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Do socially responsible higher education institutions contribute to sustainable regional growth and innovation?

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Abstract

Purpose – This study aims to analyse the efficiency of public higher education institutions (HEIs) through teaching and learning (T&L), research and technology (R&T) and social responsibility (SR) activities. It also aims to assess the external factors influencing the efficiency of T&L, R&T and SR, and influence of this efficiency on sustainable regional economic growth and innovation intensity.

Design/methodology/approach – The empirical approach is based on a two-step data envelopment analysis to compare the efficiency of 23 Portuguese public HEIs, using a Tobit regression, to assess the influence of the factors affecting HEI efficiency which in turn affects regional sustainability and innovation.

Findings – The results lead to the following conclusions: HEIs with better SR efficiency are situated in large urban centres; an insular location is positively associated with HEIs' T&L and SR efficiency; HEIs' T&L and SR efficiency positively influence regional gross domestic product (GDP); and HEIs' R&T efficiency positively influences R&D in regional GDP.

Practical implications – This study offers implications in the domain of sustainable regional growth. The study recommends that the policies of HEIs should concentrate on developing activities that meet the needs of the region. It also emphasizes the need to invest in recruitment of qualified lecturers and researchers, and creation of relevant PhD positions. The study also emphasizes the need for government actions to consider the most disadvantaged regions and create infrastructure to attract new companies and people.

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Originality/value – This study contributes to the existing literature on the efficiency of HEIs by considering the efficiency of not only T&L and R&T but also SR. It also analyses the influencers of both HEIs' efficiency and regional development.

Keywords Data envelopment analysis, Efficiency, Higher education, Social responsibility, Regional sustainability

Paper type Research paper

Introduction

Studies on the efficiency of higher education institutions (HEIs) focus above all on aspects related to teaching and research (Wolszczak-Derlacz, 2017). However, because HEIs operate in different environments, studying the transformation of their inputs into outputs related to social responsibility (SR) and the environments can result in contributions and implications to redefine action strategies and policies, both for HEIs managers and regional authorities (Pedro *et al.*, 2021). HEIs are embedded in an environment that includes social conditions (van Vught, 2008). These institutions contribute to regional vitality and serve as agents of social justice and cultural mobility wherever they are located (Boulton and Lucas, 2011), contributing to sustainable regional growth.

This study provides an innovative contribution to the unexplored matching of HEIs' efficiency with SR and regional sustainability. First, it combines key indicators (inputs and outputs) based on studies of HEIs' impact on their region to analyse the efficiency of teaching and learning (T&L), research and technology (R&T) and SR separately, mapping the most efficient HEIs, and analysing the influencers of HEI efficiency, sustainable regional growth and innovation intensity by estimating multivariate Tobit models. Second, the implications derived from the current study can help stimulate regional wealth as well as promote sustainable economic development through innovation and technological entrepreneurship. As HEIs are framed in different institutional and regional contexts, studying their related SR can shed new light on their contributions and responsibilities at the regional level. These contributions can be seen in light of the theory of social responsibility as a new core responsibility that complements moral and legal responsibilities. As argued by Vallaeys (2014), while moral and legal responsibilities govern acts, social responsibility governs impacts; that is, it does not govern factors having immediate and local consequences but factors related to systemic and global phenomena, even if distant.

The remainder of this paper is organised as follows. Section 2 provides a literature review. Section 3 presents the research hypothesis, research questions and conceptual model proposal. Section 4 presents the study's methodological design. Section 5 presents and discusses the results. Section 6 concludes the study and presents the implications and limitations of the study.

Teaching and learning and/or research and technology?

One of the basic principles of HEIs is positive interaction between T&L and R&T (Smeby, 1998). The HEIs' effectiveness in achieving the ideal combination of these two dimensions (Gautier and Wauthy, 2007) is not very clear in literature. Evidence from the UK suggests that universities with better research performance also perform well in teaching (Shattock, 2002), but the performance of smaller, younger, and less prestigious HEIs, in this regard, is difficult to assess (Vandamme *et al.*, 2008).

According to O'Banion (2010), T&L activities provide transcendent value that supports almost all educational activities. Audretsch *et al.* (2011) state that teaching-oriented HEIs focus more on theoretical research questions, having mostly teaching activities with only limited research, and innovative and entrepreneurial activities. Conversely, the majority of research-oriented HEIs are institutions with a multiplicity of missions, where research and postgraduate studies tend to dominate (Altbach and Salmi, 2013). This type of HEI is more innovative and

entrepreneurial (Audretsch *et al.*, 2011), and with multiple social and academic functions that establish a key link between global science and erudition, and between national science and its training system (Altbach and Salmi, 2013).

Social responsibility

According to Vilalta *et al.* (2018), HEIs have a SR that needs to be addressed and fulfilled, as they are also connected to the sustainable development goals (SDGs) of the United Nations Agenda 2030, in all its dimensions. SR is the ability to respond effectively to changes necessary for transforming society, promoting justice, solidarity, social equity and sustainable human development (Tiana and Villarreal, 2016). According to Meseguer-Sánchez *et al.* (2020), SR is a mechanism that allows the dissemination of the HEIs' values, thus ensuring its economic, environmental and social sustainability, along with committing to the requests of its various stakeholders. Creativity in the management of HEIs, the quality of the educational process, the development of scientific activities and effective communication with the public and stakeholders encourages the development of SR in HEIs (Rababah *et al.*, 2021). Adding to the previous statements, Kohl *et al.* (2021) highlighted that activities related to SR, such as social innovation, must be encouraged to translate the SDGs into the local context, underlining their significance in defining relevant issues and problem solving.

SR encompasses amoral and ethical responsibility towards individuals and the environment, apart from economic advancement (Ali *et al.*, 2021). From a theoretical point of view, the approaches that analyse SR in HEIs are diverse, highlighting, according to Quezada (2011):

- the management, which analyses the impact of university work, and strengthens relationships between universities and stakeholders;
- the normative, which fosters and promotes university values in society through national and international networks; and
- the transformational, which links HEIs to debates and reflections through research and training.

The SR of HEIs contributes towards consolidating the role of HE as a catalyst for sustainable processes of social and economic progress and development (QSStars, 2019). The nature of this role depends on each HEI's missions and competences, which can function as enablers of their region of influence, especially through the social contribution and services in the public interest provided to society (DfES, 2003).

Influencers of higher education institutions efficiency, and influencers of sustainable regional growth and innovation: hypothesis development

It is important to understand how HEIs' behaviour can affect the provision of education and research (Del Rey, 2001). The different levels of technical efficiency achieved by HEIs can be influenced by various factors, irrespective of HEIs' own management efforts, such as environmental conditions, which can cause differentiated effects according to the institution (Monaco, 2012). Kempkes and Pohl (2010) concluded that HEIs located in prosperous regions (e.g. West Germany) are more likely to benefit from the external environment in terms of efficiency. Considering HEIs' geographical location, in the Italian context, Monaco (2012) finds centre-northern universities are usually more efficient than southern ones.

With the above in mind, the first research hypothesis arises:

H1. The HEI's geographical location in large urban centres positively influences the (T&L, R&D and SR) efficiency of these institutions.

A Tobit model was used by Kempkes and Pohl (2010), who regressed the efficiency scores of German HEIs obtained through data envelopment analysis (DEA) on regional gross domestic product (GDP) per capita and dummies for the existence of engineering and/or medical departments. Partnerships between firms and higher education institutions (HEIs) mediated by students' curricular internships allow increased mutual benefits in the form of the exchange of knowledge and innovation, as concluded by Franco *et al.* (2019).

Thus, a second research hypothesis is formulated as follows:

H2. The type of innovative activities carried out by firms located in the same influence region as HEIs positively influences the (T&L, R&D and SR) efficiency of these institutions.

The systematic review carried out by Adamu *et al.* (2017) concluded that macro-environmental factors such as social, scientific, technological, economic, political and legal aspects; micro-environmental factors such as students, business community and society (Ashmarina *et al.*, 2015); and different types of relationships with society, firms, government, potential students and students' power affect HEIs' competitiveness (Mainardes *et al.*, 2011) and consequently their efficiency.

Considering the above, the third research hypothesis is formulated as follows:

H3. The investments of firms located in the same influence region as HEIs positively influence the (T&L, R&D and SR) efficiency of these institutions.

Oliveira and Santos (2005) found that Portuguese public HEIs' efficiency can be positively explained by the number of physicians per population and negatively by the unemployment rate in the surrounding region. Another important aspect is cooperation between companies and HEIs through students' work placements. These are ways for students to gradually become part of the labour market, promoting a relationship of mutual cooperation between companies and HEIs (Franco *et al.*, 2019).

Keeping in mind the above, the following research hypothesis arises:

H4. Resident qualified students in the same influence region as HEIs positively influence the (T&L, R&D and SR) efficiency of these institutions.

The presence of HEIs may benefit regional sustainability through new firm creation and performance (Fritsch and Aamoucke, 2017). The geographical proximity between HEIs and new firms seems to affect the "quality" of spillovers generated between different agents (Stahlecker and Koschatzky, 2004) and the role of HEIs tends to be especially important in structurally weak regions (Baptista *et al.*, 2011). In the German context, Lehmann and Menter (2016) find that the region and HEI spillovers are interrelated. Ferreira (2019) concludes that R&D activities have a positive effect on GDP through increased human capital productivity, income earned by graduates and increased productivity of other production factors.

In this context, the fifth research hypothesis is derived:

H5. The efficiency of HEIs (T&L, R&D and SR) positively influences sustainable regional growth.

According to Mainardes *et al.* (2011), HEIs play an important role in fostering local development, as they prepare professionals who will act in regional organizations, cooperate toward innovation and create economic advantages originating from these practices. Baptista *et al.* (2014) established a positive relationship between educated human capital and entrepreneurial activity through start-up creation. Wolszczak-Derlacz (2017) indicates a

positive association between an institution's efficiency and regional GDP per capita. Martin (1998) shows a positive relationship between R&D expenditure and increased human capital in HEIs, and the growth of regional GDP and employment in the context of Canadian HEIs.

Taking into consideration the above, the sixth research hypothesis is presented:

H6. The efficiency of HEIs (T&L, R&D and SR) positively influences the innovation intensity of their surrounding regions.

Considering the literature review and research hypothesis above, two research questions (RQs) emerge:

RQ1. What factors influence the efficiency of HEIs in Portuguese state, in terms of teaching and learning, research and technology and socially responsible activities?

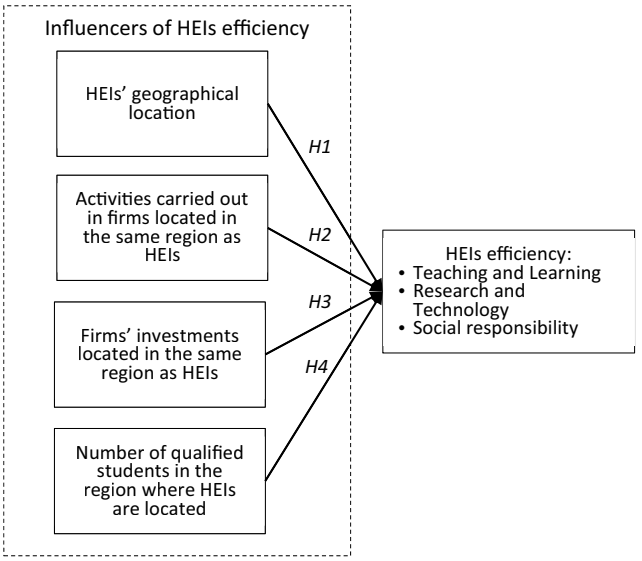
RQ2. How can efficiency influence sustainable regional growth and innovation, or be influenced by the region where HEIs are situated?

DEA is one of the most common methods used to measure HEI efficiency (Monaco, 2012; Wolszczak-Derlacz, 2017; Salas-Velasco, 2020; Lee and Johnes, 2021; Tavares *et al.*, 2021; Thai and Noguchi, 2021; Herberholz and Wigger, 2021). A two-step DEA was developed to conduct a comparative analysis of the efficiency of 23 Portuguese public HEIs. Some studies have employed a two-step approach (Salas-Velasco, 2020; Thai and Noguchi, 2021) to identify the factors that underpin efficiency (using efficiency scores). With reference to these researches, the first step in the current study consists of identifying and systematizing the indicators representing the inputs and outputs for T&L, R&T and SR, through a literature review, followed by validation through qualitative assessment carried out with various HEIs' stakeholders. The efficiency scores are then determined using DEA with different sets of inputs/outputs. In the second step, as advocated by Anastasopoulos *et al.* (2012) a multivariate Tobit regression assesses the hypothetical influence of the factors affecting HEI efficiency, or the factors related to HEI efficiency, which can affect regional wealth and innovation intensity. Accordingly, two conceptual models of the analysis are proposed. Model 1 presents the influencers of HEIs' efficiency, and Model 2 presents the influencers of sustainable regional growth and innovation intensity. The models are outlined in Figures 1 and 2, respectively.

Methodological design

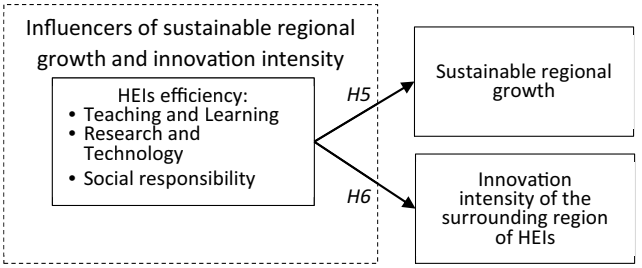
Based on data from 2018, the analysis of technical efficiency was carried out for 23 top public Portuguese HEIs (for HEIs' profile, see Table 1). For the three-fold purpose of determining HEIs' key indicators (inputs and outputs), measuring efficiency, and considering their effects on the region, previous studies have been considered (Wolszczak-Derlacz, 2017; Salas-Velasco, 2020). To identify and validate the key indicators found in these studies, a semi-structured interview was conducted face-to-face or via Skype with 20 relevant individuals in academic, political, social and economic circles residing in the areas of the HEIs. First contact was established by telephone or e-mail. The interviews with close and open questions were conducted after receiving their informed consent to carry out this pre-validation. The interviews were held during June to December 2019. Finally, the responses were analysed, and the key inputs/outputs and respective indicators to measure efficiency through DEA were identified (Table 2).

It should be noted that the "number of publications" was considered as an input in this study. Goldstein and Renault (2005) consider work as an input, and research is part of the



Source: Own elaboration

Figure 1.
Conceptual Model 1: influencers of higher education institutions (HEIs) efficiency and proposed research hypothesis



Source: Own elaboration

Figure 2.
Conceptual Model 2: influencers of sustainable regional growth and innovation intensity and proposed research hypothesis

work, in the context of teachers, researchers and even students. The data were obtained from the Portuguese National Statistics Institute (INE), the Database of Contemporary Portugal (PORDATA), the Sales Index (Grupo Marktest) and available elements in activity reports, management and accounting reports, and websites of the HEIs analysed. The frontier analyst application (version 4.4.0) was used to execute the DEA.

To assess technical efficiency, a multivariate Tobit regression was performed considering the two model specifications. Model 1 estimates the factors influencing HEIs' efficiency, taking the efficiency scores for T&L, R&T and SR obtained in the DEA analysis as dependent variables, the factors related to HEIs' geographical co-location, regional companies' R&D activities and the number of regional PhD students as independent variables. Model 2 estimates whether an HEI's efficiency affects sustainable regional growth and innovation intensity. The dependent variable is related to regional GDP, considering GDP per capita as a measure of progress and measuring economic growth per capita

HEIS' Name/acronyms	Region (NUTS 2/3)	Nr. of students
University of Lisbon (UL)	LMA/LMA	52,084
University of Porto (UP)	North/PMA	31,362
University of Coimbra (UC)	Center/Coimbra Region	22,145
NOVA University Lisbon (UNL)	LMA/LMA	20,963
Polytechnic Institute of Porto (IPP)	North/PMA	18,428
University of Minho (UM)	North/Cávado	18,335
University of Aveiro (UA)	Center/Aveiro Region	13,654
Polytechnic Institute of Leiria (IPL)	Center/Leiria Region	11,129
University Institute of Lisbon (ISCTE)	LMA/LMA	9,465
University of Algarve (UALg)	Algarve/Algarve	8,264
University of Beira Interior (UBI)	Center/ Beiras and Serra da Estrela	7,432
University of Évora (EU)	Alentejo/Central Alentejo	6,947
University of Trás-os-Montes and Alto Douro (UTAD)	North/Douro	6,460
Open University (UAB)	LMA/LMA	5,033
Polytechnic Institute of Viseu (IPV)	Center/Viseu Dão and Lafões	4,997
Polytechnic Institute of Cávado and Ave (IPCA)	North/Cávado	4,379
Polytechnic Institute of Viana do Castelo (IPVC)	North/Alto Minho	4,189
Polytechnic Institute of Castelo Branco (IPCB)	Center/Beira Baixa	4,107
Polytechnic Institute of Santarém (IPS)	Alentejo/Leziria do Tejo	3,840
University of Açores (UAC)	ARA/ARA	2,827
University of Madeira (UMA)	ARM/ARM	2,726
Polytechnic Institute of Portalegre (IPPortal)	Alentejo/Alto Alentejo	2,130
Nursing School of Lisboa (ESEL)	North/LMA	1,272

Notes: LMA: Lisbon Metropolitan Area. PMA: Porto Metropolitan Area. ARA: Autonomous Region of Açores. ARM: Autonomous Region of Madeira

Table 1.
Higher education institutions (HEIs) profile

(Coscieme *et al.*, 2020; Eurostat, 2020), and the independent variables are the ones concerning the efficiency scores obtained in the DEA analyses for T&L, R&T and SR. A control variable was also introduced to assess whether the number of public HE establishments in the regions could influence the results. Given the factors explored in the hypotheses and particularly geographic location (*H1*), it would be beneficial to understand if efficiency may also be driven by greater collaboration or competition originating from HEIs located outside the influence region.

All the values of the variables were transformed into polychotomous nominal variables, presenting four mutually exclusive classes, except for the variable of "insular areas" which is a binary one. Stata software (version 15.1.) was used to estimate the Tobit model specifications. For a detailed explanation of the variables, please consult Table 3.

Results and discussion

The DEA method uses a constant return to scale (CRS) model in an output-oriented framework, which establishes an analysis with constant returns to scale and determines a proportional relationship between inputs and outputs, where the inputs are fixed, and the objective is to maximise the outputs.

Following Daraio and Simar (2017), a summary of the descriptive statistics on inputs and outputs was performed, which revealed a set of very homogeneous results (Table 4). DEA validity should be confirmed through the ratio between the number of decision-making units (DMUs) and the product of the number of inputs and outputs, which must be above 1.333 (Li and Reeves, 1999). In view of the above, it was decided that, for each model, two inputs and

Table 2. Key inputs/outputs and indicators

Inputs	Outputs T&L	R&T	SR
I1 - Ratio: own income/SB *I2* - Ratio: expenditure on staff/SB *I3* - Ratio: n° of 1st cycle students*/total students *I4* - Ratio: total n° of lecturers and researchers/total students *I5* - Ratio: declared amount of service provision/total own income *I6* - Ratio: n° of ISI publications/total n° total of publications (ISI+SCOPUS) *I7* – Rate of scientific, cultural and social, and sporting events *I8* – Ratio: Student's annual cost of living (per HEI)/ national minimum salary	*O1A* - Ratio: n° of graduates/ total n° of Diploma-holders *O1B* - Rate of schooling in HE	*O2A*-Ratio: total n° of patents registered with INPI and WIPO/total patents *O2B*-Ratio: n° of companies in R&D activities/total R&D companies	*O3A* - Ratio: Total no. of social action grants awarded/total grants requested *O3B* - Proportion of women in HE graduates *O3C* - Inequality in the distribution of the declared gross income of tax aggregates

Notes: *Polytechnic education includes a variant of professional technical courses. SB: State Budget. T&L: Teaching and learning. R&T: research and technology. SR: Social responsibility. SB: State Budget. ISI: International Scientific Indexing Web of Science. SCOPUS: SciVerse Scopus. HEI: Higher Education Institutions. INPI: Portuguese Institute of Intellectual Property. WIPO: World Intellectual Property Organization. R&D: research and development
Source: Own elaboration

Table 3.
Variables included in the two regression models (tobit)

Reference studies	Type	Description	Designation
Model 1: Influencers of HEIs efficiency			
Oliveira and Santos (2005), Kempkes and Pohl (2010), Monaco (2012)	Dependent	Efficiency scores in T&L obtained from the DEA analysis	T&L efficiency
		Efficiency scores in R&T obtained from the DEA analysis	R&T efficiency
		Efficiency scores in SR obtained from the DEA analysis	SD Efficiency
	Independent	The HEI is situated in an insular area of the country	Insular region
		Ratio of the n° of firms with R&D activities/Total R&D firms in the region (NUTS3)	R&D activities in firms
		Rate of firms' total investment in the region (NUTS3)	Firms' investment
		Rate of Ph.D.s from higher education in areas of science and technology in the region (NUTS3)	Ph.D.s S&T areas
Model 2: Influencers of sustainable regional growth and innovation intensity			
Baptista *et al.* (2014) Lehmann and Menter (2016), Wolszczak-Derlacz (2017), Ferreira (2019)	Dependent	Regional GDP at current prices (NUTS3)	Regional GDP
		Proportion of expenditure on R&D in the Regional GDP and firm sector (NUTS3)	R&D regional GDP/firm sector
		Proportion of expenditure on R&D in the Regional GDP and higher education sector (NUTS3)	R&D regional GDP/higher education
		Efficiency scores in T&L obtained from the DEA analysis	T&L Efficiency
	Independent	Efficiency scores in R&T obtained from the DEA analysis	R&T Efficiency
		Efficiency scores in SD obtained from the DEA analysis	SD Efficiency
	Control variable	Number of HEIs in the region	Nr. HEIs

Notes: T&L: Teaching and learning. R&T: research and technology. SR: Social responsibility. HEI: Higher Education Institutions. R&D: research and development. S&T: science and technology. DEA: Data envelopment analysis. GDP: Gross domestic product. NUTS: Nomenclature of territorial units for statistics

Variable	I1	I2	I3	I4	I5	I6	I7	I8	O1A	O1B	O2A	O2C	O3A	O3C	O3D
I1	1														
I2	0.461*	1													
I3	−0.217	−0.329	1												
I4	−0.187	−0.087	0.017	1											
I5	0.144	−0.011	0.065	0.317	1										
I6	0.193	−0.369	−0.260	−0.097	−0.344	1									
I7	0.181	0.219	−0.613**	0.098	−0.136	0.055	1								
I8	0.108	0.267	−0.053	−0.193	0.123	−0.376	−0.058	1							
O1A	−0.317	−0.145	−0.062	−0.111	−0.100	0.201	−0.020	−0.056	1						
O1B	0.389	0.185	−0.469*	0.169	0.421*	−0.055	0.123	0.413	−0.480*	1					
O2A	0.114	0.244	−0.744**	0.032	−0.049	0.046	0.644**	0.230	−0.042	0.327	1				
O2B	0.302	0.227	−0.453*	0.024	−0.037	0.334	0.050	0.047	−0.073	0.292	0.075	1			
O3A	0.030	0.107	−0.137	0.519*	0.229	0.105	−0.047	0.142	0.030	0.236	0.133	0.058	1		
O3B	0.088	0.147	−0.240	−0.246	−0.184	0.154	−0.052	0.056	−0.079	0.080	−0.087	0.840**	−0.416*	1	
O3C	−0.308	−0.353	0.193	0.157	0.341	−0.020	−0.169	−0.401	0.145	−0.050	−0.271	−0.367	0.176	−0.389	1
Kurtosis	2.005	1.271	−0.448	−0.592	2.755	−1.222	2.115	0.030	1.722	0.584	1.376	1.570	−4.430	1.468	1.086
Skewenss	5.685	2.401	−1.409	0.844	9.13	3.213	4.332	−0.842	1.965	0.729	1.006	0.858	20.622	0.160	0.558
Mean	0.558	1.261	0.676	0.081	0.147	0.481	0.314	2.799	0.287	0.395	0.044	0.095	0.735	0.317	1.014
Stand. Dev.	0.327	0.134	0.211	0.019	0.168	0.140	0.442	0.243	0.295	0.198	0.0569	0.130	0.1640	0.5108	0.0526

Notes: *The correlation is significant at the 0.05 level (2 tails). **The correlation is significant at the 0.01 level (2 tails)

Table 4. Descriptive statistics and correlations matrix of HEIs inputs and outputs (n = 23)

one output would be considered active to maximise the outputs. Considering the indicators presented in Table 1, it was necessary to create a composite indicator (CI) for each factor, forming T&L, R&T and SR efficiency.

Daraio and Simar (2017) mention several multivariate statistical tools that can be of interest for use with a multivariate dataset (Härdle and Simar, 2003), normalized principal component analysis (PCA) being the best known one.

The correlation matrix of HEIs' inputs and outputs, the correlations of the first two principal components with the original variables and the cumulative percentage of variance explained by the eigenvalues are quite homogeneous among all variables (Tables 4 and 5).

Twelve models were analysed, and the means of the results (scores) for each model, as well as the global average, variance, skewness and kurtosis, were verified (Table 6). Figure 3 presents a radar chart for visual inspection.

The results for T&L activities revealed that three HEIs stand out with an efficiency average above 90.0%: UAL (97.13), UMA (95.33), and UAC (93.76). Considering global efficiency, among the three activities, UL (85.66) clearly stands out, followed by UNL (76.68). Those with the lowest values were the IPPortal (31.10) and UTAD (33.63).

Appreciation of the global average by model (Table 6) reveals that two of the SR models (*SR1* = 72.32; *SR4* = 62.64) have the highest averages, and the four R&T models have the lowest averages.

The most efficient DMUs by T&L models is UALg, which is situated on the efficiency frontier (100%) in three of the four models analysed (cf. Models 1, 2 and 4). For SR models, the results show that ISCTE and ESEL are the HEIs on the efficiency frontier (100%) in Models 3 and 4, and Models 1 and 4, respectively, and both are in regions of high population density. It is also seen, that in general, all HEIs manage to be more efficient in terms of SR, highlighting Portuguese public HEIs' concern about SR.

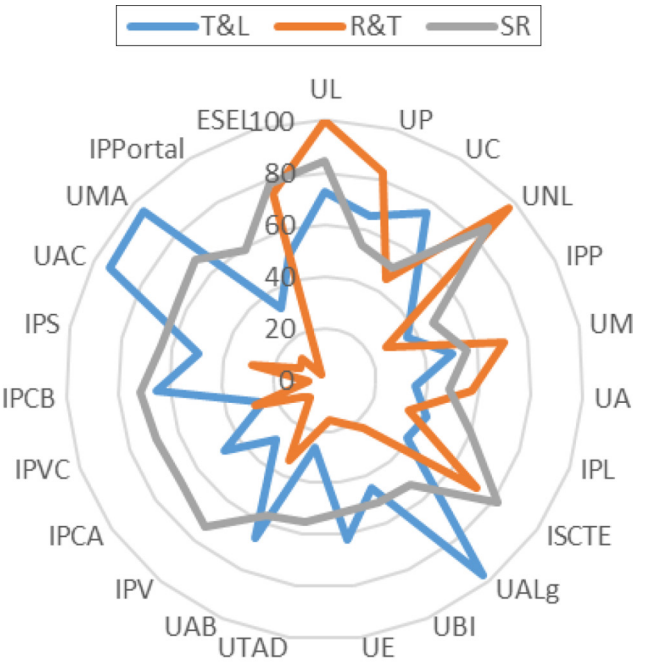
For the second-stage results, descriptive statistics were first produced, observing that all the values of correlation coefficients, descriptive statistics and significance levels of Models 1 and 2 were within normality (Table 7). The probability was estimated of each variation of the representations of "Insular region", "R&D activities in firms", "Firms' investment" and "Ph.D.s in areas of science and technology" having an effect on the dependent variables representing "T&L efficiency", "R&T efficiency" and "SR efficiency" (Model 1). The probability was estimated of each variation of "T&L efficiency"; "R&T efficiency"; and "SR

Table 5.
Correlations of the first two partial correlations with the original variables (factors loadings), eigenvalues and percentages of variances explained of HEIs inputs and outputs (n = 23)

Original variable	% First pc	Second pc	Eigenvalues	% of variance	Cumulated %
I1	0.309	0.016	3.480	0.232	0.232
I2	0.308	0.081	2.388	0.159	0.391
I3	−0.419	−0.019	1.995	0.133	0.524
I4	−0.053	0.348	1.707	0.114	0.638
I5	−0.017	0.423	1.163	0.078	0.716
I6	0.054	−0.274	1.028	0.069	0.784
I7	0.281	0.052	0.986	0.066	0.850
I8	0.201	0.156	0.906	0.060	0.910
O1A	−0.153	−0.156	0.537	0.036	0.946
O1B	0.327	0.319	0.301	0.020	0.966
O2A	0.341	0.160	0.244	0.016	0.982
O2B	0.332	−0.232	0.145	0.010	0.992
O3A	0.027	0.411	0.082	0.005	0.998
O3B	0.232	−0.420	0.032	0.002	1.000
O3D	−0.312	0.201	0.006	0.000	1.000

Table 6. Values and average values (scores) by model: data envelopment analysis

HEIs	Models T&L 1	2	3	4	Mean T&L efficiency	Models R&T 1	2	3	4	Mean R&T efficiency	Models SR 1	2	3	4	Mean SR efficiency	Mean of global efficency
UL	66.02	100	58.04	67.2	72.82	100	100	100	100	100	79.03	98.41	61.41	97.84	84.17	85.66
UP	55.08	100	48.53	59.79	65.85	81.73	80.38	82.45	87.68	83.06	50.55	61.90	38.33	63.82	53.65	67.52
UC	73.53	100	59.71	67.67	75.23	50.75	35.96	47.08	47.02	45.20	54.36	47.97	38.33	60.53	50.30	56.91
UNL	37	76.04	35.67	38.07	46.70	94.07	100	100	95.65	97.43	75.56	100.00	74.05	94.10	85.93	76.68
IPP	35.72	35.72	27.35	45.28	36.02	26.79	21.52	24.21	35.37	26.97	45.57	45.57	28.63	69.41	47.30	36.76
UM	38	69.59	53.29	40.49	50.34	68.73	59.36	88.16	65.46	70.43	47.48	55.87	61.83	59.56	56.19	58.99
UA	32.91	39.98	34.18	33.42	35.12	58.61	43.95	66.85	58.81	57.06	46.24	43.18	48.79	54.61	48.21	46.79
IPL	24.6	24.27	71.81	46.97	41.91	21.03	16.67	71.05	29.27	34.51	41.59	41.04	100.00	56.16	59.70	45.37
ISCTE	24.8	42.35	52.85	35.05	38.76	56.78	50.23	100	79.32	71.58	60.83	67.00	100.00	100.00	81.96	64.10
UALg	100	100	88.52	100	97.13	32.01	18.27	22.13	21.92	23.58	58.65	50.31	39.92	59.94	52.21	57.64
UBI	39.29	46.87	51.7	42.35	45.05	19.15	11.02	22.39	18.93	17.87	48.80	37.67	57.14	62.20	51.45	38.13
UE	58.64	69.96	60.45	58.17	61.81	15.86	13.7	18.23	15.55	15.84	47.79	51.40	50.71	55.14	51.26	42.97
UTAD	29.54	26.81	17.81	30.19	26.09	30.15	13.83	13.83	21.7	19.88	68.74	47.73	33.10	70.12	54.92	33.63
UAB	38.92	88.58	100	38.8	66.58	10.59	16.39	100	8.62	33.90	35.47	77.19	74.64	40.19	56.87	52.45
IPV	18.43	17.9	47.15	35.28	29.69	3.93	1.76	25	3.1	8.45	69.02	51.13	100.00	70.46	72.65	36.93
IPCA	30.47	54.19	49.38	55.27	47.33	8.4	12.3	15.33	9.76	11.45	51.95	94.74	67.64	56.30	67.66	42.14
IPVC	17.04	14.4	18.84	49.23	24.88	6.51	3.07	5.4	100	28.75	66.63	47.73	61.18	100.00	68.89	40.84
IPCB	38.96	30.65	100	89.31	64.73	3.56	1.23	15.81	5.21	6.45	70.89	39.81	100.00	75.25	71.49	47.56
IPS	35.14	26.64	35.7	100	49.37	7.35	2.73	4.76	100	28.71	66.72	39.45	51.14	100.00	64.33	47.47
UAC	100	87.12	87.91	100	93.76	18.22	6.15	7.84	9.7	10.48	85.76	50.36	47.92	72.69	64.18	56.14
UMA	100	84.52	100	96.78	95.33	25.62	4.92	8.88	8.01	11.86	100.00	45.30	60.72	67.43	68.36	58.52
IPPortal	26.83	19.51	26.21	56.41	32.24	3.45	1.23	2.51	3.29	2.62	69.19	37.89	49.17	77.54	58.45	31.10
ESEL	48.98	29.6	34.49	87.77	50.21	100	36.89	63.13	100	75.01	100.00	50.00	63.84	100.00	78.46	67.89
Mean By model	46.52	55.86	54.76	59.72	54.22	36.66	28.33	43.70	44.54	38.31	62.64	55.72	61.24	72.32	62,98	51,83
Variance	646.4	949.2	666.4	585.6		1072.1	941.61	1353.6	1431.5		305.22	363.47	475.85	320.71		
Skewness	1.20	0.24	0.54	0.65		0.87	1.36	0.51	0.46		0.68	1.48	0.67	0.46		
Kurtosis	0.47	−1.56	−0.70	−1.04		−0.58	0.90	−1.47	−1.53		−0.02	1.14	−0.37	−0.86		



Notes: Legend: T&L: Teaching and learning. R&T: Research and technology. SR: Social responsibility. UL: University of Lisbon. UP: University of Porto. UC: University of Coimbra. UNL: NOVA University Lisbon. IPP: Polytechnic Institute of Porto. UM: University of Minho. UA: University of Aveiro. IPL: Polytechnic Institute of Leiria. ISCTE: University Institute of Lisbon. UALg: University of Algarve. UBI: University of Beira Interior. UE: University of Évora. UTAD: University of Trás-os-Montes and Alto Douro. UAB: Open University. IPV: Polytechnic Institute of Viseu. IPCA: Polytechnic Institute of Cávado and Ave. IPVC: Polytechnic Institute of Viana do Castelo. IPCB: Polytechnic Institute of Castelo Branco. IPS: Polytechnic Institute of Santarém. UAC: University of Açores. UMA: University of Madeira. IPPortal: Polytechnic Institute of Portalegre. ESEL: Nursing School of Lisbon

Figure 3.
Distribution of average values (scores) by model: data envelopment analysis by model

efficiency" having effects on the variables of: "GDP"; "R&D in GDP firms"; and "R&D in GDP HE" (Model 2).

The two estimated models were statistically significant (Model 1: *Wald chi*^{2}*(12)* = 23.24; $p = 0.003$; Model 2: *Wald chi*^{2}*(9)* = 20.47; $p = 0.002$) because they were below the significance level of 5%. The log-likelihood statistic was −58.468901 for Model 1 and −44.469452 for Model 2, corroborating the global importance of the models compared to the null models.

The results for Model 1 (Table 8), which tests the influencers of HEIs' efficiency, reveals that *H1* [*The HEI's geographical location in large urban centers positively influences the*

Variables Model 1	1	2	3	4	5	6	7	8
T&L efficiency	1							
R&T efficiency	0.138	1						
SD efficiency	0.056	0.433*	1					
Insular region	0.557**	0.112	0.212	1				
R&D activities in firms	0.070	0.630**	0.658**	0.141	1			
Firms' investment	0.063	−0.105	−0.083	0.238	0.021	1		
Ph.D.s S&T areas	0.180	0.435*	0.000	0.135	0.148	−0.123	1	
Nr. HEIs	−0.151	0.506*	0.433*	−0.195	0.617**	−0.418*	−0.092	1
Mean	1.087	1.087	1.1739	0.087	0.913	0.783	1.000	0.522
Skewness	0.519	0.574	0.441	3.14	0.969	1.169	0.938	1.16
Kurtosis	−1.02	−1.172	−1.464	8.605	−0.96	0.691	−0.566	−0.52
Variance	1.174	1.356	1.514	0.083	1.719	0.905	1.364	0.715
Variance inflation factor	1.502	2.428	1.957	1.241	3.396	1.681	1.732	3.27
Variables Model 2	*1*	*2*	*3*	*4*	*5*	*6*		
Regional GDP	1							
R&D regional GDP/firm sector	0.307	1						
R&D regional GDP/higher education	0.172	0.666**	1					
T&L efficiency	0.278	0.008	0.262	1				
R&T efficiency	0.623**	0.770**	0.403	0.138	1			
SD efficiency	0.719**	0.152	−0.031	0.056	0.433*	1		
Nr. HEIs	0.632**	0.265	−0.081	−0.151	0.506*	0.433*	1	
Mean	0.739	1.391	0.957	1.087	1.087	1.174	0.739	
Skewness	1.236	0.068	0.735	0.519	0.574	0.441	1.236	
Kurtosis	−0.446	−1.213	−0.353	−1.020	−1.172	−1.464	−0.446	
Variance	1.656	1.158	0.953	1.174	1.356	1.514	1.656	
Variance inflation factor	4.387	4.615	1.491	1.446	2.150	2.357	2.441	

Notes: **The correlation coefficient is significant, at 1% (2 extremities). *The correlation coefficient was significant at 5% (two extremities)

Table 7. Correlation coefficients, descriptive statistics and significance levels: Models 1 and 2

(T&L, R&D and SR) efficiency of these institutions] is not rejected. Being located in an "Insular region" has a positive and significant effect on "T&L efficiency" ($p = 0.015$). *H2: The type of innovative activities carried out by firms located in the same influence region as HEIs positively influences the (T&L, R&D and SR) efficiency of these institutions*, fails to be rejected, as the "Firms' R&D activities" has a positive and significant effect on "R&T efficiency" and "SR efficiency" (both with $p = 0.001$). The same holds for *H4: The resident qualified students in the same influence region as HEIs positively influences the (T&L, R&D and SR) efficiency of these institutions,* which cannot be rejected, since "Ph.D.s in science and technology" has a positive and significant effect on "SR efficiency" ($p = 0.001$). Concerning *H3: The investments of firms located in the same influence region as HEIs positively influence the (T&L, R&D and SR) efficiency of these institutions*, no significant effect was found on the efficiency variables under study and hence this hypothesis is rejected.

In Model 2 (Table 8), testing the influencers of regional wealth and innovation intensity, when considering *H5: The HEI's (T&L, R&D and SR) efficiency positively influences sustainable regional growth*, it is verified that both "T&L efficiency" and "SR efficiency" have a positive and significant influence on GDP, with a $p = 0.089$ and $p = 0.250$, in corresponding terms, which allow us to not reject this hypothesis. *H6: The HEI's (T&L, R&D and SR) efficiency positively influences the innovation intensity of their surrounding region,* is also not rejected since the HEIs "R&T efficiency", affects both "R&D in regional

Table 8.
Results of Tobit analysis

Hypothesis confirmation	Variables	Coefficient	Std.Error	*z*	*P*>|*z*|	*P*>|*z*| with control variable
	Model 1: Influencers of HEIs efficiency					
H1	Dependent: T&L efficiency					
	Insular region	*2.552*	1.054	2.42	0.015**	0.027**
	R&D activities in firms	−0.015	0.234	−0.07	0.946	0.752
	Firms' investment	−0.201	0.341	−0.59	0.555	0.468
	Ph.D.s S&T areas	0.207	0.264	0.78	0.432	0.577
	Nr. HEIs	−0.289	0.651	−0.44	–	0.657
	Constant	0.461	0.523	0.88	0.377	0.323
	Dependent: R&T efficiency					
H2	Insular region	−0.323	1.212	−0.27	0.789	0.953
	Firms' R&D activities	*0.713*	0.222	3.21	0.001**	0.239
	Firms' investment	0.205	0.352	−0.58	0.560	0.848
	Ph.D.s S&T areas	*0.535*	0.254	2.10	0.035**	0.014**
	Nr. HEIs	0.669	0.553	1.21	–	0.226
	Constant	−0.379	0.549	−0.69	0.491	0.240
H3	Dependent: SR efficiency					
	Insular region	1.361	1.102	1.24	0.217	0.310
	Firms' R&D activities	*0.826*	0.244	3.38	0.001**	0.010**
	Firms' investment	−0.312	0.351	−0.89	0.374	0.265
	Ph.D.s S&T areas	−0.364	0.303	−1.20	0.229	0.190
	Nr. HEIs	−0.474	0.690	−0.69	–	0.492
	Constant	0.414	0.538	0.77	0.441	0.301
	Number of obs = 23					
	Wald chi2(12) = 23.24					
	Log likelihood =–58.468901					
	Prob> chi2 = 0.003					
	AIC = 142.938					
	BIC = 157.699					
	Model 2: Influencers of regional sustainable economic growth and innovation intensity					
H4	Dependent: Regional GDP					
	T&L efficiency	*0.886*	0.521	1.70	0.089*	0.057*
	R&T efficiency	0.618	0.508	1.22	0.224	0.939

(*continued*)

Table 8.

Hypothesis confirmation	Variables	Coefficient	Std.Error	z	$P>\|z\|$	$P>\|z\|$ with control variable
	SR efficiency	*1.508*	0.675	2.23	0.025**	0.035**
	Nr. HEIs	−1.669	0.922	1.81	–	0.070*
	Constant	−4.828	2.035	−2.37	0.018	0.018
H5	Dependent: R&D in regional GDP and business sector					
	T&L efficiency	−0.208	0.192	−1.08	0.279	0.206
	R&T efficiency	*0.963*	0.181	5.32	0.000***	0.000***
	SR efficiency	−0.200	0.165	−1.22	0.224	0.308
	Nr. HEIs	−0.292	0.265	−1.10	–	0.272
	Constant	−0.647	0.318	2.03	0.042	0.024
	Dependent: R&D in regional GDP and HE sector					
	T&L efficiency	0.199	0.270	0.73	0.464	0.666
	R&T efficiency	*0.673*	0.275	2.45	0.014**	0.006**
	SR efficiency	−0.297	0.246	−1.21	0.227	0.406
	Nr. HEIs	−0.445	0.431	−1.03	–	0.302
	Constant	−0.007	0.505	−0.02	0.988	0.912
	Number of obs = 23					
	Wald chi2(9) = 20.47					
	Log likelihood = −44.469452					
	Prob> chi2 = 0.002					
	AIC = 110.939					
	BIC = 123.429					

Notes: Level of significance *$p < 0.100$; **$p < 0.050$; ***$p < 0.001$. AIC: akaike's information criteria. BIC: bayesian information criteria. The italics (originally bold) emphasize the name and result of the two different models

GDP and business sector" ($p = 0.000$), and "R&D in regional GDP and HE sector" ($p = 0.014$) in a positive and significant way.

When considering the control variable: "Nr. of HEIs in the region", after verifying that the two estimated models remained statistically significant, small changes in the significance of some of the independent variables are denoted (Table 8). In Model 1, when the dependent variable is "T&L efficiency", "Insular region" suffers a decrease (0.012) in significance; in "R&T efficiency", there is no longer significance at the level of "Firms R&T activities" and there is a slight increase (0.021) in significance in "PhD in Science and technology". When "SR efficiency" is the dependent variable, the "Firms R&D activities" also decreases slightly in significance (0.009). In Model 2, when the dependent variable is "regional GDP", the significance level associated with "T&L efficiency" increases slightly (0.032), whereas the one related to the "SR efficiency" decreases by 0.010. In turn, when the dependent variable is "R&D in regional GDP and HE sector", the significance of "R&T efficiency" also increases (0.008).

As stated earlier, the first research question RQ1 is as follows: *How efficient are Portuguese State HEIs in the production of teaching and learning (T&L), research and technology (R&T) and social responsibility (SR)?* In this regard, some HEIs (e.g. UAlg, UMA and UAC) have higher means in T&L and lower means in R&T, which indicates a pro-teaching orientation. These results may indicate that HEIs present different competitive orientations and stances, and may give greater prominence to T&L activities or R&T activities, due to various restrictions regarding their context and location (Del Rey, 2001), available budget and resources (Gautier and Wauthy, 2007), matrix and form of functioning or even strategic options (Vandamme *et al.*, 2008).

Other HEIs present a higher mean in R&T, but a lower mean in T&L (e.g. UM, UP, UL, UNL and ISCTE). This may indicate that these institutions concentrate more on R&T activities than T&L activities, suggesting research-orientation of universities, as mentioned by Altbach and Salmi (2013). This result is in line with the view of Gautier and Wauthy (2007), who observed that a combination of high-quality teaching and high-quality research is observed when HEIs are mostly financed on a per-student basis.

Furthermore, three of the four HEIs situated in Greater Lisbon (UL, UNL and ISCTE) presented higher efficiency in terms of SR. Considering that these institutions are situated in greater Lisbon, a densely populated region, this result agrees with van Vught (2008), who states that HEIs' positioning depends on the stock or resources available in the region. Mazzarol and Soutar (2008) underline that HEIs located in regions with greater resources are more efficient in transforming those resources and developing more capacities to respond appropriately to regional needs. Dias *et al.* (2019) advocated that if HEIs adapt to their surrounding population, the population also ends up adapting to the existing educational supply, culminating in a certain synergy between the characteristics of teaching, educational institutions and the local population/social context. If it is considered that HEIs are a social referential that can (or cannot) promote progress, qualify human capital, responsibly build social capital, prepare students for external realities, provide access to knowledge, and so on (Vallaeys, 2014), it would be important to assess the different ways in which Portuguese HEIs relate to their physical and social environments, to determine the presence of asymmetries between the various regions (Pedro *et al.*, 2021).

RQ2, as stated before, is as follows: *In what way does this efficiency influence or are influenced by the region in which HEIs are situated?* In response to this question, it can be stated that, considering the influencers of HEIs' efficiency, geographical location influences the efficiency of HEIs (*H1*) through "Insular region", which is significant in T&L. An HEI situated in an insular region can explain the differences in the T&L efficiency. This result,

which agrees with the study by Monaco (2012), mentioning that efficiency differences are explained by taking geographical location into consideration.

In addition, the type of activities carried out by firms located in the HEIs' influence region affects the efficiency of HEIs (*H2*), especially through firms' R&D activities, which affect HEIs' R&T. According to the European Union (2011), taking into account a regions' demand pull, a region can have one (or several) HEIs. Nevertheless, regarding industry, it has a limited absorption capacity in local companies, especially in micro, small and medium-sized companies, or in branches of multinationals without local R&D (Pereira and Leitão, 2016). This finding agrees with Colombelli *et al.* (2020), who stated that HEIs' knowledge transfer to local companies can be affected by their absorption capacity. These arguments are supported by the results of the DEA analysis, which found that HEIs with lower efficiency percentages related to R&T are located in isolated areas of mainland Portugal or in the archipelagos.

Another aspect found to be very influential in HEIs' efficiency is the number of qualified students in the region where HEIs are located (*H4*), indicating a possible improvement in PhDs related to R&T in the region. The importance of R&T for HEIs and regional development is shown in terms of structural capital, through creating appropriate infrastructure for developing R&T activities and relational capital, through improving relations and regional research networks.

The results also suggest that the efficiency of HEIs positively influences sustainable regional growth (*H5*) through R&T and the innovation intensity of their surrounding region (*H6*) through T&L and SR. Concentrating on R&T is certainly crucial, not only for HEIs but also for regional GDP. Another notable result is that T&L and SR efficiencies can positively influence regional GDP. This result can be explained by the influx of both students and lecturers/researchers along with their families. This involvement becomes a bonus and competitive advantage for regional sustainability which, according to QSStars (2019), can come through education as a tool of structural change; cultural changes that arise in the classroom and have repercussions for the internal and external environments, and impact of these changes at both the regional and national levels. However, it should be considered that SR can confuse acts with their impacts as advocated by Vallaeys (2014), which in turn dooms any attempt to address the causes of adverse impacts of failure. There is a need of reorganisation system (political co-responsibility), rather than just good initiatives within the system, for stakeholders to follow sustainability practices.

Concerning the control variable, it must be noted that there were small influences on the outcomes of both models. In this respect, some highlights have been mentioned as follows: The case of firms' R&D activities ceases to be statistically significant; in Model 1, it infers that as there are more HEIs in the region, it means that firms possibly collaborate and/or establish protocols with more HEIs and therefore disperse their R&D activities without concentrating on a single institution. Another aspect is that the number of HEIs per region probably influences insular regions in terms of T&L efficiency. Large regions, as is the case in the Lisbon metropolitan area, gain from having a greater density of resources, and T&L efficiency can be boosted by greater partnerships/competition with other HEIs located in the same region.

Conclusions

This study analyses the efficiency of public HEIs through T&L, R&T and SR activities by assessing which external factors influence T&L, R&T and SR efficiency, and the mode by which efficiency influences sustainable regional economic growth and innovation intensity. The empirical approach is based on a two-step DEA to compare the efficiency of 23 Portuguese public HEIs using multivariate Tobit regression.

Empirical contributions advance knowledge on factors influencing the efficiency of both T&L and R&T activities. HEIs with better SR efficiency are in large urban centres, the inputs that must be improved are associated with a lack of financial sources and service provision, and insular localisation is associated with T&L and SR efficiency. HEIs' T&L and SR efficiency positively influence regional GDP. The multivariate Tobit regression reveals the influencing role of R&T over HEIs' efficiency, which is ratified through robustness checks of the single-stage results. HEIs' efficiency also depends on the underlying economic (or contextual) factors in the surrounding region, suggesting that a region with greater economic power will help its HEIs achieve better results, which in turn may contribute even more to regional development.

Practical implications are related to the HEIs investment in recruiting qualified lecturers and researchers and create Ph.D. courses that are more interconnected with the firms and institutions located in their regions. HE policies should be more attentive, provide HEIs with more resources and appropriate tools, and provide conditions for studying and developing R&D at the regional level. HEIs should be catalysts of change and innovation, and must ensure a formal commitment to curricula that teach SR and encourage philanthropic and voluntary projects contributing in a more practical way to both HEIs and regions' SR.

The main limitation of this study is that only 23 HEIs were included. The lack of data for the year of study resulted in exclusion of some Portuguese HEIs. However, the 23 HEIs in the sample represented all Portuguese regions at the NUTS2 level (Nomenclature of Territorial Units for Statistics at the level of basic regions for the application of regional policies). Future research could extend this study. For instance, a wider comparison of socially responsible HEIs in different countries could be useful for policy purposes to assess the impact of the efficiency of T&L and R&T activities and private funding on the international performance of responsible HEIs. To intensify R&D activities and attract highly qualified human capital (e.g. Ph.Ds), at the regional level, HEIs need to reinforce collaborative activities with enterprises/industry, government, and society, implementing and co-creating collaborative laboratories, which bring together enterprises/industry and academia in a single direction to intensify the knowledge and technology transfer into tangible solutions in the areas that are more important for reinforcing the innovative capability of that target region or country.

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