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Assessment of the Internal Efficiency of Slovenia's Tertiary Education System

Sandi Vrabec*
University of Primorska, Faculty of management, Izolska vrata 2, 6000 Koper, Slovenia
sandi.vrabec@gmail.com

Borut Kodrič
University of Primorska, Faculty of management, Izolska vrata 2, 6000 Koper, Slovenia
borut.kodric@fm-kp.si

Abstract:

Research Question (RQ): In this article, we address the question of how efficient Slovenia's tertiary education system is compared to the systems of other Organisation for Economic Co-Operation and Development (OECD) member countries and identify elements within the Slovenian system that could be further improved to achieve optimal relative efficiency.

Purpose: The research aims to shed light on the internal efficiency of Slovenia's tertiary education system and compare it with those of other OECD member countries, with the goal of analyzing areas where the Slovenian system falls short of achieving optimal performance.

Method: Using theoretical foundations to identify relevant inputs and outputs, along with secondary data from international databases, we applied the Data Envelopment Analysis (DEA) method to examine the internal efficiency of tertiary education systems in 29 OECD member countries with complete data available for the study period.

Results: Results show that Slovenia's tertiary education system did not achieve optimal relative efficiency in any of the four models applied. In terms of relative efficiency, Slovenia ranked between 20th and 25th among the 29 OECD countries examined. To achieve optimal relative efficiency, improvements in output measures for both pedagogical and research activities should be made.

Organization: The research results can serve as a valuable tool for decision-makers at the national level, as well as for managers of individual tertiary education institutions, in achieving greater efficiency.

Society: Achieving efficiency in tertiary education is crucial for a broader society, not only for individuals participating in the educational process but also due to the wider impact that tertiary education has on the economy and society.

Originality: This is the first research to provide an overview of past studies on the efficiency of tertiary education systems, with a focus on evaluating the outcomes of Slovenia's tertiary education system. The study also delves into a detailed assessment of its efficiency achievements.

Limitations / further research: The research is based on secondary data obtained from international databases. The sample studied is not randomly selected but consists of 29 out of 38 OECD member countries for which complete data were available for the entire period, as the analysis was constrained by the absence of data for the remaining countries. It would

* Korespondenčni avtor / Correspondence author
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be appropriate to enhance the research with a broader sample of countries and by using other or additional inputs and outputs, especially those that reflect the qualitative component of the utilized inputs and outputs.

Keywords: efficiency, tertiary education systems, DEA method, OECD countries, education funding, graduates.

1 Introduction

One of the defining characteristics of the modern global economy is the dominance of the knowledge economy, which has gradually replaced earlier economic models where growth and wealth were based on ownership of natural and productive resources, such as raw materials, land, and manufacturing facilities (Olssen & Peters, 2005, p. 331; Sum & Jessop, 2013, p. 30). The knowledge economy is an economic model in which knowledge is the most critical capital, driving continued growth and development (OECD, 1996, p. 9; Drucker, 1993, pp. 2-3). This era is generally considered to have begun in the post-World War II period (Sinuany-Stern & Hirsch, 2021, p. 482).

In today's developed nations, tertiary education is viewed as a vital instrument for fostering prosperity and competitiveness (Bloom et al., 2006, p. 1; Lane, 2012, p. 1). Consequently, the knowledge economy has spurred the massification of tertiary education. This trend stems from the increasing demand in industries for a skilled workforce and from individuals' aspirations to achieve higher education levels that provide better socio-economic opportunities (Kaneko, 2006, p. 4; Bonaccorsi et al., 2014, p. 1; Ghaffarzadegan et al., 2017, p. 1085; Calderon, 2018, pp. 6-8). With a growing awareness of the role of knowledge and education in economic and social progress, academic and policy circles alike emphasize the need to expand, improve, and increase access to tertiary education (Sum & Jessop, 2013, pp. 25-27; Choong & Leung, 2021, pp. 1577-1578).

A key challenge faced by many countries worldwide is ensuring a high-quality, accessible, and fiscally sustainable tertiary education system that produces a highly skilled workforce while also generating new knowledge through research activities. As the expansion of tertiary education systems is inherently linked to rising costs, countries are increasingly striving to achieve efficiency in publicly funded areas (Hanushek, 2005, p. 69; Giménez et al., 2007, pp. 996-997; Mihaljević Kosor, 2013, p. 1032; Agasisti, 2014, p. 543; Liu & Xu, 2017, p. 82).

Research on efficiency in education spans a wide field, attracting the interest of many scholars. Economic efficiency in education can be assessed at multiple levels, from smaller units (such as departments, faculties, and branches) to the international level,

where the focus is on national education systems. This article specifically addresses efficiency at the international level: a topic that, until recently, received limited attention. This gap is largely attributed not to a lack of academic interest but to insufficient data for meaningful analysis and comparison across countries' tertiary education systems.

One of the most extensive reviews on this subject was conducted by De Witte and López-Torres (2017), who examined 223 studies on educational efficiency, finding only nine that focus on the international level. Agasisti (2009, p. 201), who authored the first study on tertiary education system efficiency, highlights that the rapid advancement of internationally comparable databases e.g., United Nations Educational, Scientific and Cultural Organisation (UNESCO), Organisation for Economic Co-Operation and Development (OECD), International Labour Organisation (ILO), World Bank has recently made it possible to conduct more detailed and objective efficiency studies at the international level.

This article examines the efficiency of Slovenia's tertiary education system, comparing it with those in other OECD countries. According to OECD data, Slovenia allocated 1,19% of its Gross Domestic product (GDP) to tertiary education (including public and private funding) in 2021, below the OECD average of 1,48%. Meanwhile, in 2023, 33,51% of Slovenians aged 25 to 64 held tertiary qualifications, compared to an OECD average of 40,74%. For those aged 25 to 34, the proportion in Slovenia was 41,10%, versus an OECD average of 47,40% (OECD, n.d.). According to the Education and Training Monitor (European commission, 2024), the share of tertiary-educated individuals aged 25-34 has shown a slight upward trend over the years but experienced a decline in 2023, reaching 40,7%, which falls below the European Union (EU) average of 43,1%. Between 2015 and 2022, the share of public expenditure allocated to tertiary education consistently exceeded the EU average, accounting for 1% of GDP or 2,1% to 2,2% of total government expenditure. Simultaneously, annual spending per full-time equivalent student in higher education institutions increased significantly, rising by 34,8% between 2015 and 2021. This article explores whether Slovenia's tertiary education system delivers efficiency considering its funding levels and other relevant inputs.

This work makes a significant contribution to understanding the relative efficiency of Slovenia’s tertiary education system, as a detailed comparison between Slovenia and other OECD countries has not yet been conducted. The aim of the research is to assess how successful Slovenia is in ensuring the efficient operation of its tertiary education system relative to other countries and to identify areas where improvements can still be made. The findings of this research are valuable for shaping policies for the development of tertiary education in Slovenia, helping to enhance both the efficiency and quality of the system.

The article is structured into six chapters. In addition to the introductory (first) chapter, the second chapter outlines the theoretical foundations used to construct an appropriate model for studying efficiency. It also provides a review and analysis of previous international studies on efficiency in tertiary education, including those involving Slovenia. The third chapter describes the methodology for data collection, the development of inputs and outputs, and the protocol for creating an appropriate model for DEA analysis. In the fourth chapter, we conduct our own analysis of the efficiency of tertiary education systems in OECD countries and present the results. These results are then further explained and analyzed in the fifth chapter. The final (sixth) chapter presents key findings and concluding thoughts.

2 Theoretical framework

2.1 Measuring efficiency in tertiary education

Efficiency measurement, which relies on Pareto allocation principles (Bevc, 1999, p. 59; Tajnikar, 2006, p. 17; Mihaljević Kosor, 2013, p. 1032), proves more difficult in tertiary education than in economic fields, due to the inherent complexities and unique features of educational systems (Estermann & Kupriyanova, 2019, p. 10).

The literature uses various, sometimes inconsistent, terms to describe types of efficiency in tertiary education (Johnes, 2006, p. 274; Mihaljević Kosor, 2013, pp. 1032-1034). Generally, efficiency is examined from two perspectives: the production process, often termed technical, cost, or internal efficiency, and a broader perspective encompassing both graduate and research outputs. This broader concept, known as allocative or external efficiency, considers the alignment between the system's outputs and the needs of society and the economy (Bevc & Uršič, 2008, p. 234). For instance, internal efficiency focuses on the ratio of enrolled students to graduates, while external efficiency evaluates whether the number and profile of graduates meet societal and economic demands, as indicated by employment rates and levels of over- or under-education (Bevc, 1999, pp. 60-61; Miningou & Tapsoba, 2020, p. 587; Salas-Velasco, 2019, p. 162).

This article centers on efficiency within the framework of the production function (internal efficiency), focusing on the relationship between input resources and produced outputs. Due to the clear limitation that this study examines only the production aspect and does not address the appropriate allocation of outputs, it is essential to clarify that the term "efficiency," as used in this research, pertains solely to the concept of internal efficiency in tertiary education systems. This premise also forms the theoretical basis for selecting the inputs and outputs in our models.

Moreover, internal efficiency in education can be examined from two distinct analytical perspectives: one may focus on maximizing outputs given a set level of inputs, or

alternatively, on achieving a targeted level of outputs with the minimum possible inputs. In both approaches, the relationship between inputs and outputs remains a fundamental aspect of efficiency analysis (Coelli et al., 2005, pp. 180-181; Estermann & Kupriyanova, 2019, pp. 10-11).

Salerno (2003, p. 16) outlines the progression of efficiency measurement techniques from simple regression analysis to more advanced methods that allow for constructing an efficiency boundary, commonly termed the "envelope." These approaches enable the assessment of relative efficiency by examining how far each unit is from this efficiency envelope. In this study, we employ Data Envelopment Analysis (DEA) to evaluate the efficiency of tertiary education systems, as DEA is frequently used as a synonym for all non-parametric efficiency measurement techniques in the field (Salerno, 2003, p. 18; De Witte & López-Torres, 2017, p. 341).

A key advantage of DEA is its ability to handle multiple inputs and outputs, making it particularly suitable for tertiary education systems, which use a variety of inputs to generate a diverse set of outputs. As a non-parametric technique, DEA does not require a predefined production function to construct the efficiency envelope - a requirement that is often challenging in educational research. Instead, DEA forms this envelope based on empirical data from all observed units, referred to as Decision Making Units (DMUs), identifying the most efficient units that define the maximum efficiency boundary. Each DMU is then assigned a relative efficiency score ranging from 0 to 1, with a score of 1 representing full efficiency, indicating that the DMU is located on the efficiency envelope. It is important to emphasize that the data obtained through the DEA method represents relative efficiency. Therefore, when evaluating a unit as efficient or inefficient, it must be understood that this classification pertains to relative efficiency, not absolute efficiency.

A detailed description of the DEA method is provided in Chapter 3, while the rest of this chapter focuses on reviewing previous studies that have analyzed the efficiency of tertiary education systems, including those that have examined Slovenia.

2.2 Review of Previous Studies on Tertiary Education Efficiency

Upon reviewing the available literature, we identified nine studies that assess the efficiency of tertiary education at the system (country) level, each of which includes an analysis of the Slovenian tertiary education system. These studies encompass a variety of models and examine different time periods. In total, 37 distinct models were analyzed, differing in terms of the number of DMUs, selection of inputs and outputs, model orientation (input- or output-oriented) and returns to scale (constant or variable), as well as the time frames under consideration. A comprehensive overview of all models and the efficiency scores of the Slovenian tertiary education system across these models is presented in table1.

Table 1
Review of previous studies on tertiary education efficiency

No.	Study	Model type				DMU	Slovenia's results	
		Model no.	CRS or VRS	OO or IO	Time		Efficiency score	Ranking
1	Aubyn et al. (2009)	model 1	VRS	IO	1998-2001	28	0,909	9.
2			VRS	IO	2002-2005	28	0,664	14.
3			VRS	OO	1998-2001	28	0,593	15.
4			VRS	OO	2002-2005	28	0,414	18.
5		model 2	VRS	IO	1998-2001	28	0,317	25.
6			VRS	IO	2002-2005	28	0,394	25.
7			VRS	OO	1998-2001	28	0,273	25.
8			VRS	OO	2002-2005	28	0,315	20.
9	Aristovnik & Obadić (2011)	model 1	VRS	OO	1999-2007	37	1,000	1.
10		model 2	VRS	OO	1999-2007	37	1,256*	13.
11		model 3	VRS	OO	1999-2007	37	1,029*	12.
12	Yotova & Stefanova (2017)	model 1	VRS	IO	2012-2014	9	0,850	4.
13		model 2	VRS	IO	2012-2014	9	0,828	4.
14		model 3	VRS	IO	2012-2014	9	0,828	3.
15	Jelić & Kedžo (2018)	model 1	VRS	OO	2004-2006	24	0,811	21.
16			VRS	OO	2007-2009	24	0,735	23.
17			VRS	OO	2010-2012	24	0,741	23.
18			VRS	OO	2013-2015	24	0,768	22.
19		model 2	VRS	OO	2004-2006	24	0,810	19.
20			VRS	OO	2007-2009	24	0,763	23.
21			VRS	OO	2010-2012	24	0,789	22.
22			VRS	OO	2013-2015	24	0,752	21.
23		model 3	VRS	OO	2004-2006	24	0,824	20.
24			VRS	OO	2007-2009	24	0,763	23.
25			VRS	OO	2010-2012	24	0,789	23.
26			VRS	OO	2013-2015	24	0,833	21.

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No.	Study	Model type				DMU	Slovenia's results	
		Model no.	CRS or VRS	OO or IO	Time		Efficiency score	Ranking
27	Ahec Šonje et al. (2018)	model 1	VRS	IO	2005-2013	11	0,800	9.
28		model 2	VRS	IO	2005-2013	11	0,750	8.
29	Stefanova (2019)	model 1	VRS	IO	2013-2018	7	0,610	6.
30	Mihaljević Kosor et al. (2019)	model 1	VRS	IO	2012-2016	28	0,883	2.
31	Stefanova & Velichkov (2020)	model 1	VRS	IO	2013-2018	10	1	1.
32		model 2	VRS	IO	2013-2018	10	0,893	4.
33		model 3	VRS	IO	2013-2018	10	0,893	3.
34	Sinuany-Stern & Hirsh (2021)	model 1	CRS	OO	2019	29	0,831	19.
35		model 2	CRS	OO	2019	29	0,663	15.
36		model 3	VRS	OO	2019	29	1	1.
37		model 4	VRS	OO	2019	29	1	1.

Note. IO denotes an input-oriented model, while OO represents an output-oriented model. The CRS model refers to a DEA model with constant returns to scale, whereas the VRS model indicates a DEA model that accounts for variable returns to scale. The time label specifies the period during which the data was collected. *In this study, values above 1,000 indicate a projection of increased outputs necessary to achieve full efficiency, rather than relative efficiency.

Table 1 provides an overview of the studies analyzed, with the second and third columns listing each study along with the specific models employed. The fourth and fifth columns detail the model subtypes (IO or OO, and CRS or VRS), while the "DMU" column indicates the total number of countries analyzed within each model. The final two columns present the DEA analysis outcomes, including the relative efficiency coefficient and Slovenia's ranking among all countries (DMUs) assessed.

The data in table 1 yields several critical insights: DEA was consistently employed as the methodology for assessing efficiency across all 37 models, with the VRS model utilized in 35 cases, while the basic CRS model appeared in only two. The CRS model is generally considered less suitable for comparative analysis due to its greater variability in assigning weights to individual DMUs (Sinuany-Stern & Hirsch, 2021, p. 488). Additionally, notable heterogeneity is evident in the choice of model orientation, with the OO model applied in 23 cases and the IO model in 14, indicating diverse methodological approaches across the studies.

The findings from various studies suggest that the Slovenian tertiary education system does not function at the efficiency frontier, as it was identified as fully efficient (relative efficiency = 1) in only four models. Unfortunately, the studies offer limited insight into the

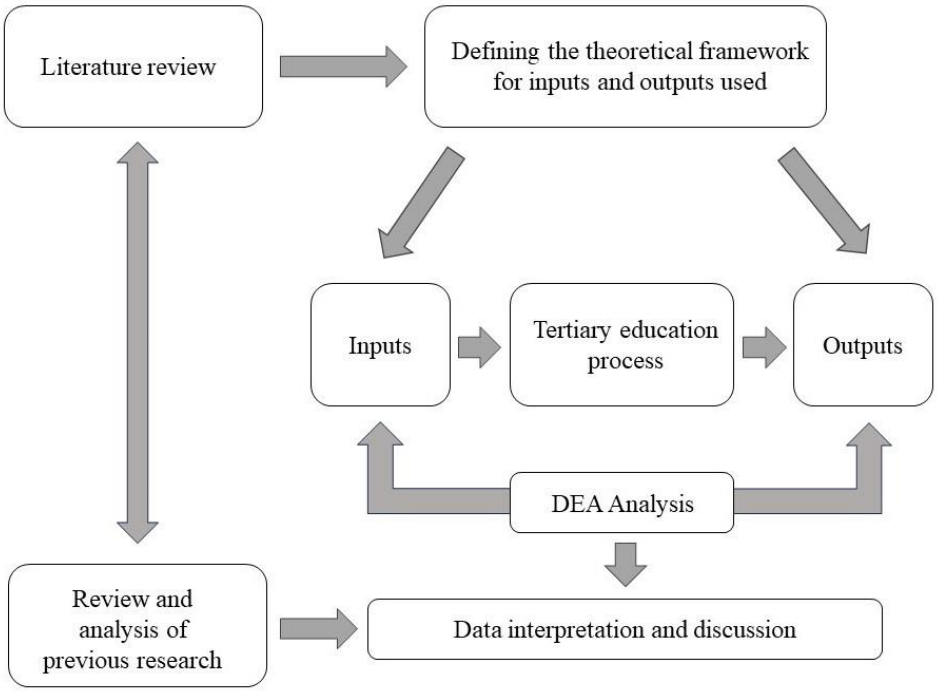
underlying causes of inefficiency within the Slovenian system. Mihaljević Kosor et al. (2019, pp. 404-405) posit that, given the financial resources allocated to tertiary education, Slovenia should increase both its graduate output and the employment rate among individuals with tertiary qualifications. From an input minimization perspective, Ahec Šonje et al. (2018, p. 10) observe that Slovenia's GDP expenditure per student could be reduced by 4,1% to achieve full efficiency.

In this study, we aim to reinforce previous findings that suggest potential for improving the efficiency of the Slovenian tertiary education system by employing carefully selected inputs and outputs focused exclusively on internal efficiency (with the justification for these choices detailed in the next section). This article seeks to address the following research questions: Does the Slovenian tertiary education system operate at the efficiency frontier relative to other OECD member countries, and which specific elements should be improved within the Slovenian system to enhance its efficiency, should it be found to be operating not efficiently. The following sections discuss the methods for data collection, the formulation of relevant indicators, and the data processing methodology.

3 Method

Figure 1 presents a visual representation of the research model. First, we conducted a literature review to establish the theoretical foundation, which allowed us to define the appropriate inputs and outputs for the model. Additionally, the reviewed studies helped us compare our research findings with those of previous studies.

Figure 1.
Model of research



The DEA method was originally developed by Charnes, Cooper, and Rhodes (1978), with their model based on the principle of constant returns to scale (CRS). This implies the assumption that an increase in the quantity of inputs leads to a proportional, linear increase in outputs. Subsequently, Banker, Charnes, and Cooper (1984) extended the CRS model to develop a version that operates under variable returns to scale (VRS). The main distinction between the two models is that the VRS model yields a higher number of fully efficient units compared to the CRS model, which consequently reduces its discriminative power (Sinuany-Stern & Hirsch, 2021, p. 488).

As with any method, DEA has its limitations and potential challenges, making it essential to follow established protocols for accurate application. According to Golany & Roll (1989, p. 238) and Dyson et al. (2001, p. 247), the initial step is to define the DMUs being observed, ensuring they are sufficiently comparable (possessing a substantial number of shared characteristics) to make efficiency comparisons meaningful. In this study, we evaluate the efficiency of tertiary education systems across OECD member countries. The primary reasons for this choice include the relative homogeneity of the sample, as these are economically advanced nations that adhere to democratic and free-market principles (Sinuany-Stern & Hirsch, 2021, p. 482), as well as the availability of robust data (the OECD maintains a comprehensive dataset of high-quality information from its member countries, supporting objective and unbiased international comparisons). As outlined by Golany & Roll (1989, pp. 239-241) and Dyson et al. (2001, pp. 248-253), the next step is to define the inputs and outputs to be included in the model, considering the following constraints:

- The ratio between the number of DMUs and the total number of inputs and outputs should ideally be greater than 1:3 to ensure sufficient discriminative power in the DEA method. As the number of inputs and outputs increases, so does the number of efficient units (with a relative efficiency score of 1) in DEA models. This rise in efficient units complicates result interpretation and the ranking of DMUs.
- The selected inputs and outputs must satisfy the criteria of exhaustiveness and exclusivity, meaning that each system input is represented by only one indicator, and the entire set of indicators encompasses all inputs and outputs of the system (Mihaljević Kosor et al., 2019, p. 399).
- Inputs and outputs must be expressed in consistent units (either absolute or relative) and designed to meet the isotonicity condition. This means that an increase in input values should contribute to a decrease in overall efficiency, while an increase in output values should lead to higher relative efficiency of the DMUs.
- Consideration must also be given to the time required for the production process that converts inputs into outputs, which necessitates defining appropriate time periods for recording inputs and outputs.

- It is advisable to use the average value over a multi-year period rather than focusing on a single year, as this approach mitigates the impact of potential extremes in any given year.
- When selecting appropriate indicators, it is also necessary to consider the qualitative component of each input or output (Bevc, 1999, p. 64; Jelić & Kedžo, 2018, p. 382).

In the subsequent section, we provide a rationale for the selection of secondary data used in our models and clarify the formulation of inputs and outputs. Accordingly, the models incorporate six distinct inputs (I) and four outputs (O).

In selecting inputs, we draw on foundational economic theory, which, even in the context of educational systems, considers labor and capital as the primary production factors (Scheerens, 2011, p. 49; Salas-Velasco, 2019, p. 162). Thus, our model includes inputs from both categories, with additional structuring. A review of inputs and outputs used in previous studies on the efficiency of tertiary education systems indicates that financial resources are consistently included as an input, although different studies employ various indicators for this input (such as the proportion of GDP allocated to tertiary education, the share of government budget for tertiary education, funding per student, and so forth).
Since the amount of financial resources does not directly indicate quality, we contend that a more comprehensive understanding of system performance requires examining the structure of individual factors that influence efficiency. An essential consideration in constructing an efficiency model is that objective and impartial analysis of efficiency in tertiary education systems should encompass both teaching and research activities. This aspect has largely been overlooked in prior research, as only two of the 12 reviewed studies (Aubyn et al., 2009; Sinuany-Stern & Hirsch, 2021) included indicators for research activity in their models. Data on education resources was retrieved from the OECD database (OECD, n.d.), specifically from the Education and Skills section. Drawing on available data, our study incorporates two financial indicators that provide deeper insights into the funding structure of tertiary education systems. Both indicators reflect relative values, showing financial resources (public and private) as a percentage of each country's GDP. They differ in that input I1 represents financial resources allocated to the entire tertiary education system, excluding research and development (R&D) funds, which are captured separately in input I2:

- **I1:** Financial resources for tertiary education (excluding R&D funding),
- **I2:** Financial resources allocated for research and development within the tertiary education system.

Despite the general neglect of labor-related inputs in previous studies on education and research efficiency (with exceptions like Aubyn et al., 2009 and Aristovnik & Obadić, 2011, who included labor as an input), we contend that including labor as a production factor in efficiency models is essential for achieving unbiased results. In this context, we consider both students (participants) and employees (providers) as key labor inputs. Aubyn et al. (2009, p. 10) argue that students are a fundamental production input, necessary for tertiary education systems to produce graduates as outputs, and that each student who fails to graduate contributes to the system's inefficiency.

Inputs I3 and I4 reflect the proportion of the population actively engaged in tertiary education. Input I3 represents the number of students in International Standard Classification of Education (ISCED) levels 5, 6, and 7 programs, while Input I4 captures students enrolled in ISCED level 8 (doctoral programs). There are two main reasons for this structuring: ISCED levels 5, 6, and 7 focus primarily on knowledge acquisition and later successful entry into the labor market, whereas ISCED level 8 programs are designed for those intending to pursue research careers. Since some OECD member states (e.g., Estonia, Finland, Greece, Lithuania) do not include ISCED level 5 programs in their national frameworks, we use an aggregate indicator. Data on students was retrieved from the OECD database (OECD, n.d.), specifically from the Education and Skills section. Both indicators are expressed in relative terms, showing the number of enrolled students as a share of the total population:

- **I3:** Students enrolled in ISCED levels 5, 6, and 7 programs,
- **I4:** Students enrolled in ISCED levels 8 programs.

In our model, we also include the number of employees as an input. The student-to-staff ratio, as used by Jelić & Kedžo (2018, p. 388), might indicate cost efficiency; however, it could also suggest a decline in teaching quality as instructors manage a larger number of students (Johnson, 2010, pp. 701-702). Consequently, similar to the approach of Aubyn et al. (2009), we include the number of academic staff as a proportion of the total population, defining this as input I5:

- **I5:** Employed academic staff.

Data on academic staff was retrieved from the OECD database (OECD, n.d.), specifically from the Education and Skills section.

In the context of including indicators that reflect the quality of each production factor, Rothschild & White (1995, pp. 574-576) emphasize the significance of students, particularly their prior knowledge and intellectual abilities. Consequently, in our model, we focus on developing indicator I6 to capture the quality of students' knowledge, using data from the 2009 (OECD 2010) and 2012 (OECD 2014) Programme for International Student Assessment (PISA) study. While Jelić & Kedžo (2018, p. 385) also draw on PISA

data, our approach differs in that we do not rely on the national average score. Instead, we consider only the top third of the population, acknowledging that only a portion of the population advances to tertiary education. We argue that, in studying tertiary education, it is relevant to focus solely on the segment likely to enter higher education, as analyzing the full sample of 15-year-olds could produce misleading results. This approach defines the sixth input (I6):

- **I6:** The average PISA score of the top third of the population.

On the output side, we follow the previously established premise that both educational and research outputs must be equally considered when evaluating the efficiency of tertiary education systems, as both are fundamental activities within these institutions. Accordingly, we define two groups of outputs: O1 and O2, representing educational outputs, and O3 and O4, representing research outputs.

O1 and O2 reflect the number of graduates across various levels of study. As noted by Warning (2004, pp. 398-399), Scheerens (2011, p. 49), and Salas-Velasco (2019, p. 162), the number of graduates serves as a representative indicator of educational output. Following the structure used for student numbers as inputs, we incorporate two graduate indicators into the model: graduates at ISCED levels 5, 6, and 7, and graduates at ISCED level 8. Both indicators are presented as relative values, showing the proportion of the total population, with data drawn from the OECD database (OECD, n.d.):

- **O1:** Graduates at ISCED levels 5, 6, and 7,
- **O2:** Graduates at ISCED levels 8.

O3 and O4 pertain to research activities within tertiary education systems. The number of scientific articles and other research publications produced by researchers (students and faculty) at each university is typically considered the primary output of research activities (Warning, 2004, pp. 398-399; Aubyn et al., 2009, p. 19; Saljoughian et al., 2013, p. 25). Agasisti et al. (2011, p. 277) also find that the number of published articles is a commonly used measure of research output. To develop the indicators representing research activity outputs, we utilize data from the Web of Science bibliographic database (Clarivate, n.d.), which provides comprehensive information on scientific works by country and institution, as well as citation counts.

Indicator O3 is constructed by identifying articles from each country where at least one author is affiliated with a domestic tertiary education institution (excluding foreign institutions, research institutes, hospitals, private companies, government agencies, etc.). The number of such articles is then calculated relative to the country's total population. The data on scientific publications used for indicator O3 also provide the basis for an indicator reflecting the quality component of research outputs (O4), which

can be assessed using citation indices, indirectly indicating the impact and quality of the research (Aksnes et al., 2019, pp. 1-2). For the selected articles in indicator O3, we examine the number of citations received in the publication year and in the following two years to capture the most recent citation impact.

Citation data were collected in November 2024, allowing us to include all scientific works published through 2022 and to analyze their citation counts for the publication year and the two subsequent years. The model incorporates the following indicators:

- O3: Published scientific works,
- O4: Citations.

In selecting inputs and outputs, we rigorously adhere to the principle of evaluating the efficiency of tertiary education systems strictly within the confines of the production function (i.e., technical, or internal efficiency). Consequently, indicators that assess the appropriateness of output allocation (such as the unemployment rate or earnings of tertiary-educated individuals) are excluded from our models. While most of the analyzed models incorporate unemployment as an indicator, and some even include income or poverty metrics as outputs, we argue that these reflect the interaction between production and demand, aligning more closely with the concept of external efficiency, which falls outside the scope of this study. We maintain that a comprehensive and objective efficiency analysis requires that internal and external efficiency be examined separately. It is also important to note that incorporating output indicators to reflect graduate quality would enhance the model's depth. However, due to the absence of a standardized instrument to measure the quality and breadth of graduate knowledge at the OECD country level, such an indicator cannot presently be included in the model.

The defined set of inputs and outputs is applied across four different models, focusing on two distinct periods. For data collection, we calculated a three-year average for both inputs and outputs, maintaining a four-year gap between the input and output periods. An exception is made for I6, which relies on PISA results, as the PISA assessment occurs every three years and involves 15-year-olds who typically enter tertiary education three to four years later. For the first period, we used PISA results from 2009, and for the second, we used results from 2012. Table 2 outlines the data collection periods for each input and output in both time frames.

Table 2
Time frame for input and output collection

	Inputs		Outputs
	I6 (PISA)	I1 - I5	O1 - O4
First time period	2009	2013 - 2015	2017 - 2019
Second time period	2012	2016 - 2018	2019 - 2022

We performed a DEA analysis for both the input-oriented (IO) and output-oriented (OO) models on data from each time period, resulting in four distinct models. The VRS model was applied in all four cases. Alongside measuring relative efficiency, we also analyzed changes in efficiency between the two periods using the Malmquist index - MI (Liu & Xu, 2017, p. 82). This model is designed to address the research question of whether the Slovenian tertiary education system operates efficiently compared to other OECD member countries. Furthermore, it will provide a detailed analysis of the individual input and output values, allowing for a thorough examination of factors contributing to inefficiency, should the Slovenian system be found lacking, and facilitating the proposal of targeted improvements.

4 Results

This section presents the findings of the efficiency analysis conducted for tertiary education systems in 29 OECD member countries. Although the OECD has comprised 38 member countries since 2010, the analysis for the period 2013 to 2022 is restricted to 29 countries due to missing data for the I1, I2, and I5 variables. As DEA requires complete datasets, countries with incomplete information could not be evaluated. Table 3 displays the relative efficiency coefficients obtained through the DEA method. These results pertain to the two observed periods described in the previous section, with analyses conducted for both input-oriented (IO) and output-oriented (OO) models in each period. In addition to the relative efficiency coefficients, table 3 shows each country's ranking within the sample of 29 countries. Table 3 also includes Malmquist index (MI) values, with the penultimate column presenting the index for input-oriented models, showing the ratio of relative efficiency between the first and second periods, and the final column showing MI values for output-oriented models, indicating the changes in relative efficiency across the two periods.

Table 3
DEA analysis results

Country (DMU)	First time period				Second time period				MI IO	MI OO
	IO		OO		IO		OO			
	Score	Rank	Score	Rank	Score	Rank	Score	Rank		
Australia	1	1.	1	1.	1	1.	1	1.	1,007	1,041
Austria	0,989	20.	0,942	22.	0,988	24.	0,885	26.	1,004	1,032
Belgium	1	1.	1	1.	0,986	25.	0,975	16.	1,301	1,072
Czech Republic	0,996	17.	0,966	20.	0,997	17.	0,857	27.	0,965	0,779
Denmark	1	1.	1	1.	1	1.	1	1.	0,812	0,882
Estonia	1	1.	1	1.	1	1.	1	1.	1,411	1,212
Finland	0,979	24.	0,978	17.	1	1.	1	1.	1,321	1,113
France	1	1.	1	1.	1	1.	1	1.	1,239	1,080
Germany	1	1.	1	1.	1	1.	1	1.	0,896	0,966
Hungary	1	1.	1	1.	1	1.	1	1.	1,241	1,560
Ireland	1	1.	1	1.	1	1.	1	1.	1,655	1,029
Italy	1	1.	1	1.	1	1.	1	1.	1,288	1,121
South Korea	0,970	28.	0,858	25.	0,978	28.	0,957	18.	1,054	1,111
Latvia	0,986	22.	0,754	29.	0,990	22.	0,764	29.	1,003	1,112
Lithuania	0,979	25.	0,799	27.	0,992	21.	0,927	20.	1,019	1,233
Luxembourg	1	1.	1	1.	1	1.	1	1.	1,876	1,057
Mexico	1	1.	1	1.	1	1.	1	1.	0,896	1,078
Netherlands	1	1.	1	1.	1	1.	1	1.	1,325	1,003
New Zealand	0,967	29.	0,968	19.	0,979	26.	0,912	21.	1,138	1,026
Norway	0,996	18.	0,975	18.	0,988	23.	0,906	23.	0,996	0,974
Poland	0,977	26.	0,948	21.	0,971	29.	0,784	28.	0,991	0,924
Portugal	0,990	19.	0,768	28.	1	1.	1	1.	1,008	1,239
Slovakia	0,987	21.	0,813	26.	0,994	18.	0,904	24.	1,000	1,016
Slovenia	**0,981**	**23.**	**0,874**	**24.**	**0,993**	**20.**	**0,887**	**25.**	**1,009**	**1,115**
Spain	1	1.	1	1.	0,993	19.	0,910	22.	0,682	0,692
Sweden	1	1.	1	1.	0,998	16.	0,972	17.	1,028	0,994
Turkey	1	1.	1	1.	1	1.	1	1.	1,019	0,824
United Kingdom	1	1.	1	1.	1	1.	1	1.	1,351	0,954
USA	0,974	27.	0,940	23.	0,979	27.	0,939	19.	1,038	1,073

The next section examines the results for the Slovenian tertiary education system within the broader analysis. Table 4 shows the countries whose tertiary education systems were deemed efficient and share the most similarities with the Slovenian system in terms of characteristics and structure. For each of the four models analysed, table 4 presents three benchmark countries for Slovenia. Lambda values are also included in the table 4, indicating the degree of similarity between the Slovenian tertiary education system and these foreign systems.

Table 4
Benchmark countries

Time period	Model used	Benchmark countries (lambdas)		
		Benchmark 1	Benchmark 2	Benchmark 3
First time period	Input oriented	Luxembourg 32,28%	Ireland 28,80%	Mexico 26,15%
	Output oriented	Luxembourg 52,58%	Ireland 34,60%	Belgium 12,83%
Second time period	Input oriented	Luxembourg 43,39%	Ireland 36,46%	Mexico 20,16%
	Output oriented	Luxembourg 54,97%	Ireland 33,95%	Italy 7,86%

Table 5 presents the values of all inputs and outputs for the second time period for Slovenia, alongside Luxembourg and Ireland, which were previously identified as benchmark models for achieving efficiency. The last row of table 5 provides the average values of all inputs and outputs across the 29 OECD countries analyzed in this study, offering a comparative perspective on Slovenia's performance relative to the broader sample.

Table 5
Input and output values for Slovenia, Ireland, Luxembourg and OECD averages (second time period)

Country	I1	I2	I3	I4	I5	I6	O1	O2	O3	O4
Slovenia	0,821	0,211	3,696	0,124	0,342	595,864	0,758	0,021	2,550	8,244
Ireland	0,631	0,240	4,512	0,176	0,201	596,464	1,930	0,031	3,881	9,581
Luxembourg	0,275	0,180	1,069	0,109	0,170	597,743	0,317	0,027	2,537	10,138
OECD average	0,989	0,407	4,310	0,145	0,338	594,710	1,034	0,024	2,477	8,854

Table 6 presents the results of the indicator values for the four outputs in both output-oriented models, along with the projected ideal value for each indicator that the Slovenian system should meet in order to achieve optimal efficiency. Additionally, Table 6 shows the percentage increase in output values needed for Slovenia to attain full efficiency.

Table 6
Output targets for Slovenia

	First time period (OO)				Second time period (OO)			
	O1	O2	O3	O4	O1	O2	O3	O4
Result	0,773	0,023	1,985	7,463	0,758	0,021	2,550	8,244
Target	0,884	0,027	2,687	8,539	0,912	0,027	2,875	9,730
Change	14,42%	14,94%	35,34%	14,42%	20,31%	30,34%	12,77%	18,03%

5 Discussion

The results shown in table 3 validate prior research, confirming that the Slovenian tertiary education system does not operate at the efficiency frontier. While a significant number of DMUs are classified as efficient (due to the relatively large number of inputs and outputs) Slovenia is not among them. In none of the four models tested does the Slovenian system reach full relative efficiency, consistently placing near the bottom of the rankings among the 29 countries analyzed. Slovenia's relative efficiency and ranking

are marginally higher in both input-oriented models than in the output-oriented models. Despite the poorer performance in the output-oriented models, an improvement in relative efficiency is observed between the two periods. The MI exceeds 1,000 in both cases suggesting that the Slovenian system is gradually moving closer to the efficiency frontier.

As evidenced by the data in table 4, Slovenia should primarily look to Luxembourg and Ireland as benchmarks for improving efficiency. Similar conclusions were drawn by Mihaljević Kosor et al. (2019, p. 403), who identified Luxembourg, Ireland, and Hungary as benchmark models for Slovenia. While Hungary was also recognized as fully efficient in our study, it was not classified as a benchmark model for Slovenia. It is crucial, however, to approach the interpretation of benchmark results and derived lambda values with caution and a critical perspective, particularly regarding their applicability to Slovenia.

Luxembourg and Ireland stand out as OECD countries with the highest GDP per capita, exceeding Slovenia's GDP per capita by more than twofold (OECD, 2025). This economic advantage allows these countries to sustain effective tertiary education systems even while allocating a lower proportion of GDP to this sector. As detailed in table 5, Luxembourg dedicates a smaller share of its GDP to research activities (I2) and broader tertiary education efforts (I1). However, it is important to account for Luxembourg's unique circumstances, where the majority of its population pursues tertiary education in neighboring countries (OECD, 2023, p. 39). This factor may distort the reported data on the number of students and graduates for Luxembourg.

The comparison with Ireland is particularly insightful. Although Ireland allocates a smaller percentage of its GDP to the overall functioning of the tertiary education system (I1 + I2) than Slovenia, table 5 reveals that Ireland directs a higher percentage of its GDP toward research activities (I2), compared to Slovenia. This higher investment is probably reflected in Ireland's superior performance in research-related outputs (O3 and O4). The data show that Slovenia lags significantly behind Ireland in the production of scientific outputs (O3), with a somewhat smaller gap in citation rates (O4). These trends, also confirmed by values in table 6, underscore the necessity for Slovenia to enhance its research outputs, particularly O3 and O4.

An even greater disparity is observed in the educational outputs (O1 and O2) between Slovenia and Ireland during the second period. As shown in Table 5, Ireland significantly outperforms Slovenia in the share of graduates at ISCED levels 5, 6, and 7. It is important to note also that Slovenia's values of O1 and O2 are below the average of the analysed countries. Given the intrinsic link between the number of students enrolled (I3) and the number of graduates (O1), the analysis shows that the gap in O1 is significantly wider than

in I3. This finding suggests that Ireland achieves substantially higher completion rates, which is a key factor in Slovenia's inability to attain full relative efficiency.

A similar discrepancy is evident in the comparison of students (I4) and graduates (O2) at ISCED level 8. Once again, the gap in outputs is more pronounced than in inputs. These observations, corroborated by table 6, highlight the urgent need for Slovenia to improve its educational outputs, particularly O1 and O2, to achieve a higher level of efficiency within its tertiary education system.

The data in table 5 indicates that, based on PISA results, Slovenian students begin secondary education with solid foundational knowledge and sufficient intellectual capacity. Additionally, the number of academic staff in Slovenia is comparable to the average across the analysed OECD sample.

6 Conclusion

The results of our research show that the Slovenian higher education system is not operating at the boundary of optimal efficiency, which confirms the findings of previous studies. To achieve optimal and efficient performance, it would be necessary to either reduce the volume of inputs or increase the volume of outputs. Given that the proportion of financial resources allocated to the Slovenian higher education system is below the average of OECD member countries, and that Slovenia also lags behind the OECD average in terms of the share of the population with tertiary education, a strategy focused on reducing inputs would be quite risky in terms of maintaining both the scale and the quality of higher education. This presents a significant challenge, particularly in the context of the knowledge-based economy.

As established in the discussion, Slovenia's efficiency is particularly constrained by low graduation rates at all ISCED levels. A relatively small proportion of students enrolled in tertiary education successfully complete their studies, which negatively impacts output values. Addressing this issue requires a thorough analysis of systemic factors contributing to low completion rates. However, efforts to improve graduation rates must not compromise educational quality.

Beyond educational outputs, research activities remain a crucial area for improvement. While Slovenia's scientific output volume is above average, enhancing both the quantity and quality of high-impact academic publications is essential for achieving efficiency. A deeper evaluation of research processes and targeted policy measures would be beneficial.

To improve efficiency, a multifaceted approach is necessary. Providing stronger academic and financial support, such as mentoring, tutoring, and targeted scholarships,

could help students complete their studies more successfully. Additionally, institutional reforms aimed at optimizing resource allocation and enhancing research productivity should be considered.

It is crucial to address the limitations of this research and delineate directions for future studies, particularly those focusing on the efficiency of tertiary education systems. As outlined in the introduction, this study is centered exclusively on the concept of internal efficiency within tertiary education systems. The selection of inputs and, more notably, outputs reflect this specific focus. However, this emphasis on internal efficiency should not be interpreted as a diminishment of the importance of external efficiency. On the contrary, external efficiency provides a deeper understanding of the applicability and societal relevance of the outputs produced by tertiary education systems. It also addresses critical questions about whether these outputs are coherent and appropriately allocated to meet the evolving needs of society and the economy. Accordingly, future research should integrate the concept of external efficiency to offer a more holistic evaluation of tertiary education systems. Future research should also prioritize expanding the analysis to include a larger and more diverse set of countries, including non-OECD members, once comprehensive and reliable data become available. Another significant limitation of this research is the restricted range of inputs and outputs available to capture qualitative dimensions of the indicators used, due to the lack of suitable data. Indicators that better reflect the quality of graduates' knowledge, evaluations of academic staff performance, and assessments of research output quality would be particularly beneficial.

Finally, we emphasize that future research should also examine external factors influencing efficiency that may not be directly controlled by individual countries, particularly in the short term. These external variables, such as global economic trends, international mobility of students and researchers, and cross-border collaboration, could provide valuable insights into the broader context affecting tertiary education systems. Including such variables would shed additional light on this complex and multifaceted topic, enabling a more comprehensive understanding of the determinants of efficiency in tertiary education.

We believe that this study will contribute to a deeper understanding of the challenges in ensuring the effective functioning of the higher education system in Slovenia and will encourage both academic and political stakeholders to seek solutions that could improve efficiency. These solutions are likely to be found within the higher education process itself, which, however, was not the primary focus of this study.

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Sandi Vrabec is a PhD candidate at the Faculty of Management in Koper. He is employed at the Ministry of Education of Slovenia.

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Borut Kodrič earned his doctorate in statistics at the Faculty of Economics in Ljubljana. At the Faculty of Management of the University of Primorska, he contributes to the delivery of courses such as Business Mathematics and Statistics, Research in Management, and Statistics in Economics and Finance. His research areas include official statistics methodologies and the financing of tertiary education.

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Povzetek:
Vrednotenje notranje učinkovitosti slovenskega Sistema terciarnega izobraževanja

Raziskovalno vprašanje (RV): v članku podajamo odgovor na vprašanje koliko je je slovenski sistem terciarnega izobraževanj učinkovit v primerjavi z drugimi sistemi terciarnega izobraževanja v državah članicah Organizacije za gospodarsko sodelovanje in razvoj (OECD) ter kateri so tisti elementi, ki jih je mogoče v slovenskem sistemu še izboljšati oz. optimizirati za doseganje optimalne relativne učinkovitosti.
Namen: raziskava poskuša osvetliti slovenski sistem terciarnega izobraževanja z vidika učinkovitega delovanja ter ga primerjati s sistemi ostalih držav članic OECD s ciljem, da se identificira tista področja, v katerih slovenski sistem ne dosega ustreznih rezultatov, ki bi omogočali popolnoma učinkovito delovanje.
Metoda: Z uporabo teoretičnih osnov za identificiranje ključnih inputov in outputov ter sekundarnih podatkov iz mednarodnih virov smo izvedli analizo relativne učinkovitosti z uporabo metode DEA, da bi proučili notranjo učinkovitost sistemov terciarnega izobraževanja v 29 državah OECD, za katere so bili na voljo celoviti podatki v obdobju študije.
Rezultati: Rezultati kažejo, da slovenski sistem terciarnega izobraževanja ni dosegel popolne učinkovitosti v nobenem od štirih uporabljenih modelov. Po stopnji relativne učinkovitosti se je Slovenija uvrstila med 20. in 25. mesto med 29 proučevanimi državami članicami OECD. Za doseganje popolne učinkovitosti bi bilo potrebno izboljšati rezultate outputov tako na področju pedagoške kot raziskovalne dejavnosti.
Organizacija: Rezultati raziskave lahko predstavljajo uporabno orodje za doseganje relativne učinkovitosti odločevalcem na državni ravni kot tudi managerjem posameznih inštitucij terciarnega izobraževanja
Družba: Doseganje učinkovitosti na področju terciarnega izobraževanja je pomembno za širšo družbo predvsem z vidika oseb, ki se vključujejo v proces kot tudi z vidika širšega vpliva, ki ga ima terciarno izobraževanje na gospodarstvo in družbo
Originalnost: To je prva raziskava, ki opravi pregled dosedanjih študij, ki obravnavajo učinkovitost sistemov terciarnega izobraževanja z vidika analize rezultatov slovenskega sistema terciarnega izobraževanja ter podrobneje ugotavlja doseganje učinkovitosti slovenskega sistema terciarnega izobraževanja.
Omejitve/nadaljnje raziskovanje: Raziskava temelji na sekundarnih podatkih, pridobljenih iz mednarodnih baz podatkov. Raziskovani vzorec ni naključno izbran, temveč vključuje 29 od 38 držav članic OECD, za katere so bila na voljo popolna podatki za celotno obdobje, saj je bila analiza omejena z odsotnostjo podatkov za preostale države. Vključene so tiste države, za katere so bili podatki na voljo za celotno obdobje. Primeren bi bil širši vzorec držav in uporaba drugih ali dodatnih vhodov in izhodov, še posebej tistih, ki odražajo kvalitativno komponento uporabljenih inputov in outputov.

Ključne besede: učinkovitost, sistemi terciarnega izobraževanja, metoda DEA, države članice OECD, financiranje izobraževanja, diplomanti.