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Efficiency of Higher Education Systems in the European Union Member States: A DEA Approach

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Abstract: The system of higher education is formed as one of the main pillars in the modern economic development of each country. The consequences of educational activities can be both positive by creating opportunities for achieving greater added value, and negative, expressed in various market deficits and vulnerabilities in financial management and the implementation of government policy. Therefore, the analysis of higher education is important for the national economy, the labour market, the participants in the educational process (teachers, students, PhD students, researchers, administrators, etc.), as well as for all taxpayers who indirectly finance the state education system. This has resulted in a significant number of scientific publications evaluating various aspects of higher education institutions. The present study aims to evaluate, by means of a non-parametric model such as Data envelopment analysis, the technical efficiency of higher education systems in the European Union in three main aspects: teaching activity, research activity and management of education expenditure. The analysis covers the period from 2013 to 2021, and this period is divided into two sub-periods to track changes in the efficient management of education systems.

Keywords: higher education; efficiency; DEA; students.

JEL classification: H52; H44; I22; I23.

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1. INTRODUCTION

In the context of economic theory, education represents a mixed good. Moreover, education is a good that is often classified as a merit good, or as Brussarski (2007) points out, it is a good that brings much greater benefits to society and to specific consumers than they actually appreciate. Shaw and Allison (1999) classify these types of benefits as tangible and intangible (or qualitative), indicating that they are obtained in the course of information transmission during teaching/learning. The authors also relate education to modern models of economic development based on knowledge and skills.

Higher education, including doctoral study constitutes the highest form of the education system. The significance of the higher education system for the development of the national economy is extremely important. Oketch *et al.* (2014) present a conceptual framework for the impact of higher education on economic growth and development and highlight three main pillars: teaching, developing research and innovative approaches, and providing educational benefits. The process of training current and future students (investment in human capital) plays a significant role in shaping the profile of potential participants in the labour market, including the opportunities for improving their economic well-being. On the other hand, the structure of the higher education system, teaching models and their modernization can contribute to meeting the requirements and expectations of employers on the labour market, and can also create additional forms of market deficits of a certain type of specialists, respectively surplus of others (Angelov, 2019). The system of higher education, through the research activity of academic staff members, as well as other types of independent researchers, also contributes to the development of models and approaches, the generation of new knowledge and technological processes. These research findings, in turn, can be applied in practice in search of greater added value in production processes, or as Halaskova *et al.* (2020) point out, to achieve "*stable and sustainable social growth*". Therefore, the education system should be subject to continuous monitoring, as well as an assessment of its efficiency in terms of processes, management and financing. Precisely for this reason, the object of this paper is the higher education systems. The subject of the research is specifically the processes and activities in higher education in the 27 European Union (EU) member states. The purpose of the article is to develop models and assess the technical efficiency of higher education within the European Union. The present study seeks to examine and assess the technical efficiency of higher education systems in the EU-27 from multiple dimension and perspectives by analyzing three essential aspects – teaching activity, scientific (research activity) and financial management.

The paper consists of five sections. Section 2 provides an extensive review of the existing literature related to the evaluation of the efficiency of higher education and the applicable tools for analysis. Section 3 outlines a methodological framework for applying Data envelopment analysis (DEA) under certain constraints and develop three evaluation models. Section 4 contains a descriptive statistics of the input and output variables selected for the purpose of the analysis. Section 5 presents the results of the applied models. Section 6 includes the conclusions and future research opportunities.

2. LITERATURE REVIEW

In research practice, various approaches are used to calculate the efficiency of individual units, including in performance evaluation for units operating in both the public and private sectors. One of these approaches is the so-called DEA analysis. DEA is a non-parametric approach with extremely wide application in the evaluation of economic processes. Mihaylova-Borisova and Nenkova (2021) point out that one of the significant advantages of DEA is that it is not necessary to define the type of production function in advance, which is necessary in alternative approaches, and this in turn contributes to minimizing the possible errors. The method is based on mathematical linear programming. This approach makes it possible to assess both the overall technical efficiency of selected units, as well as pure technical efficiency, scale efficiency, cost efficiency, etc. In general, the DEA model aims to achieve comparability in the degree of efficiency between the individual researched units (called "decision-making unit" or DMU), i.e. the evaluation in practice results in the so-called comparative efficiency. Efficiency evaluation through DEA is carried out on the basis of matching multiple outputs (results) and multiple inputs (resources).

The Data envelopment analysis is an extremely popular technique for evaluating the efficiency of units operating in the education system. This approach is used for assessment, both in primary and secondary education, and in the assessment of universities, colleges and the higher education system as a whole. In the theoretical and empirical literature, there is quite a large number of studies whose object is the evaluation of the efficiency of educational institutions and in which DEA is used as the main tool. Conducting such researches in the higher education system can be divided into several groups.

The first group of studies estimates the efficiency of the institutions operating in the system of higher education in a specific country, i.e. assessment of universities, colleges and other institutions according to the national classification (Abbott and Doucouliagos, 2003; Johnes, 2006; Worthington and Lee, 2008; Katharaki and Katharakis, 2010; Cunha and Rocha, 2012; Tochkov *et al.*, 2012; Nazarko and Šaparauskas, 2014; Srairi, 2014; Mikušová, 2015; Selim and Bursalıoğlu, 2015; Yuangyai, 2017; Figurek *et al.*, 2019; Hammes Junior *et al.*, 2020; Perović and Kosor, 2020; Cossani *et al.*, 2022; Sun *et al.*, 2023; Temoso *et al.*, 2023; Tran *et al.*, 2023).

The second group of studies makes a comparative assessment of the efficiency of higher education systems in different countries. Within these studies, performance is assessed not at the level of an individual educational institution, but at the level of individual countries and their higher education systems (Agasisti, 2011; Obadić and Aristovnik, 2011; Agasisti and Pohl, 2012; Wolszczak-Derlacz, 2017; Yotova and Stefanova, 2017; Ahec Sonje *et al.*, 2018; Nadoveza Jelić and Gardijan Kedžo, 2018; Din and Coculescu, 2019; Blecich, 2020; Stefanova and Velichkov, 2020).

The third group of studies focuses on the performance evaluation at the level of individual university/college structures, such as faculties, departments, research centers (Halkos *et al.*, 2012; Abd Aziz *et al.*, 2013; Laaraf and Bouguera, 2020; Ramírez-Valdivia *et al.*, 2022; Wildani *et al.*, 2023).

The last group of researches evaluates the efficiency of the entire system of education and its individual subdivisions, including the system of higher education (Tyagi *et al.*, 2009; Aristovnik, 2011; Brzezicki *et al.*, 2022).

Studies related to the evaluation of the efficiency of higher education systems through DEA can also be distinguished according to the specific model used. The differences can be outlined in several aspects:

- the evaluation approach can focus on either the input side or the output side of the process,

- the estimation approach can be established under the assumption of constant returns to scale (CRS) or variable returns to scale (VRS),
- the assessment approach can also differ to a great extent in terms of the selected variables that are used as input and output.

Based on the first distinguishing criterion (the focus of analysis), the DEA approach can be input-oriented. Such an approach aims to minimize the input resources, assuming that there is no change in the outputs, in order to achieve efficiency from the actions of the unit under analysis. The DEA approach can also be output-oriented, in cases where the purpose is to maximize the results of the individual unit through more efficient utilization of the available input resource. The choice of a specific model in the application of DEA depends mostly on the degree of influence of the analysed DMUs on the input and output. If it is assumed that the analysed DMUs in the higher education system have a greater influence on the selected input resources, then the input-oriented DEA approach can be applied (Abbott and Doucouliagos, 2003; Katharaki and Katharakis, 2010; Mikušová, 2015; Yotova and Stefanova, 2017; Ahec Sonje *et al.*, 2018; Stefanova and Velichkov, 2020). Incidentally, this is a widely accepted approach to assessment, especially when the focus is on evaluating units in the public sector. The reason is that this strategy permits searching different options for optimizing the use of scarce resources. This approach also has some disadvantages such as the dominant emphasis on resource use and focus shifts away from possibilities for improvement current results, even when this is achievable. A negative aspect also occurs within the regulatory and institutionally established minimum levels of resources used, as well as in the case of significant differences between the assessed units. If the degree of influence on the selected output variables is greater, it is recommended to use output-oriented DEA (Aristovnik, 2011; Obadić and Aristovnik, 2011; Tochkov *et al.*, 2012; Nazarko and Šaparauskas, 2014; Selim and Bursalıoğlu, 2015; Wolszczak-Derlacz, 2017; Nadoveza Jelić and Gardijan Kedžo, 2018; Din and Coculescu, 2019; Hammes Junior *et al.*, 2020; Laaraf and Bouguera, 2020; Cossani *et al.*, 2022). It is possible to use this approach also in the evaluation of educational policies when the goal is to achieve better results by using available resources (without requiring any adjustments). A disadvantage of output-oriented DEA is that it places too much emphasis on results and underestimates the efficient use of scarce resources. In the pursuit of a potentially higher result, this may occur at the expense of excessive use of budgetary resource. It is usually more preferred in analyses and assessments of activities in the private sector, but in fact, it also finds application in the public sector.

When choosing a DEA approach based on returns to scale, expectations regarding the relationship between changes in the selected outputs and changes in the inputs are relevant. If changes in higher education outputs are expected to be proportional to changes in inputs, then DEA with constant returns to scale can be applied. In the absence of such proportionality, a DEA approach based on variable returns to scale including both increasing and decreasing returns to scale, should be used. In the existing scientific literature, there are also studies that establish rather the presence of some form of proportionality and the possibility of applying the constant returns to scale approach (Katharaki and Katharakis, 2010; Cunha and Rocha, 2012; Nazarko and Šaparauskas, 2014; Laaraf and Bouguera, 2020; Sun *et al.*, 2023). Most researchers emphasize the existence of various forms of externalities, which support the view that an approach based on variable returns to scale would be more appropriate (Abbott and Doucouliagos, 2003; Aristovnik, 2011; Obadić and Aristovnik, 2011; Tochkov *et al.*, 2012; Mikušová, 2015; Selim and Bursalıoğlu, 2015; Wolszczak-Derlacz, 2017; Yotova and

Stefanova, 2017; Ahec Sonje *et al.*, 2018; Nadoveza Jelić and Gardijan Kedžo, 2018; Din and Coculescu, 2019; Hammes Junior *et al.*, 2020; Stefanova and Velichkov, 2020; Çetin and Maral, 2022). It is further supported by the fact that higher education institutions can change their scale over time in pursuit of certain goals.

The choice of specific input and output variables of the DEA model is extremely difficult, and this actually creates the most significant differences in the existing studies on the topic when the object of evaluation is the efficiency of higher education. It should be noted that DEA is also quite sensitive to the selected input and output variables. In such cases, even a subsequent analysis of statistical robustness and sensitivity of the obtained results is recommended, and for this purpose the so-called bootstrap DEA, the Monte Carlo approach, etc. can be applied. Nevertheless, with smaller samples, or when studying entire populations, as is the present case with the 27 EU member states, such additional analyses and assessments are not always conceptually justified. Tests and analyses of this kind can lead to high variability and difficult interpretation of the results, including unstable and unreliable estimates, especially confidence intervals that represents the simulation procedure more than the true variability. Although the criticism of the classic DEA model is that it does not evaluate the statistical error or also known as noise due to the influence of external factors, it is necessary to take into account that additional simulations, such as those in the Monte Carlo method, can „cause noise", associated with relatively stable indicators for which frequent fluctuations are not typical. Under such circumstances, the classical DEA model can be considered to provide an estimate that is robust to a certain extent, maintaining logical interpretability, especially in studies aimed at comparing well-established and specific educational systems operating within recognized institutional and economic structures.

The difficulty in choosing input and output variables of the model is due to several reasons:

(1) personal subjective preferences of researchers, based on their views on the importance and priority of various factors related to the higher education system,

(2) subjective preferences of researchers consistent with their selected DEA approach (under the circumstances mention above), as well as,

(3) objective circumstances related to the available data used for estimation and the scope of the study.

Despite the availability of substantial databases containing educational information, analysing performance at the cross-country level is hindered by obstacles in gathering enough data on the preselected indicators and time periods. The choice of variables in the evaluation of the efficiency of the higher education system also depends on the scope of the activities analysed: teaching and learning activities, administrative responsibilities, research endeavours, financial management (including sources of revenue or expenditure), international cooperation and mobility, other types of activities or the general functioning of educational institutions.

Most researchers who focus on the efficiency of higher education primarily use the following variables as inputs to their DEA models (see Table no. 1):

The indicators mentioned above are among the most commonly used input variables in research practice, but certainly others can be specified. It should be noted that in the analysis of higher education performance, including public expenditure on higher education as an input variable is not always the most appropriate approach. The reason for such a conclusion is that in quite a few countries higher education is offered as a service by the private sector, and in other countries it can even be said that private higher education dominates in terms of relative market share (Latvia, Cyprus and Belgium). In addition, even in public institutions in the field of higher education there are payments made by private entities, such as payment of tuition fees by students. It is typical for some EU countries that the share of private payments significantly exceeds public funds for higher education (France, Spain, Austria, Bulgaria, Italy and Slovakia). In some studies, the budget of a higher education institution, and more specifically the focus on the *revenue* part, is considered as an input variable (Wolszczak-Derlacz and Parteka, 2011; Agasisti and Berbegal-Mirabent, 2021), especially when the studies are devoted to a particular educational institution.

Table no. 1 – Input variables

Input variables	Summary of relevant empirical studies
Number of academic staff	(Abbott and Doucouliagos, 2003; Johnes, 2006; Worthington and Lee, 2008; Katharaki and Katharakis, 2010; Tochkov *et al.*, 2012; Bonaccorsi *et al.*, 2013; Mikušová, 2015; Selim and Bursalıoğlu, 2015; Quiroga-Martínez *et al.*, 2018; Blecich, 2020; Brzezicki *et al.*, 2022; Cossani *et al.*, 2022; Temoso *et al.*, 2023; Tran *et al.*, 2023)
Number of non-academic staff	(Abbott and Doucouliagos, 2003; Katharaki and Katharakis, 2010; Bonaccorsi *et al.*, 2013; Srairi, 2014; Wolszczak-Derlacz, 2017; Tran *et al.*, 2023)
Operating costs	(Ramírez-Correa *et al.*, 2012; Tochkov *et al.*, 2012; Mikušová, 2015; Yuangyai, 2017; Blecich, 2020; Cossani *et al.*, 2022)
Number of entrants or enrolled students in various forms of higher education - bachelor's, master's, phd	(Johnes, 2006; Agasisti and Pohl, 2012; Sav, 2013; Figurek *et al.*, 2019; Perović and Kosor, 2020)
Ratio between the number of academic staff and the number of students or reciprocal to it	(Cunha and Rocha, 2012; Yuangyai, 2017; Nadoveza Jelić and Gardijan Kedžo, 2018; Perović and Kosor, 2020)
Total expenditure on higher education	(Hammes Junior *et al.*, 2020; Sun *et al.*, 2023; Temoso *et al.*, 2023)
Expenditure on higher education as percentage of GDP	(Agasisti, 2011; Nadoveza Jelić and Gardijan Kedžo, 2018; Din and Coculescu, 2019; Perović and Kosor, 2020)
Expenditure per student as a percentage of GDP per capita	(Obadić and Aristovnik, 2011; Yotova and Stefanova, 2017; Ahec Sonje *et al.*, 2018; Stefanova and Velichkov, 2020)
Research expenditure	(Johnes and Yu, 2008; Tran *et al.*, 2023)
Capacity (or size) of edu–cational and research area	(Tochkov *et al.*, 2012; Dogan *et al.*, 2016)

The process of selecting appropriate input and output variables is a complex task. Every researcher should search for the most accurate output variables possible so that they provide an adequate response to the research goal, on the one hand, and its relationship with the input variables, on the other hand. In terms of choosing indicators for the result related to teaching and learning activity, the focus is usually placed *on the number or share of enrolled or graduated students in different forms of higher education* (Avkiran, 2001; Aubyn *et al.*, 2009; Aristovnik, 2011; Cunha and Rocha, 2012; Nazarko and Šaparauskas, 2014; Hammes Junior *et al.*, 2020; Laaraf and Bouguera, 2020). Tochkov *et al.* (2012) also pay attention to another segment of student learning as an aspect used for evaluation (result), namely *the share of* *foreign students in the total number of students studying*. As the authors point out, such an indicator highlights the qualitative effects and results of education in higher education institutions. The higher the proportion of foreign students, the more it is assumed that local higher education institutions may offer higher standards and better training. Blecich (2020) points out that this is a clear expression of the recognition of a given higher education institution. In this context, Johnes and Yu (2008) include a *reputation index* as a result, although they take into account the effect of subjectivity in its modeling. Another group of authors targets certain *members of society* (segmented mainly by age within the groups: 20-34 years, 25-34 years, 30-34 years, 25-29 years, 25-64 years, etc.) *with acquired higher education*, using indicators (strategic goals) set at the pan-European level in their studies (Yotova and Stefanova, 2017; Din and Coculescu, 2019). In addition, to being directly related to the educational activity, some of the output indicators are reflected in research on the relationship between the higher education system and the labour market by tracking the subsequent *realization of students*, based on *employment* indicators (Abbott and Doucouliagos, 2003; Selim and Bursalıoğlu, 2015; Din and Coculescu, 2019; Mihaljevic Kosor *et al.*, 2019) and *unemployment* (Obadić and Aristovnik, 2011; Ahec Sonje *et al.*, 2018; Stefanova and Velichkov, 2020). Yuangyai (2017) adds another significant aspect of the labour market-higher education relationship, namely, the *degree of satisfaction of employers in hiring graduates of the given university*. Although the author points out that this is an indicator of a result related more to the teaching activity, it is certainly related to the abilities for career development.

Research activity and its results are also an important component of the higher education system. Therefore, many authors involve the *number of scientific publications* (including monographs, articles, reports presented at scientific conferences, books, patents, etc.) as an output variable in their analyses. In particular, attention is paid to *publications* in international journals or conference proceedings that are *indexed in* major world-renowned databases, such as Scopus (2024) *and Web of Science (2024)* (Tochkov *et al.*, 2012; Bonaccorsi *et al.*, 2013; Sagarra *et al.*, 2017; Wolszczak-Derlacz, 2017; Dolgikh, 2023). Some additional indicators are also used to evaluate the scientific publication, such as the *number of citations, or specific evaluation indices,* e.g. *Hirsch Index* (Dolgikh, 2023), *own calculated (weighted) indices* (Tyagi *et al.*, 2009), or by weighting the *number of publications per academic staff member (Yuangyai, 2017)*, etc. In the efficiency analysis of public universities and colleges, the *amount of research grant* is also used as an output related to scientific activity (Katharaki and Katharakis, 2010; Thanassoulis *et al.*, 2011; Srairi, 2014).

3. METHODOLOGY

The object of analysis in the present study is the higher education systems in the 27 EU member states. Although the United Kingdom is part of the European Union until 2020, this country is not included in the current analysis. Given that the assessment is at the national level (among EU member states), the higher education system takes on the role of DMUs. As a result, it is assumed that educational institutions would have greater opportunities to influence the input variables, considering that in most EU countries (predominantly in Northern and Western Europe) universities maintain a relatively high degree of academic, staffing and organizational autonomy. Circumstances change significantly with regard to the model's output variables, which depend on processes associated with socio-economic development, labour market conditions, psychological and motivational attitudes of students, as well as on the government's approach to education and research policy. Therefore, the present study adopts input-oriented DEA. This is a logical consequence of the fact that, despite the dominant share of public higher education institutions, the analysis also includes private universities and colleges, which have greater decision-making autonomy. Also, the selection of input resources takes into account the possibility of encouraging institutions to have more freedom in decision-making. Of course, it is essential to consider that government policy sometimes places public educational institutions in a position where they do not have much authority to make independent decisions, but if the elements of input and output are compared, certainly the possibility of influencing the input is greater.

The present study supports the fact that the proportionality in input and output dynamics cannot be guaranteed. Therefore, the research uses the DEA approach under the assumption of variable returns to scale. This allows to evaluate the pure efficiency ($Technical\ efficiency_{VRS}$) and the scale efficiency of educational institutions. The use of variable returns to scale is a reliable tool, especially when in the evaluation of heterogeneous units, although it often shows lower discriminative ability, leading to an artificial increase in the number of units classified as efficient. For this reason, and in order to estimate the scale efficiency of educational institutions, it is necessary to calculate the technical efficiency, assuming a constant returns to scale ($Technical\ efficiency_{CRS}$), or the so-called overall technical efficiency.

$$\text{Scale efficiency} = \frac{Technical\ efficiency_{CRS}}{Technical\ efficiency_{VRS}} \tag{1}$$

As a result of the above-mentioned determination of the model approach (oriented toward input) and the assumption made about changes in the scale of the studied units (with variable returns to scale), the DEA model can take the following envelopment form:

$$\text{Min } \theta_f \tag{2}$$

Subject to Constraints:

$$\mathrm{Y_{rf}} - \sum_{d=1}^{n} \lambda_d \mathrm{Y_{rd}} \leq 0, \qquad where\ \mathrm{r} = 1,2,3,\ldots\ldots,w$$

$$\theta_f \mathrm{X_{if}} - \sum_{d=1}^{n} \lambda_d \mathrm{X_{id}} \geq 0, \qquad \text{where i} = 1,2,3,..,v$$

$$\sum_{d=1}^{n} \lambda_d = 1$$

$$\lambda_d \geq 0, \quad \forall \mathrm{d} = 1,2,3,\ldots\ldots,\mathrm{n}$$

where: Y_{rf} is the quantity of r^{th} output produced by DMU *f*, X_{if} is the quantity of i^{th} input used by DMU *f*, *n* is the number of DMU to be evaluated (in the present study these are the 27 national systems of higher education), *w* is the number of outputs, *v* is the number of inputs, θ_f is the relative efficiency score for DMU *f*, λ is the vector with weights Ix1, X_{id} is the quantity of i^{th} input used by DMU d and Y_{rd} is the quantity of r^{th} output produced by DMU d.

For each DMU that is located on the efficient frontier, θ will be equal to 1, while for the remaining DMUs that are located below the efficiency frontier, the value of θ will be lower than 1. The first DMUs with efficiency equal to 1 can function as conditional benchmarks, whereas the second ones appear to be as inefficient.

The selection of specific input and output variables in this study mainly relies on the components of the higher education system that are subject to estimation and on the basis of the literature review conducted on the researched topic. Due to the fact that the research aims to answer the question of the efficiency of the higher education systems in the EU in terms of teaching activity, financial management and research activity, the analysis involves specifying three different evaluation models.

The teaching activity assessment model consists of one input variable (ratio of the number of academic staff members to enrolled students, % (RAsENRst)) and four output variables ([1] share of graduated bachelors to enrolled bachelor's students, % (RGEund), [2] share of graduated master's and PhD students to enrolled master's and PhD students, % (RGEpost), [3] share of foreign students to enrolled students, % (RFSENR) and [4] employment of the population aged 25-64 with higher education, % ($EMTE_{25-64}$)). Despite the intention to include the number of non-academic members of higher education institutions as an input variable, which has a direct impact on the modern educational process, the lack of sufficient data to cover all the higher education systems encompassed in the analysis and referring to entire period studied, means that it is necessary to exclude this indicator from the input variables.

The model for evaluating the expenditure efficiency (financial management) consists of one input variable (ratio of expenditure per student to GDP per capita, % (RTEpsGDPpc)) and three output variables ([1] share of graduates to enrolled students, % (RGradTOErn), [2] share of the population aged 25-64 with higher education to the total population in the same age group, % ($PopTE_{25-64}$) and [3] ratio of unemployment among the population aged 25-64 with higher education to unemployment among the population aged 25-64 with all levels of education, % ($invRUNE_{25-64}$)). It is worth mentioning that the unemployment is an output with a negative effect, and DEA aims to estimate the positive effects of the input resource. In this regard, the unemployment result is transformed as shown in equation 3 below:

$$invRUNE_{25-64} = 1 - \left(\frac{UNETE_{25-64}}{UNEAllISCED_{25-64}}\right) \text{x } 100 \quad (1)$$

where: $invRUNE_{25-64}$ is the unemployment output that is included in the model, $UNETE_{25-64}$ is the unemployment among university graduates, $UNEAllISCED_{25-64}$ is the unemployment among those who have completed some degree of education.

The presented frameworks of the two models above include indicators related to the labour market with the age group 25-64 years selected because the analysis assumes that most graduates start their professional activity around the middle of their twenties. On the other hand, in most countries the set retirement age is around 65 (or anticipated to be so in the future).

The research performance evaluation model consists of two input resources ([1] number of academic staff members (As) and [2] number of enrolled PhD students (PhDenr)) and three output variables ([1] number of publications indexed in the Scopus (2024) database (ScopusPub), [2] number of publications indexed in the Web of Science (2024) database (WoSPub) and [3] Hirsch index (H-index) based on information from the Scopus database).

4. DATA AND DESCRIPTIVE STATISTICS

Over the last ten years, there has been a gradual trend within the EU towards an increase in the number of people enrolled in higher education institution. While in 2013, slightly more than 17 million students were studying within the European Union, the latest Eurostat (2024) data (as of the end of 2021) indicate that the number of students has risen to 18.5 million. Most students study in Germany (about 3.35 million, which represents about 18.1%), France (2.8 million, or 15.2%), Spain (2.26 million, or 12.2%), Italy (2.1 million or 11.3%), Poland (1.34 million or 7.27%) and the Netherlands (0.98 million or 5.33%). Between 1.2 and 1.45 million members of the academic staff of higher education institutions (incl. professors, associate professors, assistant professors, lecturers, researchers, etc.) are involved in the training of these students. On average, each academic staff member in the European Union is responsible for between 12 and 13 students, but it is necessary to highlight that serious differences are observed, both between individual countries and also with regard to different scientific fields. While in Greece a member of the academic staff teaches about 40-41 students, in Ireland - between 26 and 27, in Luxembourg the number of students taught is significantly smaller (5), in Austria - 7, and in Poland, Croatia and Lithuania – 9. In the present study, the reciprocal of this value is used, namely the number of academic teachers per student (%). As can be seen from Table no. 2 below, for the period 2013-2016, academic staff members formed between 2.39% and 13.88% of the enrolled students, while during the period 2017-2022 this percentage varied in the range between 2.38% and 17.98%. The data shows that there is an increase in differentiation between the lowest and highest value. Table no. 2 contains descriptive statistics for the selected input variables, with two sub-periods defined. The purpose is to compare the results of the input management and the obtained output for these two sub-periods. Main sources of data are the Eurostat educational statistics database, as well as the Scopus (2024), including Scimago Journal & Country Rank (2024) and Web of Science (2024) databases.

Table no. 2 – Descriptive statistics of input variables

Indicator and period		Min	Max	Mean	SD
Number of academic staff members (As)					
Period	2013-2016	777	388,144	47,842	78,326
	2017-2021	1,309	441,858	51,411	88,291
Number of enrolled PhD students (PhDenr)					
Period	2013-2016	104	205,275	23,309	39,607
	2017-2021	256	195,110	24,426	39,544
Ratio of the number of academic staff members to enrolled students, % (RAsENRst)					
Period	2013-2016	2.39	13.88	7.72	2.79
	2017-2021	2.38	17.98	8.36	3.43
Ratio of expenditure per student to GDP per capita, % (RTEpsGDPpc)					
Period	2012-2015	15.07	54.04	35.46	7.54
	2016-2020	12.66	46.61	34.13	7.01

Source: authors' calculations based on data from Eurostat (2024), Scimago Journal & Country Rank (2024), Web of Science (2024)

From the previously mentioned 18.5 million students, nearly 80% of them study in public universities, and based on data from Eurostat (2024) for 2021, this share in Greece and

Luxembourg is 100%, in Denmark 99.6%, Ireland 96.57%, Estonia 93.41%, Croatia 90.97%, Czech Republic 89.73%, Lithuania 88.49%, Sweden 88.38%, Slovakia 88.10%, Romania 87.77% and Bulgaria 87.67%. As already indicated above in the literature review, there are European Union member states in which the majority of students study at organizations whose control is not government, but predominantly private. These are Latvia (92.51% of students study at private universities), Cyprus (73.41%) and Belgium (58.35%). In Finland, the ratio approximates one to one (48.18% in private universities). The relative share is high in Poland (31.55% of students), Hungary (27.95%) and Spain (25.50%). This, in fact, predetermines the decision to include the total expenditure of education in the model for evaluating the expenditure efficiency of higher education. This expenditure includes transfers made by governments for the state education policy, but also expenditure incurred by students (in the form of paid fees), by corporate/non-governmental (non-educational) organizations (in support of funding of student training, scholarships) and by international organizations.

The conducted research presents the expenditure of higher education in the form of a ratio, which, on the one hand, includes the number of enrolled students, and on the other hand, compares these cost per student to the dynamics of the main macroeconomic indicator, which is the GDP per capita. Through this approach, the aim is to establish the extent to which the expenditure of higher education changes in response to the changes occurring in the economy. The descriptive statistics of the input data in Table no. 2 show downward trend for the period 2016-2020 compared to the first sub-period 2012-2015. Furthermore, in the analysis of expenditure efficiency, the input resource is purposefully included with a time lag of t-1 relative to the main variables in the model (assuming that the years 2013 and 2016 represent the t period for the two sub-periods). The reason is to trace how the expenditure incurred (and their dynamics at the macro level) influence subsequent activities and processes within the higher education system. In this regard, the output variables in the specified model for assessment the expenditure efficiency also differ in terms of time periods (see Table no. 3). For example, the ratio of graduates to enrolled students (RGradTOErn) is calculated for the sub-periods 2013-2016 and 2017-2021, which provides an opportunity to check the result on main educational activities within a year. It is indicative of the data in Table no. 3 that for the second sub-period the average values of the ratio increase by about 0.22 pp, noting that this increase in Hungary averaged between sub-periods to 8.94 pp, in Ireland 4.86 pp, Denmark 2.43 pp and Estonia 2.05 pp. A decline is observed in half of the EU countries (Slovenia -4.2 pp, Slovakia -3.86 pp, Romania -2.03 pp, Latvia -1.81 pp, Czech Republic -1.78 pp, Netherlands -1.29 pp, Malta and Bulgaria -0.81 pp, Greece -0.62 pp, Croatia -0.61 pp, Lithuania - 0.59 pp, France -0.57 pp and Cyprus -0.51 pp). The other two indicators in this model (the share of the population aged 25-64 with a university degree and the output variable for unemployment) are included with data from sub-periods 2013-2017 and 2018-2022. The purpose is to assess the lag effect of previously incurred expenditure. In research practice, an even larger lag is sometimes taken, consistent with the years of study in higher education.

Table no. 3 – Descriptive statistics of output variables

Indicator and period		Min	Max	Mean	SD
Number of publications indexed in the Scopus database (ScopusPub)					
Period	2013-2017	762	180,402	33,958	44,400
	2018-2022	1,189	198,700	39,499	49,687
Number of publications indexed in the Web of Science database (WoSPub)					
Period	2013-2017	803	207,427	38,591	49,982
	2018-2022	1,293	231,184	45,633	57,299
Hirsch index (H-index)					
Period	2013-2017	169	1,584	682	406
	2018-2022	169	1,584	682	406
Share of foreign students to enrolled students, % (RFSENR)					
Period	2013-2016	0.77	45.06	8.17	8.32
	2017-2021	3.01	48.16	10.69	8.82
Employment of the population aged 25-64 with higher education, % ($EMTE_{25-64}$)					
Period	2013-2017	69.70	90.14	84.12	4.24
	2018-2022	76.20	91.08	86.64	3.25
Share of graduated bachelors to enrolled bachelor's students, % (RGEund)					
Period	2013-2016	8.73	31,37	20.63	4.84
	2017-2021	7.42	31.64	21.41	5.66
Share of graduated master's and PhD students to enrolled master's and PhD students, % (RGEpost)					
Period	2013-2016	17.02	48.50	20.63	7.75
	2017-2021	18.78	60.34	27.71	8.48
Ratio of graduates to enrolled students (RGradTOErn)					
Period	2013-2016	9.77	33,41	22.96	5.27
	2017-2021	9.16	36.96	23.18	5.59
Share of the population aged 25-64 with higher education to the total population in the same age group, % ($PopTE_{25-64}$)					
Period	2013-2017	16.74	44.40	30.90	8,12
	2018-2022	18.68	50.06	35.49	8.67
Ratio of unemployment among the population aged 25-64 with higher education to unemployment among the population aged 25-64 with all levels of education, % ($invRUNE_{25-64}$)					
Period	2013-2017	16.47	62.09	38.53	12.47
	2018-2022	5.69	57.70	34.09	13.60

Source: authors' calculations based on data from Eurostat (2024), Scimago Journal & Country Rank (2024), Web of Science (2024)

In all 27 member states, the share of the population aged 25-64 with higher education has increased in the sub-period 2018-2022 compared to 2013-2017. The average growth rate for the EU is around 4.59 pp, with the highest growth rates recorded in Malta (8.28 pp), the Netherlands (6.46 pp) and Slovenia (6.44 pp), and the lowest growth rate in Bulgaria (1.86 pp), Romania (1.94 pp), Finland (2.24 pp) and Italy (2.4 pp). In addition, Romania and Italy are the countries with the lowest relative share of university graduates (aged 25-64) in the entire EU according to the latest Eurostat (2024) data for 2022. For Romania, this share is only 19.7% in 2022 (or almost twice less than the EU average level), and in Italy 20.3%. Bulgaria also has a rather low value of the considered indicator (29.8%), while the data show that Finland reports above the EU average levels. It should be noted, however, that in Bulgaria the employment rate of higher education graduates (aged 25-64) is one of the highest compared to the employment rate of the rest of the population with acquired education as a whole. This can be deduced from the ratio of unemployment among people with higher education (ISCED levels 5-8) and unemployment among persons included in all ISCED levels. The relative share for Bulgaria is about 0.4 (as much as it is in Hungary and Slovakia), while in Denmark is 0.97 for 2022. As a result, it is not surprising that in the second sub-period 2018-2022 the lowest value of the indicator $invRUNE_{25-64}$ (5.69%) is calculated for Denmark. In 2022, in Romania the unemployment among people with higher education aged 25-64 is 1.3%, while the unemployment for all ISCED levels is 4.5%. Therefore, the ratio is 0.29 (while for 2012 it is 0.71), respectively $invRUNE_{25-64}$ for Romania is 71% for 2022 and for the entire second sub-period 2018-2022 is 57.7%. The average value of $invRUNE_{25-64}$ for EU countries in 2018-2022 shows a decrease compared to 2013-2017, which should be perceived as a negative effect. At the same time, the standard deviation grows, which means that the variation between countries is increasing.

Table no. 3 provides an opportunity to analyse the indicators of the publication activity of the academic staff of higher education institutions in the EU countries. Undoubtedly, when comparing the two sub-periods, it can be concluded that not only the members of the academic staff are increasing (see Table no. 2 above), but also the number of publications indexed in Scopus (2024) (an average increase of about 5 541 publications) and Web of Science (2024)(an average increase of about 7 042 publications). A significant relative rate of growth between the sub-periods considered in the data for publications indexed in Scopus (2024) is observed in Cyprus (69%), Malta (56%), Bulgaria (53%), Latvia (41%) and Lithuania (39%). According to Web of Science (2024) Database, the relative growth rate is highest in Luxembourg (91%), Cyprus (69%), Malta (61%), Lithuania (34%), Bulgaria and Croatia (32%). It is necessary to note that some of these countries have a relatively lower base and a more tangible change leads to the data indicated above. The countries with the highest number of publications indexed in Scopus (2024) are Germany (198,700 publications average for the period 2018-2022), Italy (142,756), France (126,055) and Spain (112,189), but this is also due to the significantly greater number of higher education institutions and academic staff members in these countries. The reference also shows similar data on Web of Science (2024). In relation to the inclusion of an index of publication relevance and productivity, such as the H-index, it should be emphasized that, apart from the leading countries (in terms of a greater number of researchers), the Netherlands, Belgium, Denmark and Sweden also report extremely high value of this index.

5. RESULTS AND DISCUSSION

As already mentioned above, the analysis of the efficiency of higher education systems within the European Union is carried out over the period 2013-2021, which is divided into two sub-periods to ensure comparability of results. Although it is indicated that some of the variables are included with their lagged values (t+1 and t+2) or for period t-1, sub-periods can be conceptually distinguished as: first sub-period (2013-2016) and second sub-period (2017-2021). The study incorporates three evaluation models in the methodological framework section. The study applies the Data Envelopment Analysis Program (DEAP) software, version 2.1 for analysis. The results below summarize the findings by type of activity subject to performance evaluation, more specifically: teaching activity, scientific (research) activity and financial management (expenditure efficiency).

Teaching activity

Table no. 4 below presents the results from model application for evaluating the efficiency of teaching activity within the education systems of EU member states. The data show that the member states have an average value of the overall efficiency of their teaching activity of 0.628 (CRSTE), respectively assuming that variable returns to scale is the more appropriate approach, the average efficiency is 0.751 (VRSTE) in the first sub-period and 0.729 in the second sub-period. Consequently, the inefficiency levels under the variable returns to scale model vary on average from about 25% in the first sub-period to around 27% in the second sub-period across the EU. The inefficiency levels are actually calculated by subtracting from 100% (*equivalent to an efficiency ratio of 1, or θ=1*) the calculated value of the efficiency ratio for the given period for the respective Member State.

Table no.4 – Summarized data from the evaluation of the efficiency of the teaching activity in the EU member states

	2013-2016			2017-2021		
	CRSTE	**VRSTE**	**SCALE**	**CRSTE**	**VRSTE**	**SCALE**
Number of DMUs	27	27	27	27	27	27
Number of efficient DMUs	5	11	5	3	8	3
Number of inefficient DMUs	22	16	22	24	19	24
Mean	0.628	0.751	0.842	0.578	0.729	0.802
Max	1.000	1.000	1.000	1.000	1.000	1.000
Min	0.283	0.375	0.392	0.302	0.368	0.385
SD	0.233	0.237	0.186	0.223	0.234	0.163

Source: authors' calculations with DEAP, version 2.1

Figure no. 1 and Table no. A1 of the Annexes provide detailed information by country. The data show that during the first period under consideration Czech Republic, Greece, Luxembourg, Ireland, France, Poland, Romania and Netherlands demonstrate pure technical efficiency *(θ=1)*, whereas the remaining sixteen countries are inefficient *(θ<1)*. In the second sub-period, the number of efficient higher education systems decreased to eight (Greece, Cyprus, Ireland, Luxembourg, Romania, Poland, Hungary and Malta), leading to an increase in the number of inefficient DMUs (from 16 to 19). At the same time, the period 2013-2016 shows a difference in the number of efficient DMUs under VRS and CRS.

The results show that only five out of eleven efficient higher education systems in terms of their management of teaching activities reach their optimal scale (Czech Republic, Greece, Luxembourg, Ireland and France). In the remaining countries, there is inefficiency arising from the scope of the education systems (see Table no. A1 of the Annexes). A similar result appears in the second sub-period, where three of the efficient systems have reached their optimal scale (Greece, Cyprus and Ireland).

The Hungarian higher education system demonstrates a notable change in the pure technical efficiency during the second sub-period, but not in terms of its optimal scale. For the period 2017-2021, the data show a slight increase in inefficiencies of scale among EU Member States in respect of their education outputs compared to 2013-2016. This may be partly due to the emerging COVID-19 pandemic in the EU and globally in early 2020.

The analysis of the data in Table no. 4 and Table no. A1 of the Annexes indicates that the efficiency of the teaching activity is the lowest in both periods in Croatia (0.375 in 2013-2016 and 0.368 in 2017-2021). The Austrian system of higher education, as well as that of

Spain, also does not show particularly favourable results related to the teaching activity compared to other EU countries. Most higher education systems in the EU member states operate under decreasing returns to scale (drs). Given the value of returns to scale (scale <1), it is good for these countries to adapt to their optimal scale and this contributes to reducing the input resource, or in this case, the number of academic staff. Similar conclusions are valid for Germany, Portugal and Slovenia. While in the period 2013-2016 six countries (Poland, Romania, Netherlands, Sweden, Lithuania and Malta) operate under conditions of increasing returns to scale (irs), in 2017-2021 the situation in Luxembourg, Romania, Poland Hungary and Malta remains analogous. Sweden, as well as Denmark, the Netherlands and Finland, despite possessing systems that demonstrate a high degree of organizational autonomy (Pruvot *et al.*, 2023), are unable to manage their human resources in the most efficient manner.

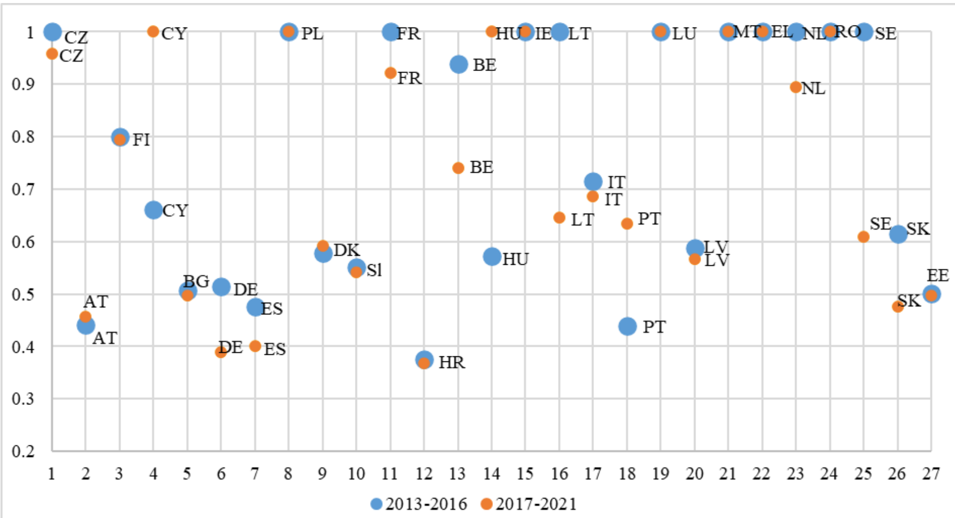

Figure no. 1 – Pure technical efficiency of educational activity in the EU member states for the periods 2013-2016 and 2017-2021

Source: authors' calculations with DEAP, version 2.1

Scientific (research) activity

Another important segment of the activity of higher education institutions in the EU is the research activity of members of the academic staff, as well as PhD students. Table no. 5 presents the results of the applied model. In both sub-periods eleven out of the 27 member countries achieve efficient systems for managing research activity. However, during the period 2017-2021, the average value of pure technical inefficiency increased to 25.9% compared to 24.4% observed in 2013-2016.

Another key aspect to consider when analyzing teaching activity, is that over 85% of countries with efficient management of their research activity simultaneously show some inefficiency in the optimal input used to achieve their output (scale<1). This is especially relevant to Germany, France, Sweden and Finland, where the inefficiency of scale is greatest, which implies optimizing the input, in particular of the academic staff and the number of PhD students (see Table no. A2 of the Annexes).

Table no. 5 – Summary data from the assessment of the efficiency of research activity in the EU member states

	2013-2016			2017-2021		
	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE
Number of DMUs	27	27	27	27	27	27
Number of efficient DMUs	3	11	3	4	11	4
Number of inefficient DMUs	24	16	24	23	16	23
Mean	0.511	0.756	0.687	0.593	0.741	0.818
Max	1.000	1.000	1.000	1.000	1.000	1.000
Min	0.173	0.238	0.244	0.245	0.277	0.261
SD	0.247	0.278	0.186	0.248	0.265	0.177

Source: Authors' calculations with DEAP, version 2.1

The data in Figure no. 2 and Table no. A2 of the Annexes show that the Netherlands, Malta and Luxembourg are EU countries that, in addition to effectively managing their research activities in educational institutions, also reach their optimal scale. University researchers in Malta have managed to increase the number of their publications indexed in the Scopus (2024) and Web of Science (2024) databases by between 50 and 60%. Similar trends also emerge in Luxembourg, where during the period 2018-2022, the publications indexed in Scopus (2024) increased by over 30%, and those indexed in Web of Science (2024) grew by over 90%. A possible key factor contributing to this rise could be the increased number of academic staff members, but also the growing interest in enrolling in doctoral programs. Furthermore, Italy in 2013-2016 does not achieve optimal scale and has a relatively low level of overall technical inefficiency, which changes sharply in 2017-2021. In the first analyzed period, seventeen out of 27 EU member states show pure technical efficiency that is higher than the EU average, while in the second period the number of countries with higher than the average efficiency decreases to fifteen.

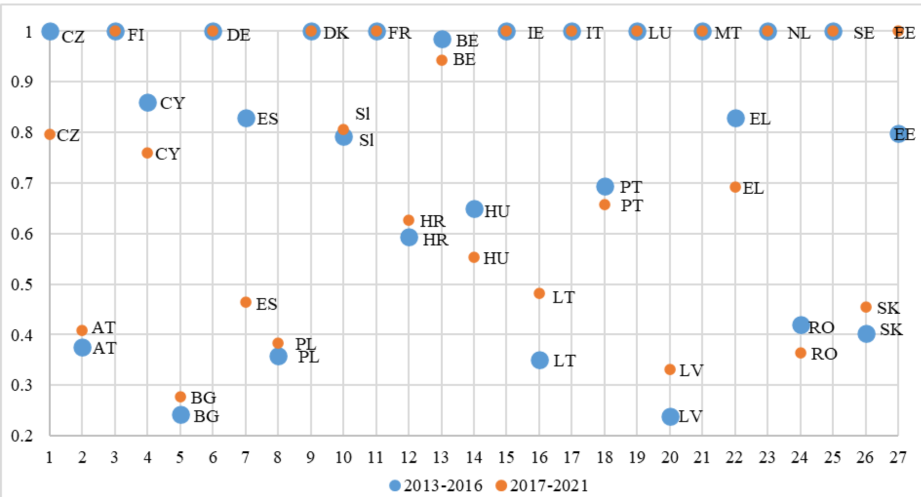

Figure no. 2 – Pure technical efficiency of research activity in the EU member states for the periods 2013-2016 and 2017-2021

Source: authors' calculations with DEAP, version 2.1

The average returns to scale for the both sub-periods improve significantly, respectively the inefficiency of scale decreases by nearly 13 pp. Latvia is the only country whose higher education system in the scientific part operates with increasing returns to scale. However, Latvia and Bulgaria are characterized by the lowest efficiency in the implementation of their research activity, although these countries reduce the degree of overall and pure technical inefficiency in 2017-2021 compared to 2013-2016 relative to the benchmark countries. Complex factors can explain the reasons for this. A possible explanation is that these are countries in the EU with one of the lowest ratios of students enrolled in doctoral programs to number of academic staff, and although this initially reflects on a reduction in the input, it cannot but impact the expected results (output). Latvia even shows a decrease in the number of enrolled doctoral students since 2016. On the other hand, with an average of 0.76 Scopus-indexed publications per author for the EU-27, in Bulgaria this value amounts to 0.32, and in Latvia it is 0.4. The trend is similar for indexed publications in Web of Science (2024), where the EU-27 average is 0.88 publications per author, compared to 0.31 in Bulgaria and 0.44 in Latvia. Consequently, the research activity in countries such as Bulgaria and Latvia is indicative of a modest contribution of these countries in an international context, both in terms of the volume of scientific publications and the degree of their visibility, citation and integration into global scientific communication. These outcomes, of course, may also arise from certain systematic and institutional challenges, expressed in insufficient funding of scientific activity in the countries, as well as in the absence of appropriate policies aimed at stimulating publication activity.

Spain is one of the countries that has experienced a significant decline in pure technical efficiency during the second sub-period. This is due to the substantial growth in enrolled doctoral students (their number increased by more than 157 % in the period 2017-2021 compared to 2013-2016). At the same time, the results of research activity in the form of indexed/refereed publications in Scopus (2024)and Web of Science (2024) have registered growth of approximately 21 to 22%. Additional financial capacity is needed to support publication activity, a pursuit of higher publication quality and most notably, emphasis on publishing in international journals. Changes in the educational workload of academic staff are also necessary, as many universities in Spain observe a substantial number of teaching hours during which lecturers are engaged in classrooms which reduces the time for carrying out scientific activities.

Expenditure efficiency

Expenditure management of the higher education system and its participants is one of the most important aspects of the activity. This is of particular importance in the case of a public resource generated by national taxpayers. In the present study, the efficiency analysis is carried out in relation to the aggregate resource used for higher education, not only public but also private. Table no. 6 below presents the results. The average value of the pure technical efficiency in the period 2017-2021 (0.658) compared to the first period (0.798) has decreased by nearly 14 pp. More generally, this can also be inferred from a reduction in the number of operationally efficient DMUs from 7 (Greece, Hungary, Ireland, Lithuania, Poland, Slovakia and Malta) to 5 (Greece, Ireland, Romania, Lithuania and Hungary) in the two sub-periods (see Table no. 6 and Table no. A3 of the Annexes). Obviously, some of the countries in Eastern Europe and the Balkans perform better in managing the expenditure of higher education. In most countries in this region, higher education costs have remained relatively stable over time, without any sudden increases. On the contrary, in some countries, expenditures in certain years during the period 2016-2020 even show a noticeable decline (Estonia, Greece, Croatia, Latvia and Lithuania). Nevertheless, the RTEpsGDPpc indicator in Estonia remains the highest value over the 2016-2020 period, which is indicative of the country's positioning at the bottom of the ranking, as no similar trend is observed in terms of output.

Romania improves its pure technical efficiency and thus its position among the other EU member states. This stems from relatively stable costs over time, which results in a consistent value of the input variable. Simultaneously, in terms of the output, Romania succeeds in raising the value of the invRUNEMP25-64TE&ALLISCED indicator by approximately 60%. The reason for this is the sharp decrease in the share of unemployed persons with higher education aged 25-64 in the total unemployment rate for this age range. During the period 2017-2021, Romania records the highest value of the invRUNEMP25-64TE&ALLISCED indicator (57.7), followed by Hungary (56.4) and Bulgaria (55.1). Romania also shows progress in the share of people aged 25-64 who have acquired higher education, although the country holds the lowest position on this indicator among EU member states.

Table no. 6 – Summarized data from the expenditure efficiency assessment in the EU member states

	2013-2016			2017-2021		
	CRSTE	**VRSTE**	**SCALE**	**CRSTE**	**VRSTE**	**SCALE**
Number of DMUs	27	27	27	27	27	27
Number of efficient DMUs	4	7	4	3	5	3
Number of inefficient DMUs	23	20	23	24	22	24
Mean	0.751	0.798	0.945	0.622	0.658	0.949
Max	1.000	1.000	1.000	1.000	1.000	1.000
Min	0.467	0.523	0.651	0.378	0.396	0.831
SD	0.159	0.163	0.087	0.185	0.196	0.054

Source: authors' calculations with DEAP, version 2.1

For the period 2013-2016, fourteen of the member states countries reached pure technical efficiency greater than the average for all 27 countries, while in 2017-2021 the number of countries with higher than the average efficiency decreases to eleven. In addition, during the period 2017-2021, 22 out of 27 member states manage their higher education expenditure inefficiently. This should be of paramount importance in managing higher education expenditure in the short-term, while achieving optimal scale is a very difficult task and may be realized in the medium or long-term.

The calculations presented in Figure no. 3 and Table no. A3 of the Annexes show that Estonia experiences low operational (pure technical) efficiency in higher education expenditure management in both sub-periods. Denmark's position in this activity relative to other countries has significantly deteriorated (pure technical inefficiency increased from 2.4% to 56.3%). Two principal reasons can explain this and they can be classified into two main categories: (1) a sharp rise in higher education spending in Denmark for the period from 2016 to 2020 compared to the preceding years, leading to an increase in the input by over 60 % and (2) a significant decline in the invRUNEMP25-64TE&ALLISCED indicator, which is a result of the decreasing total unemployment in Denmark for persons aged 25-64, but at the same time many of those still unemployed possess higher education qualifications. The increase in higher education spending in Denmark during the second sub-period is to some extent also related to a reform in the financing of the higher education system, which entered into force in 2019 and contributed to a rise in the share of block grants for public universities (up to 25%) at the expense of activity-based subsidies (OECD, 2021). Portugal and the Netherlands are also among the countries with high technical inefficiency score. As distinguished from the results of the previous two models, here it is noticeable that especially during the period 2013-2016, most countries operate with increasing returns to scale.

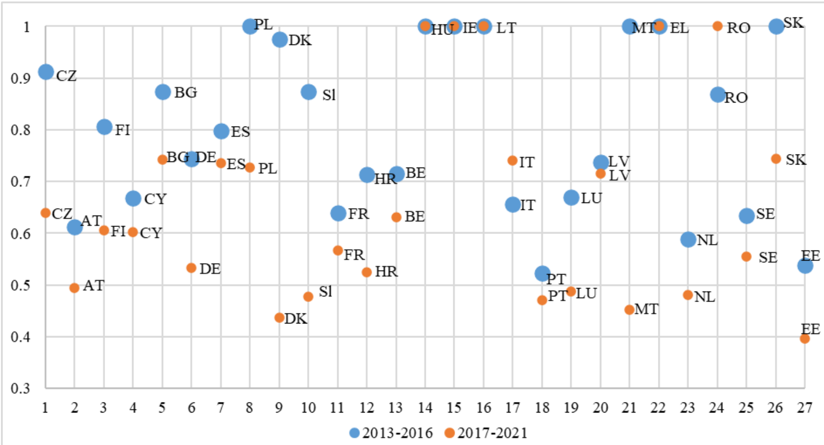

Figure no. 3 – Pure technical efficiency in higher education expenditure management in the EU member states for the periods 2013-2016 and 2017-2021.

Source: authors' calculations with DEAP, version 2.1

Besides the higher education system in Romania, the Italian one is the other that also manages to increase its pure efficiency of expenditure management during the second sub-period. The main reason for this is the observed decline in the RTEpsGDPpc variable by about 16 %. On the other hand, within the EU, Italy ranks second in terms of the rise in the invRUNEMP25-64TE&ALLISCED indicator. However, during the period under review, it is noteworthy that Italy is among the EU countries with one of the highest youth unemployment rates. Significant challenges facing the labour market in Italy include the lack of practical applicability of higher education (a low share of graduates finding jobs related to their specialty), the difficult and postponed job search, as well as the weak involvement of employers in the educational process (including participation in syllabus development), poorly implemented dual programs and the lack of sufficient internships and practical training during university studies. It is important to point out that similar education-related processes and labour market linkage are also present in Greece, which is among the countries with the highest efficiency. In contrast to Italy, the share of higher education expenditure per capita in GDP is nearly 2.3 times lower (and also tends to decrease within the period under study) in Greece. It should be mentioned that the problems with the labour market and its relationship with the higher education system are characteristic of most countries in Southern Europe – this applies to both the already discussed Italy and Greece, as well as Spain and Portugal, and this, not surprisingly, also affects their results. As is the case with Italy and Greece, the input parameter also declines in Spain and

Portugal, but this is insufficient to lead to an improvement in the pure technical efficiency of expenditure management in the second sub-period.

The decrease in the technical efficiency of expenditure management in the second sub-period in some of the Central and Eastern European countries, such as Bulgaria, the Czech Republic, Slovenia, Poland and Estonia, may stem from the more substantial increase in the input parameter associated with higher education expenditure per capita to GDP per capita. This may be due to a combination of complex factors – from the pursuit of convergence with the levels that are characteristic of Western and Northern European countries (as well as the EU average rates) and reforms aimed at increasing university administrative and management expenditures, to slower economic growth during the analysed period compared to the growth of expenditures themselves. This parameter changes noticeably in the context of the shifts occurring in some of the aforementioned countries in the model's output variables. Although countries, predominantly from Eastern and Southeastern Europe, allocate a comparatively lower budget for higher education, which to some extent explains their higher efficiency, the budget, considered in light of their degree of economic development, does not always imply a low relative share. A substantial challenge for Central and Eastern European countries, especially with respect to public financing of higher education, is the lack of well-established funding mechanism based on attained results. Despite attempts to introduce similar approaches in countries such as Bulgaria, Croatia, Romania, Slovakia, the Czech Republic, etc., the leading criterion remains either the number of admitted (enrolled) students or the volume of activity. In certain cases, there is even a lack of budgetary flexibility, using historically based models that maintain higher levels of spending, notably in conditions of declining student enrolment, and this is actually a reason for lower efficiency of expended funds. The applicable approaches in most Western and Northern European countries (Finland, Denmark) are entirely different, but the indicators that underlie the assessment of results are also essential, including their periodic evaluation and improvement of the models.

The analysis of the three components of the higher education systems within the EU member states shows that perhaps the best performing system focused on the preparation of students, the conduct of scientific research and in terms of financial management, is that of Ireland. In both analysed sub-periods, the efficiency assessment based on the assumption of variable returns to scale shows that the governance of higher education in Ireland is efficient. This country ranks first. The reasons for the good performance of Ireland's higher education system can be illustrated in a variety of aspects, including:

(1) This country has the highest share of people aged 25-64 with higher education (compared to the EU-27 average of 36.7% in 2020, Ireland registers a share exceeding 52%), which is due to its adaptive learning models and short-duration training.

(2) Ireland demonstrates one of the highest values of indicators, measuring the proportion of bachelor's/ master's graduates compared to admitted (enrolled) students, which is significantly influenced by well-established university mentoring services, provision of academic assistance and career advising, which encourage student persistence and successful completion of their studies.

(3) The country also shows one of the lowest values for the indicator measuring the ratio of higher education spending to GDP per capita, despite providing substantial financial support for students.

Ireland is among the EU countries that are distinguished by a very high degree of academic autonomy (Pruvot *et al.*, 2023), which ensures the ability of universities to manage their resources in the most appropriate way. The results of the applied models on Ireland's performance are consistent with the findings of Perović and Kosor (2020), despite the differences in the selected input and output variables. The only problematic element for Ireland appears to be the inefficiencies of scale in terms of research activity, which can be solved by gradually reducing inputs.

Malta's education system in the period 2013-2016 also achieves a high degree of pure technical efficiency. In parallel, the country is characterized by a rather high degree of overall technical inefficiency in teaching and in the management of higher education expenditure, caused by inefficiencies of scale. This is perhaps one of the reasons that in the second sub-period (2017-2021) the country loses positions compared to other EU member states and reports inefficiency in terms of higher education expenditure management. The Lithuanian higher education system can also be considered among those that report a higher degree of pure technical efficiency. This applies to the management of teaching activities (2013-2016) and higher education expenditure, but not to the implementation of research activities, where the country has a high degree of technical inefficiency, pure technical inefficiency and inefficiency of scale. The results for the higher education in Greece are similar, with the difference that the Greek higher education system in terms of teaching activity and expenditure management is not only technically efficient, but also shows scale efficiency. The higher education system in Romania shows more efficient results compared to the rest of the countries in the second sub-period, with the exception of research activity. An improvement in positions is also present in Hungarian higher education, but again research activity is a serious challenge that generates pure technical inefficiency. Luxembourg, France, Sweden and the Netherlands show a high degree of pure technical efficiency in teaching and research activity, but not in expenditure management efficiency.

The results of the conducted research show quite a few weaknesses (inefficiency) in the higher education systems of countries such as Austria and Croatia (for all three components), Portugal (for all three components, although in the second sub-period there are some improvements in the positions) and Germany (in expenditure management and in teaching activity). Estonia is also among the countries reporting inefficiency, excluding the good positions in research activity in the second period. Latvia and Bulgaria report weak positions in teaching and research activity. At the same time, in the evaluation of the expenditure efficiency, Latvia and Bulgaria maintain more advanced positions, although an increase in inefficiency is noticeable in 2017-2021. Kolev and Tsoklinova (2023) compare the efficiency of higher education expenditure in Bulgaria in 2008-2020 and their findings show that the lowest efficiency is observed in 2020 (the beginning of the COVID-19 pandemic). This also explains the results of the present study and the reduced efficiency in Bulgaria compared to other EU countries. The management of the system of higher education in the Czech Republic in 2017-2021 compared to 2013-2016 shows a deterioration of the results in all three analysed components, which is evidenced by the increased pure technical inefficiency by 5 pp in the teaching activity, by 27.3 pp in expenditure management and by 20.3 pp in the management of research activity.

6. CONCLUSIONS

The topic of evaluating the efficiency of higher education always arouses significant interest, regardless of the level of analysis. Although various analysis techniques are used in research practice, the DEA approach remains perhaps one of the most widely applied options.

The implementation of this method in the present study allows to summarize some weaknesses leading to inefficiency of higher education systems within the EU member states. The analysis includes two sub-periods (2013-2016 and 2017-2021) in order to trace the change in the management of these systems and the subsequent effects. The obtained results show that, in a comparative aspect, there is a decrease in the efficiency of higher education within the EU. To the greatest extent, such a decline is evident in the assessment of expenditure efficiency, where the inefficiency of expenditure management increases by 14 pp. This is a serious challenge for most higher education systems in the EU, especially those that generate sustainable and increasing budgetary resource (mainly publicly funded) over time, which is weakly tied to the results achieved and in particular to socio-economic and demographic processes. It is essential to reform these systems, to introduce funding mechanisms that depend on the results obtained by universities, including a continuous pursuit of regular improvement of both established and recently adopted funding approaches. At any given moment, the funding system must respond to trends in social and economic development and market needs. It is inexpedient to waste financial resources in areas where the market is oversaturated, while at the same time there are staff shortages in other economic areas. The reforms should also focus on reducing the centralized approach to implementing processes, strengthening the relationship between the higher education system and the labour market, as well as introducing and financing new training models (dual training). In certain cases, particularly when expanding the scope of the higher education system, it is advisable to seek restructuring methods, including consolidation, merger of individual units, which may contribute to cutting specific types of expenditures. Such processes may also support efforts to tackle another major issue, specifically strengthening competitive positions, increasing global *visibility*, but also financial sustainability. Precisely for this reason, since 2010, similar processes have been observed within many EU member states, although it is difficult to define it as an established European practice.

The inefficiency of the management of teaching activity increases by approximately 2.2 pp, while in the management of research activity this growth is 1.5 pp. During the second sub-period, 75 % of EU countries report an increase in the ratio of the number of academic staff members to enrolled students. This actually reduces the number of students per teacher. Alongside this, in some EU countries there is a rather negative trend towards a steady rise in the age imbalance (with an emphasis on the increase in the average age of academic staff), as well as insufficient opportunities for the integration of younger staff. Typically, this trend reflects mostly on research results, which is actually the cause for the deterioration of efficiency in terms of research activity. The reason is that there is a stable capacity of human capital, the growth of which does not directly align with the outcomes of the activities. As a solution to this problem, it is appropriate to recommend the implementation of mechanisms that link employment contracts to the expected remuneration of employees. The dynamics in the number of academic staff is also related to the manner in which lecturers are hired. In approximately half of the EU countries, teaching staff on permanent contracts dominate, resulting in a trend towards stability and even an increase in the number of teachers. In some countries, universities prefer the use of temporary contracts, especially for initial (entry-level) positions, which may contribute to higher staff turnover but also to a less noticeable rise in the number of academic staff over time (although statistical data may be distorted, depending mainly on the reporting methodology).

A positive outcome of the applied models and the obtained results is the reduction of inefficiency of scale in the evaluation of expenditure and especially in the estimation of research activity. Therefore, higher education systems are thus approaching their optimal scale, but further efforts are still needed.

This study does not claim to cover all possible activities and functions of the higher education system, but rather aims to assess the most essential aspects of this system. On the other hand, the research can be a good starting point for subsequent analyses, including expanding the scope of this study with participation in other main or additional activities related to higher education. A suitable approach in future research would be to conduct a more comprehensive comparative analysis, that would highlight the main advantages and disadvantages not only of the European, but also of other educational systems in order to increase the overall efficiency.

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ANNEXES

Table no. A1 – Efficiency of the teaching activity of the higher education systems of the EU member states

2013 - 2016						2017 - 2021					
Country	CRSTE	VRSTE	SCALE	RTS	RANK	Country	CRSTE	VRSTE	SCALE	RTS	RANK
Czech Republic	1.000	1.000	1.000	-	1	Greece	1.000	1.000	1.000	-	1
Greece	1.000	1.000	1.000	-	1	Cyprus	1.000	1.000	1.000	-	1
Luxembourg	1.000	1.000	1.000	-	1	Ireland	1.000	1.000	1.000	-	1
Ireland	1.000	1.000	1.000	-	1	Luxembourg	0.757	1.000	0.757	irs	1
France	1.000	1.000	1.000	-	1	Romania	0.728	1.000	0.728	irs	1
Poland	0.832	1.000	0.832	irs	1	Poland	0.618	1.000	0.618	irs	1
Romania	0.822	1.000	0.822	irs	1	Hungary	0.522	1.000	0.522	irs	1
Netherlands	0.587	1.000	0.587	irs	1	Malta	0.385	1.000	0.385	irs	1
Sweden	0.454	1.000	0.454	irs	1	Czech Republic	0.851	0.958	0.888	drs	9
Lithuania	0.440	1.000	0.440	irs	1	France	0.911	0.922	0.988	drs	10
Malta	0.392	1.000	0.392	irs	1	Netherlands	0.592	0.895	0.661	drs	11
Belgium	0.826	0.939	0.880	drs	12	Finland	0.682	0.794	0.859	drs	12
Finland	0.702	0.801	0.876	drs	13	Belgium	0.669	0.740	0.904	drs	13
Italy	0.691	0.716	0.965	drs	14	Italy	0.672	0.687	0.978	drs	14
Cyprus	0.656	0.662	0.991	drs	15	Lithuania	0.359	0.645	0.556	drs	15
Slovakia	0.605	0.616	0.982	drs	16	Portugal	0.425	0.635	0.669	drs	16
Latvia	0.477	0.589	0.809	drs	17	Sweden	0.426	0.609	0.700	drs	17
Denmark	0.523	0.579	0.904	drs	18	Denmark	0.494	0.592	0.835	drs	18
Hungary	0.539	0.573	0.940	drs	19	Latvia	0.475	0.567	0.837	drs	19
Slovenia	0.479	0.552	0.869	drs	20	Slovenia	0.377	0.541	0.697	drs	20
Germany	0.283	0.515	0.549	drs	21	Bulgaria	0.377	0.497	0.759	drs	21
Bulgaria	0.437	0.507	0.863	drs	22	Estonia	0.454	0.496	0.914	drs	22
Estonia	0.428	0.500	0.855	drs	23	Slovakia	0.461	0.475	0.970	drs	23
Spain	0.462	0.476	0.970	drs	24	Austria	0.387	0.458	0.847	drs	24
Austria	0.393	0.441	0.891	drs	25	Spain	0.389	0.401	0.969	drs	25
Portugal	0.415	0.439	0.945	drs	26	Germany	0.302	0.389	0.775	drs	26
Croatia	0.348	0.375	0.926	drs	27	Croatia	0.306	0.368	0.831	drs	27

Source: authors' calculations with DEAP, version 2.1

Table no. A2 – Efficiency of the research activity of the higher education systems of the EU member states

2013 - 2016						2017 - 2021					
Country	CRSTE	VRSTE	SCALE	RTS	RANK	Country	CRSTE	VRSTE	SCALE	RTS	RANK
Luxembourg	1.000	1.000	1.000	-	1	Italy	1.000	1.000	1.000	-	1
Malta	1.000	1.000	1.000	-	1	Luxembourg	1.000	1.000	1.000	-	1
Netherlands	1.000	1.000	1.000	-	1	Malta	1.000	1.000	1.000	-	1
Italy	0.839	1.000	0.839	drs	1	Netherlands	1.000	1.000	1.000	-	1
Denmark	0.766	1.000	0.766	drs	1	Ireland	0.983	1.000	0.983	drs	1
Ireland	0.674	1.000	0.674	drs	1	Denmark	0.811	1.000	0.811	drs	1
Sweden	0.594	1.000	0.594	drs	1	Finland	0.748	1.000	0.748	drs	1
Czech Republic	0.540	1.000	0.540	drs	1	Sweden	0.688	1.000	0.688	drs	1
Finland	0.519	1.000	0.519	drs	1	France	0.556	1.000	0.556	drs	1
France	0.480	1.000	0.480	drs	1	Estonia	0.505	1.000	0.505	drs	1
Germany	0.244	1.000	0.244	drs	1	Germany	0.261	1.000	0.261	drs	1
Belgium	0.592	0.985	0.602	drs	12	Belgium	0.632	0.944	0.670	drs	12
Cyprus	0.565	0.861	0.656	drs	13	Slovenia	0.629	0.806	0.781	drs	13
Spain	0.627	0.830	0.756	drs	14	Czech Republic	0.703	0.797	0.883	drs	14
Greece	0.479	0.829	0.578	drs	15	Cyprus	0.713	0.760	0.939	drs	15

2013 - 2016						2017 - 2021					
Country	CRSTE	VRSTE	SCALE	RTS	RANK	Country	CRSTE	VRSTE	SCALE	RTS	RANK
Estonia	0.291	0.798	0.365	drs	16	Greece	0.629	0.692	0.910	drs	16
Slovenia	0.559	0.792	0.705	drs	17	Portugal	0.467	0.658	0.710	drs	17
Portugal	0.448	0.694	0.646	drs	18	Croatia	0.517	0.627	0.824	drs	18
Hungary	0.373	0.650	0.573	drs	19	Hungary	0.379	0.554	0.685	drs	19
Croatia	0.452	0.594	0.761	drs	20	Lithuania	0.409	0.481	0.849	drs	20
Romania	0.257	0.421	0.610	drs	21	Spain	0.353	0.464	0.761	drs	21
Slovakia	0.248	0.402	0.616	drs	22	Slovakia	0.409	0.455	0.898	drs	22
Austria	0.280	0.376	0.745	drs	23	Austria	0.345	0.409	0.844	drs	23
Poland	0.265	0.358	0.739	drs	24	Poland	0.366	0.384	0.954	drs	24
Lithuania	0.293	0.351	0.835	drs	25	Romania	0.340	0.365	0.933	drs	25
Bulgaria	0.173	0.242	0.715	drs	26	Latvia	0.331	0.332	0.996	irs	26
Latvia	0.237	0.238	0.994	irs	27	Bulgaria	0.245	0.277	0.885	drs	27

Source: authors' calculations with DEAP, version 2.1

Table no. A3 – Expenditure efficiency of the higher education systems of the EU member states

2013 - 2016						2017 - 2021					
Country	CRSTE	VRSTE	SCALE	RTS	RANK	Country	CRSTE	VRSTE	SCALE	RTS	RANK
Greece	1.000	1.000	1.000	-	1	Greece	1.000	1.000	1.000	-	1
Hungary	1.000	1.000	1.000	-	1	Ireland	1.000	1.000	1.000	-	1
Ireland	1.000	1.000	1.000	-	1	Romania	1.000	1.000	1.000	-	1
Lithuania	1.000	1.000	1.000	-	1	Lithuania	0.864	1.000	0.864	drs	1
Poland	0.929	1.000	0.929	drs	1	Hungary	0.855	1.000	0.855	drs	1
Slovakia	0.687	1.000	0.687	drs	1	Slovakia	0.673	0.744	0.904	drs	6
Malta	0.651	1.000	0.651	drs	1	Bulgaria	0.648	0.743	0.872	drs	7
Denmark	0.937	0.976	0.961	irs	8	Italy	0.735	0.740	0.994	irs	8
Czech Republic	0.910	0.913	0.997	irs	9	Spain	0.692	0.736	0.940	drs	9
Bulgaria	0.870	0.875	0.994	irs	10	Poland	0.705	0.728	0.968	drs	10
Slovenia	0.795	0.874	0.910	irs	11	Latvia	0.653	0.715	0.915	drs	11
Romania	0.851	0.869	0.980	irs	12	Czech Republic	0.639	0.640	0.999	-	12
Finland	0.711	0.806	0.883	drs	13	Belgium	0.577	0.631	0.913	drs	13
Spain	0.792	0.799	0.991	irs	14	Finland	0.533	0.606	0.880	drs	14
Germany	0.730	0.744	0.981	irs	15	Cyprus	0.592	0.603	0.980	drs	15
Latvia	0.731	0.738	0.991	irs	16	France	0.566	0.567	0.999	-	16
Belgium	0.715	0.716	0.998	irs	17	Sweden	0.461	0.555	0.831	drs	17
Croatia	0.690	0.714	0.967	irs	18	Germany	0.532	0.533	0.999	irs	18
Luxembourg	0.641	0.670	0.957	drs	19	Croatia	0.488	0.525	0.931	irs	19
Cyprus	0.626	0.668	0.937	drs	20	Austria	0.495	0.495	0.999	-	20
Italy	0.632	0.657	0.961	irs	21	Luxembourg	0.479	0.487	0.983	drs	21
France	0.637	0.640	0.994	irs	22	Netherlands	0.473	0.480	0.987	drs	22
Sweden	0.578	0.634	0.912	drs	23	Slovenia	0.474	0.477	0.994	irs	23
Austria	0.588	0.612	0.961	irs	24	Portugal	0.433	0.471	0.920	irs	24
Netherlands	0.589	0.589	0.999	-	25	Malta	0.451	0.452	0.996	irs	25
Estonia	0.524	0.538	0.974	drs	26	Denmark	0.410	0.437	0.937	irs	26
Portugal	0.467	0.523	0.892	irs	27	Estonia	0.378	0.396	0.956	drs	27

Source: authors' calculations with DEAP, version 2.1