indexed journals % of teaching staff with one or more research sections No. of research projects Patents applications No. of spin-offs

table 1

1	2	3
Johnes, & Li [19]	Staff time is the full-time staff ti student ratio. Quality of the staff inputs is reflected by the percentage of the faculty with associate professor. Doctoral students. Research expenditure. Books is an index of library books (derived from an unweighted average of the indexes formed from total and per student numbers.Buildings	Index of the total numbers of research publications. Research publications per members of academic staff
Johnes [20]	A total number of FTE undergraduate students studying for a first degree multiplied by the average A-level points for first-year full-time undergraduate students (A level score is averaged over 1994/95, 1995/96, 1996/97 and 1997/98. Note that A=10, B=8, C=6, D=4, E=2). A total number of FTE postgraduate students. A total number of full-time academic staff for teaching or teaching and research or research only purposes. Total depreciation and interest payable in £. Total expenditure on central libraries and information services, and on a central computer and computer networks excluding academic staff costs and depreciation in £. Expenditure on central administration and central services excluding academic staff costs and depreciation in £.	Total number of first degrees awarded weighted by degree classification A total number of higher degrees awarded (includes both doctorate and other higher degrees). Value of the recurrent grant for research awarded by the Higher Education Funding Council for England (HEFCE) in £.
Köksal, & Nalçaci [21]	Academic staff salaries. Potential of the department. Entering students	Research activities and quality. Education activities and quality.Other activities. Graduates
Kuah, & Wong [22]	Teaching efficiency: A number of academic staffs/ Number of taught course students/ Average students qualifications/ University expenditures. Research efficiency: University expenditures/ Number of research staffs/ Average research staffs qualifications/ Number of research students/ Research grants	Teaching efficiency: Number of graduates from taught courses/ Average graduates results/ Graduate rate/ Graduate employment rate Research efficiency: Number of graduates from research/ Number of publications/Number of awards/ Number of intellectual properties
Lee & Worthington [23]	FTE Academic. PhD students	Publications indicator. Grants Students
Leitner, Prikoszovits, Schaffhauser-Linzatti, Stowasser & Wagner [24]	Staff. Room Space	Examinations. Finished supervised diploma theses. Monographs. Jornal papers. Project reports.Presentations. Other publications. Finished supervised PhD theses. Patents. Financial funds provided by Third parties. Finisher projects ad personam.Finished projects of the department
Martí et. al. [25]	No. of students enrolled. Current expenses. No. of full-time lecturers	No. of graduates. Revenue from research. No. of the Ph.D. thesis
Martín [26]	No. of full-time lecturers. No. of part-time lecturers. No. of full-time equivalent lecturers. No. of permanent lecturers. No. of non-permanent lecturers. No. of scholars. Lecturers' salary. No. of students. Teacher load. Infrastructures. No. of computers. Physical investment. Budget. External aid for research. Expenses in books and magazines	No. of students. No. of graduates. The average score in the evaluation survey. Teachers' load. No. of publications. External aid for research. No. of the Ph.D. thesis. No. of citations
Taylor & Harris [28]	Total expenditure. Capital employed. Capital employed and student numbers. Capital employed and staff numbers. Capital employed and adjusted expenditure. Capital employed and total expenditure. Student numbers and staff numbers.	Academic qualifications completed (degrees, diplomas and certificates). Research output (books, articles in approved journals, conference proceedings, patents/licenses and research income).

table 1

1	2	3
Sagarra, Mar-Molinero & Agasisti [27]	Full-time equivalent faculty. Total enrolment. First joining graduates	Scopus papers. Graduates
Warning [29]	Inputs used to measure staff, both scientific and non-scientific, and overhead expenditures, including spending on library resources, computing services and further infrastructure.	It is based on the Science Citation Index (SCI) data for the natural sciences and on the Social Science Citation Index (SSCI) and the Arts and Humanities Index (AHI) for the social sciences. Since the ISI3 incorporates only quality journals in its indexes, the computed score provides information on both the quality and quantity of publications. The ''publication'' variable includes the total number of publications from 1997 to 1999, amounting to 14,176 in the SCI and 893 in the SSCI and AHI
Wolszczak-Derlacz [30]	Model 1: Academic staff/ Total revenue/ Total numbers of students.Model 2: Academic staff/ Total revenue. Model 3: Academic staff/ Non academic staff, total revenues/ students. Model 4: total revenues	Model 1: publications/ graduates. Model 2: publications/ graduates. Model 3: scientific articles/publications other tan scientific articles/graduates Model 4: publications/graduates.

Unsolved issues as part of the problem. As can be seen, the major part of the bibliographic review includes only the university function as an element of creation and dissemination of science. However, it overlooks two objectives that are also important, such as improving the employability of its graduates and supporting business development.

Table 2 – **Variables inputs/outputs used in the production function**

Type	VARIABLE		DESCRIPTION
1	2		3
Output	(O.1) (QS) Overall score		Overall score calculated for the indicator QS Graduate Employability. It is constructed from the following variables: Employer reputation (30%); Alumni outcomes (25%); Partnerships with Employers per Faculty (25%);Employer/Student Connections (10%); Graduate employment rate (10%)
	(O.2) Publicaciones	(O.2.1) HiCi	The number of Highly Cited Researchers selected by Clarivate Analytics. The Highly Cited Researchers list issued in November 2016 (2016 HCR List as of November 16 2016) was used for the calculation of HiCi indicator in ARWU 2017. Only the primary affiliations of Highly Cited Researchers are considered.
		(O.2.2) N&S	The number of papers published in Nature and Science between 2012 and 2016. To distinguish the order of author affiliation, a weight of 100% is assigned for corresponding author affiliation, 50% for first author affiliation (second author affiliation if the first author affiliation is the same as corresponding author affiliation), 25% for the next author affiliation, and 10% for other author affiliations. When there are more than one corresponding author addresses, we consider the first corresponding author address as the corresponding author address and consider other corresponding author addresses as first author address, second author address etc. following the order of the author addresses. Only publications of 'Article' type is considered.
		(0.2.3) PUB	Total number of papers indexed in Science Citation Index-Expanded and Social Science Citation Index in 2016. Only publications of 'Article' type is considered. When calculating the total number of papers of an institution, a special weight of two was introduced for papers indexed in Social Science Citation Index.
	(0.3) Patentes		Number of patents originating in each university

table 2

1	2		3
Inputs	(I.1) Bachelor students	(I.1.1) National bachelor students	Number of national and international students enrolled in bachelor studies
		(I.1.2) International bachelor students	
	(I.2) Postgraduate students	(I.2.1) National postgraduate students	Number of national and international students enrolled in postgraduate studies
		(I.2.2) International postgraduate students	
	(I.3) Teaching staff	(I.3.1) National teaching staff	National and international teaching staff related to bachelor and postgraduate studies
		(I.3.2) International teaching staff	

Aims of the article. The aim of the article is to carry out an overall efficiency analysis that includes three main functions of university management. We use information provided by QS Graduate Employability Rankings, Academic Ranking of the Universities of the World (ARWU) and the World's Most Innovate Universities.

Basic material. The following table includes the input/output variables used in the definition of the overall university efficiency production function.

The applied model aims to achieve the maximum amount of output given a certain level of inputs, under a restriction of ignorance of the technological level assumed by each University.

Therefore, it uses a variable-scale return model (VRS) proposed by Banker, Charles and Cooper oriented towards output (BBC-output model).

In this way, the problem to solve would be the maximization of the following expression:

$$Max\ y_j + \varepsilon(\sum_{k=1}^{s} h_k^+ + \sum_{i=1}^{m} h_i^-) \quad (7)$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j * x_{ij} = x_{ij} - h_i^-, i = 1, \dots, m \quad (8)$$

$$\sum_{j=1}^{n} \lambda_j * y_{kj} = y_{kj} * y_j = \pi r^2 + h_k^+, k = 1, \dots, m \quad (9)$$

$$\sum_{j=1}^{n} \lambda_j = 1\ \lambda_j, h_i^-, h_k^+ \geq 0, \forall i, j, k\ y_j\ is\ free \quad (10)$$

where: y_j is the radial extension that occurs in all its outputs. It can be identified with the efficiency of j if j is compared with a point belonging to the efficient frontier; h_i^- is the rectangular reduction of the input i; h_k^+ is the rectangular extension of the output k; λ_j represents the coefficients of the linear combination of inputs and outputs to which the DMU projection point is referring, on the efficient frontier. It can be interpreted as the proximity of the DMU projection point, with respect to the efficient frontier.

In this way, the efficiency frontier would be integrated by all those efficient decision units. Once the border is determined by said entities, it compares each of the universities that are being studied with the border, under the assumption that the deviations detected indicate inefficient behaviour. In this way we can measure the relative efficiency of a set of DMUs that produce a type of output from a common set of inputs.

Four possible relationships of inputs/outputs have been analyzed (Table 3).

The universities that have been selected for the DEA analysis are those that occupy the top 40 positions in the ranking lists consulted. For this, it has been necessary that all of them were included in the three lists, which has been a limitation to apply the DEA model. The list is detailed in Table 4.

Table 3 – **Typology of DEA analysis performed**

	Type of analysis	Inputs	Outputs
DEA 1	Labour efficiency analysis	(I.1) Bachelor students (I.2) Postgraduate students (I.3) Teaching staff	(O.1) (QS) Overall score
DEA 2	Academic efficiency analysis	(I.1) Bachelor students (I.2) Postgraduate students (I.3) Teaching staff	(O.2) Publications
DEA 3	Technological efficiency analysis	(I.1) Bachelor students (I.2) Postgraduate students (I.3) Teaching staff	(O.3) Patents
DEA 4	Global efficiency analysis	(I.1) Bachelor students (I.2) Postgraduate students (I.3) Teaching staff	(O.1) (QS) Overall score (O.2) Publications (O.3) Patents

Table 4 – **DMU`s analyzed**

University of Cambridge	University of Amsterdam
University of Oxford	Aarhus University
ETH Zurich - Swiss Federal Institute of Technology	Trinity College Dublin, The University of Dublin
Imperial College London	Erasmus University Rotterdam
KIT, Karlsruhe Institute of Technology	The University of Sheffield
The University of Manchester	University of Copenhagen
Politecnico di Milano	University of Southampton
Delft University of Technology	Cardiff University
University of Bristol	Ghent University
University of Nottingham	Maastricht University
The University of Edinburgh	Universität Stuttgart
The University of Warwick	Université Catholique de Louvain (UCL)
Technical University of Munich	Université Pierre et Marie Curie (UPMC)
University of Leeds	Universidad Autónoma de Madrid
University College Dublin	University of Glasgow
KU Leuven	Technische Universität Dresden
University of Birmingham	University of Oslo
Universitat de Barcelona	Leiden University
RWTH Aachen University	Universitat Politècnica de València
University of Zurich	Università di Padova
Alma Mater Studiorum - University of Bologna	University of Groningen

For the estimation of the global efficiency, variable returns to scale and an orientation towards the maximization of the selected outputs -patents, employment of its graduates and publications- according to a BBC-output model, without previous knowledge of the returns to scale that can be generated against the quantity of inputs applied in the maximizing production function.

DEA 1. Labour efficiency analysis. In this first analysis, DEA has made a study of university efficiency in labour insertion. The inputs used were the number of undergraduate students, the number of postgraduate students and the number of professors, distinguishing in the latter case between national and foreign professors. The output used is the QS Overall Score developed by QS Graduate Employability Rankings. The model used is the variable-scale return oriented output (BBC-output model), since it has been considered that the units analyzed would be more efficient if they managed to increase the score with a given number of inputs. In the model, the Cooper rule has been fulfilled, since we have worked with 4 variable inputs and one output variable. Therefore, $\alpha > 3$.

The results are shown in table 5. In it, the DMU has been sorted according to the score. In addition, a column -target of university ranking- has been added, in which the level that should be increased by their QS Graduate Employability index to move to a situation of maximum efficiency is determined.

Table 5 – **Results of the application of the DEA model labour efficiency**

Unit Name	Score	Target QS University Ranking	Unit Name	Score	Target QS University Ranking
Università di Padova	100	0	Maastricht University	74.98	33.37
Trinity College Dublin, the Univ	100	0	Technical University of Munich	74.74	33.79
Politecnico di Milano	100	0	The University of Edinburgh	74.6	34.05
Universitat de Barcelona	100	0	Rwth Aachen University	74	35.14
Universität Stuttgart	100	0	Ku Leuven	73.34	36.35
Universitat Politècnica de Valèn	100	0	Université Pierre et Marie Curie	71.62	39.61
Kit, Karlsruhe Institute of Tech	100	0	University of Birmingham	69.65	43.56
Delft University of Technology	100	0	University of Amsterdam	68.06	46.93
Eth Zurich - Swiss Federal Insti	100	0	Aarhus University	66.4	50.61
University of Cambridge	100	0	Erasmus University Rotterdam	65.76	52.06
University of Oxford	99.06	0.95	Technische Universität Dresden	63.8	56.75
Imperial College London	89.33	11.94	University of Zurich	61.1	63.66
University College Dublin	89.16	12.16	The University of Sheffield	59.27	68.71
University of Bristol	87.03	14.89	University of Southampton	58.94	69.69
Alma mater Studiorum - Universit	86.42	15.72	Ghent University	56.29	77.63
The University of Manchester	84.69	18.08	Cardiff University	54.8	82.48
The University of Warwick	81.27	23.05	University of Copenhagen	51.3	94.92
University of Nottingham	78.95	26.66	University of Oslo	49.16	103.40
Universidad Autónoma de Madrid	77.67	28.74	University of Glasgow	48.2	107.47
University of Leeds	77.4	29.20	Leiden University	44.28	125.84
Université Catholique de Louvain	77.25	29.46	University of Groningen	41.29	142.19

DEA 2. Academic efficiency analysis. In this second DEA analysis, a study of university efficiency in terms of academic efficiency has been carried out. The inputs used have been the same as in the previous case. However, an average of the HiCi, N & S and PUB values calculated in the academic ranking of the universities of the world (ARWU) have been used for the output. We have followed a variable-scale return model oriented towards output (BBC-output model). In the model, the Cooper rule has been fulfilled, since we have worked with 4 variable inputs and one output variable. Therefore, $\alpha > 3$.

The results are shown in table 6. In it, an ordering of the DMUs has been made according to the score and a column -target index of Shanghai- has been added, in which the level that should be determined by the averaged index HiCi, N & S and PUB.

Table 6 – **Results of the application of the DEA academic efficiency model**

Unit Name	Score	Target Shangai Index	Unit Name	Score	Target Shangai Index
1	2	3	4	5	6
Universitat Politècnica de Valèn	100	0	Leiden University	81.08	23.32
Università di Padova	100	0	Alma mater Studiorum - Universit	77.67	28.75
Universität Stuttgart	100	0	Cardiff University	75.68	32.14
Université Catholique de Louvain	100	0	University of Copenhagen	75.5	32.44
Trinity College Dublin, the Univ	100	0	The university of Manchester	75.13	33.12
Technische Universität Dresden	100	0	University of Southampton	75.1	33.15
Université Pierre et Marie Curie	100	0	University of Leeds	73.75	35.60
Eth Zurich - Swiss Federal Insti	100	0	University of Groningen	73.13	36.73
University of Oxford	100	0	Technical University of Munich	71.49	39.89
University of Cambridge	100	0	Universidad Autónoma de Madrid	69.62	43.62
Erasmus University Rotterdam	96.8	3.32	University of Oslo	69.22	44.46
Imperial College London	94.31	6.04	University of Glasgow	69.08	44.75
Ku Leuven	92	8.69	University College Dublin	67.58	47.96
University of Bristol	90.16	10.91	Kit. Karlsruhe institute of tech	65.97	51.59

table 6

1	2	3	4	5	6
Ghent University	88.06	13.57	University of Birmingham	65.3	53.15
Maastricht University	86.76	15.26	Politecnico di milano	65.16	53.49
Delft university of Technology	86.58	15.51	University of Zurich	64.93	54.02
Universitat de Barcelona	85.12	17.46	University of Nottingham	61.87	61.63
The university of Edinburgh	83.73	19.44	The University of Sheffield	60.89	64.21
University of Amsterdam	83.27	20.10	The University of Warwick	59.8	67.24
Aarhus University	81.08	23.34	Rwth Aachen University	56.12	78.17

DEA 3. Analysis of technological efficiency. In the third DEA analysis, a study was made of university efficiency in terms of technological efficiency. Work has continued with the following inputs: the number of undergraduate students, the number of postgraduate students and the number of professors. In this analysis, the output used has been the number of patents filed. The information has been obtained from World's most innovate universities. As in the previous analyzes, we have followed a variable-scale return model oriented towards output (BBC-output model). In the model, the Cooper rule has been fulfilled, since we have worked with 4 variable inputs and one output variable. Therefore, $\alpha > 3$.

The results are shown in table 7. We have continued presenting an ordering of the DMU according to the score and a column -target patents- has been added, in which the level that their patents should increase to reach the optimal level of technical efficiency is determined.

Table 7 – **Results of the application of the DEA technological efficiency model**

Unit Name	Score	Target Patents	Unit Name	Score	Target Patents
Università di Padova	100	0	Aarhus University	32.47	207.99
Universität Stuttgart	100	0	The University of Manchester	32.42	208.42
Trinity college Dublin. The Univ	100	0	University of Oslo	31.97	212.75
Universitat Politècnica de Valèn	100	0	University of Nottingham	31.21	220.45
Université Pierre et Marie Curie	100	0	University of Birmingham	30.83	224.36
Technische Universität Dresden	100	0	Alma mater Studiorum - University	29.52	238.79
University of Oxford	100	0	Erasmus University Rotterdam	29.27	241.67
Eth Zurich - Swiss Federal Insti	100	0	The University of Edinburgh	29.24	241.98
Imperial College London	99.37	0.63	The University of Warwick	27.64	261.78
Ku Leuven	96.22	3.93	Leiden University	26.37	279.28
Delft University of Technology	93.15	7.35	University of Southampton	25.02	299.67
Ghent University	76.59	30.57	University of Amsterdam	24.26	312.13
Kit. Karlsruhe Institute of Tech	74.72	33.83	Universidad Autónoma de Madrid	24.24	312.51
Universitat de Barcelona	71.78	39.32	The University of Sheffield	23.41	327.12
University of Cambridge	65.59	52.47	Rwth Aachen University	22.86	337.47
Politecnico di Milano	65.02	53.79	Cardiff University	22.46	345.23
Université Catholique de Louvain	63.55	57.35	University of Copenhagen	21.9	356.70
Technical University of Munich	48.03	108.21	University of Groningen	20.73	382.35
Maastricht University	44.22	126.14	University of Bristol	20.3	392.69
University College Dublin	41.81	139.19	University of Leeds	19.42	414.92
University of Zurich	41.68	139.94	University of Glasgow	17.03	487.08

DEA 4. Global efficiency analysis. Finally, in this fourth DEA analysis, a study of global university efficiency has been carried out, which encompasses labour, academic and technological efficiency. The inputs used were the number of undergraduate students, the number of postgraduate students and the number of professors. The outputs were the overall score calculated in the QS Graduate Employability Ranking, the average of the HiCi, N & S and PUB values calculated in the academic ranking of the world's universities (ARWU) and the number of patents obtained from the World's most innovate universities.

The model used is a return to variable scale oriented towards output (BBC-output model). In it, the

Cooper rule has been fulfilled since we have worked with 4 variables inputs and three variable output. Therefore, α> 3.

The results are shown in table 8. We have continued presenting an ordering of the DMU according to the score and three columns have been added that indicate how much they should increase their level QS, ARWU and number of patents to be placed in levels of maximum efficiency. Also, it is observed that to achieve it, on some occasions they should dedicate fewer resources for a certain purpose, and increase them in other outputs. In these cases, the target yields negative values.

Table 8 – **Results of the application of the global efficiency DEA model**

Unit Name	Score	Target patents	Target Shanghai Index	Target QS University Ranking	Unit Name	Score	Target patents	Target Shanghai Index	Target QS University Ranking
University College Dublin	100	0.00	0.00	0.00	Technical University of Munich	61	63.75	0.00	-22.30
Università di Padova	100	0.00	0.00	0.00	University of Oslo	56	79.84	0.00	0.00
Leiden University	100	0.00	0.00	0.00	University of Zurich	53	89.75	0.00	-21.34
Maastricht University	100	0.00	0.00	0.00	The University of Warwick	45	121.01	0.00	0.00
Universitat Politècnica de Valèn	100	0.00	0.00	0.00	University of Nottingham	44	125.32	0.00	-7.73
Universität Stuttgart	100	0.00	0.00	0.00	University of Birmingham	41	141.17	0.00	0.00
Trinity College Dublin. The Univ	100	0.00	0.00	0.00	Rwth Aachen University	39	158.10	0.00	0.00
Politecnico di Milano	100	0.00	0.00	0.00	The University of Manchester	39	158.70	0.00	-40.31
Université pierre et marie curie	100	0.00	0.00	0.00	Aarhus university	37	166.72	0.00	0.00
Delft university of technology	100	0.00	0.00	0.00	The University of Sheffield	35	188.88	0.00	0.00
Imperial College london	100	0.00	0.00	0.00	Universidad Autónoma de Madrid	33	201.05	0.00	0.00
Kit. Karlsruhe institute of tech	100	0.00	0.00	0.00	The University of Edinburgh	31	218.71	0.00	-22.20
University of oxford	100	0.00	0.00	0.00	Erasmus University Rotterdam	30	235.49	0.00	-2.40
Eth Zurich – Swiss Federal Insti	100	0.00	0.00	0.00	Alma Mater studiorum – Universit	30	238.79	-5.39	-32.05
Technische Universität Dresden	100	0.00	0.00	0.00	University of Southampton	29	239.41	0.00	0.00
Ku Leuven	100	0.40	0.00	-21.49	Cardiff University	28	260.59	0.00	0.00
Ghent University	84	19.33	0.00	0.00	University of Copenhagen	28	261.42	-8.25	0.00
Université Catholique de Louvain	81	23.91	-9.50	0.00	University of Amsterdam	27	271.56	0.00	-10.70
Universitat de Barcelona	72	39.32	-31.19	-39.12	University of Leeds	24	315.75	0.00	-15.55
University of Groningen	68	46.26	-21.52	0.00	University of Glasgow	22	346.94	0.00	0.00
University of Cambridge	66	52.47	-11.92	-13.82	University of Bristol	21	377.96	0.00	-13.38

Finally, Table 9 shows Pearson correlation coefficient of the three output variables: employability,

publications and patents. The correlation coefficient between patents and publications indicates a strong positive relationship between these two variables. This result is in accordance with recent studies which conclude that academic inventors are also more active in the generation of scientific knowledge (Bourelos et al., 2017[31]; Grimm and Jaenicke, 2015[32]; Magerman et al., 2015[33]).

Table 9 – **Correlation matrix**

	employability	***publications***	***patents***
employability	1		
publications	0.3663	1	
patents	0.6076	0.7084	1

Conclusions and directions of further researches. In this article, we have carried out a DEA analysis that has allowed us to analyze the efficiency indexes of forty-two European universities related to their academic function, the labour insertion of their university graduates, technological innovation and finally a concept that has been defined and that encompasses all of them as is the global university efficiency. To this end, a nonparametric method has been used that has allowed us to define an optimal production function and the relative position occupied by each university analyzed with respect to it.

The results obtained have to be interpreted with caution. The ignorance of the exact functioning by which inputs are transformed into outputs implies that any modification in the definition of the components of the production function could yield different results.

In any case, highlight how in this article a university comparison is collected that moves away from most of the publications in terms of efficiency analysis since it contemplates a series of variables that summarize the three main functions that universities must fulfil in current societies such as providing quality employment to their graduates, providing companies with new forms of production and advancing science regionally.

The results provide not only show a list of universities in relation to the overall level of efficiency in which they are located. In addition, the analysis allows determining for each one of them what specific aspects should be focused to increase their global efficiency levels.

In this sense, we believe that this analysis should be completed in future works in a double aspect. On the one hand, carrying out a more detailed analysis of inputs/outputs variables that can give a more accurate view in determining the overall efficiency degree. On the other hand, carry out continuous analyzes over time, through which the evolution experienced by the universities could be determined, as well as introducing other types of concepts to the academic world, such as productivity analysis through statistical tools such as the Malmquist index. This index allows its calculation associated to two periods of time. It can also be broken down into two elements, such as, on the one hand, the deviations from the production boundary -technical efficiency; and, on the other, the movements of the frontier-technological change – (Marco-Serrano and Rausell-Köster, 2006 [34]).

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Рейтинг глобальної ефективності найкращих університетів Європи

Діяльність будь-якого суб'єкта господарювання повинна базуватися на такому співвідношенні доходу до суми пов'язаних з ними витрат, при якому управління матеріальними та нематеріальними активами дозволяє досягати максимального обсягу виробництва при мінімальному обсязі залучених ресурсів. В рамках даного дослідження проведений аналіз ефективності діяльності закладів вищої освіти. Об'єктами дослідження є 42 найкращих університета Європи. Аналіз наукової літератури з теми дослідження дозволив авторам стверджувати, що невирішеними залишаються ряд теоретичних і прикладних проблем, пов'язаних з оцінкою ефективності діяльності закладів вищої освіти, зокрема врахування трьох основних функції університетів у XXI столітті, таких, як: підвищення рівня працевлаштування випускників, передача та розширення наукових знань, а також модернізація національної економічної системи шляхом поліпшення бізнес-клімату. У роботі відповідно до поставлених завдань використано непараметричний метод порівняльного аналізу (data envelopment analysis (DEA)), який дозволяє визначити відносне положення кожного з досліджуваних університетів за рівнем ефективності порівняно з максимальним (ідеальним) рівнем ефективності, а також визначити основні напрямки її підвищення. Авторами запропоновано здійснювати порівняльний аналіз ефективності діяльності закладів вищої освіти за чотирма напрямками: ступінь працевлаштування випускників – DEA 1 «Аналіз ефективності праці»; публікаційна активність – DEA 2 «Аналіз академічної ефективності»; патентна активність – DEA 3 «Аналіз технологічної ефективності»; інтегральна оцінка з урахуванням трьох попередніх складових – DEA 4 «Глобальний аналіз ефективності». Суб'єктами, які сформували основні вхідні параметри побудованої виробничої функції методу DEA, стали: студенти, аспіранти, вітчизняні та закордонні викладачі. В якості вихідних параметрів моделі прийнято рівень працевлаштування випускників, публікаційну та патентну активність університетів. Використання кореляційного аналізу дозволило авторам відзначити високий ступінь лінійної залежності між університетами, що забезпечують найкращі результати в академічній та технологічній ефективності.

Ключові слова: рейтинг, університет, працевлаштування, метод порівняльного аналізу, патенти, публікації.