On the Second Mission of Higher Education Institutions: The Case of 'Polytechnics' in Europe

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The mission of Higher Education Institutions (HEIs) has progressively developed from an educational role to knowledge production, innovation generation and engagement with society at large. At the same time, the HEIs space has been enriched with the evolution of 'non-university' institutions, and a clear drift between the university and 'non-university' sectors can be observed all over the world. This challenges current higher education (HE) non-unitary systems and questions the validity of criteria currently used to typify HEIs. This study was initiated to clarify the status of the HE divide in European countries, by assessing the research characteristics and performance of several HEIs. To this end, HEIs in France, Italy and Portugal were analyzed using a multi-dimensional set of quantitative and qualitative indicators. It can be observed that in Portugal the HE drift is both policy and practice driven. The evidence and conclusions of this study can be considered by policy makers when developing public strategies and policies aimed at the 'non-university' sector in contemporary research and innovation ecosystems.

Keywords: Universities of Applied Sciences, second mission, research performance, higher education divide

INTRODUCTION

Besides their educational mission, higher education institutions (HEIs) have been systematic generators of new knowledge through research (their second mission) since the 1800s, namely at the German (Hunboldtian) universities, where research was regularly integrated with classroom teaching (Scott, 2006). Outreach and service to society, HEI´s third mission, also first arose in the 19th century as a regular mission of HEIs, namely in North America through the Morrill Acts of 1862 and 1890 (Scott, 2006). In the last decades, the shift from a "mode 1" to a "mode 2" knowledge production, where multidisciplinary teams are brought together for short periods of time to work on specific problems in the real world, has led to the formalization of a fourth mission: innovation (Boffo & Cocorullo, 2019). Thus, it can be observed that in the last two centuries the role of HEIs developed from "knowledge storehouses" to "knowledge factories" to "knowledge hubs" (Youtie & Shapira, 2008). In particular, the university engagement with the society at large, revisited by E. Boyer in the 1990´s (Boyer, 1996), has been gaining momentum. According to Boyer: "…the academy must become a more vigorous partner in the search for answers to our most pressing social, civic, economic, and moral problems, and must affirm its historic commitment to what I call the scholarship of engagement". Aligned with this vision, the concept of Engaged University has gained importance in the last two decades and can be roughly defined as an institution that is "devoted to direct interaction with external constituencies and societies through the reciprocally advantageous exchange, discovery and usage of knowledge, expertise and information" (Holland, 2001).

In Europe, the evolution of national HEIs in the last two centuries can be divided in two waves. The first one in the 19th century, concerns the creation of the Humboldtian model, which turned the university into a scientific center, leading to the development of new sciences and technologies, and to institutional diversification (Kotlyarov & Kostjukevich, 2011). The second wave, in the 20th century, relates to differentiation in the course of Higher Education (HE) expansion, leading to the coexistence of a university sector together with a 'non-university' sector comprised of institutions focused on professional education, often with no or a limited research directive and not being allowed to grant doctorates (Georgy, 2012; Kyvik, 2004). Non-unitary systems began to emerge in Europe in the 1960s and the 1970s, when Polytechnics were created in the UK, *Fachhochschulen* in Germany, *Instituts Universitaires de Technologie* in France and *Institutos Politécnicos* in Portugal. This proceeded during the 1980s and the 1990s, e.g., with the creation of the *Ammattikorkeakoulu* in Finland. This was an unequivocal policy answer to the increasing call for higher education, trying to answer best the growing need for professional qualifications and, simultaneously, preserving universities from rising admissions (Kyvik, 2004; Lepori, 2008). Outside Europe, mention must be made to the California Master Plan for Higher Education by Clark Keer in the 1960s (Callan, 2012) as a milestone in the transition from elite to mass to universal higher education, leading to a 'ternary system' and, consequently, to both differentiation and diversification of HEIs. This topic was notably addressed for example by Martin Trow already in the 1960s and the 1970s (Trow 1962, 1965, 1969, 1972, 1976).

In Portugal, the development of a 'non-unitary' HE sector was determined by the government in the late 1980s, and further strengthened during the implementation of the Bologna three-cycle system (Veiga & Amaral, 2009). Typical study areas at 'non-university' institutions traditionally include engineering, economics, health care, art and design, social work and business administration. However, in the last three decades, the 'non-university' sector policy and practice has changed in complex ways. The binary divide itself has shown to be volatile and permeability between the two higher education sectors has been observed (Huisman & Kaiser, 2001). The term 'non-university' institutions is truly not the most accurate for this sector as these institutions, depending on their geographical location, are named e.g. Universities of Applied Sciences, University Colleges, Polytechnic Universities, Technical Universities, or Polytechnic Institutes. In this paper we will use the term 'Universities of Applied Sciences' (UAS) to name these diverse 'non-university' HEIs, for the sake of clarity, and to avoid any eventual 'discriminative' connotation.

The evolution of national HEIs in Europe has taken different directions, being the binary divide the rule. However, in countries such as France a variety of institutions (public universities, Grandes Ecoles, IUTs, etc.) exists and the HE system composition is at odds with the typical binary system. UASs can be found in Austria, Belgium, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Lithuania, The Netherlands, Norway, Portugal, Spain, Switzerland and Sweden (Taylor et al., 2008). The UK has adopted a unitary HEI system in 1992, followed by Italy. In Norway, colleges can ask to change to a university status. Outside Europe, non-unitary systems exist, for example, in Australia.

Through time, policymakers and institutions themselves came to the conclusion that it would be warranted to broaden the tasks of UASs beyond their educational missions. In almost all European countries, UASs got the right of performing research (OECD, 1998). Whilst initially driven by the institutions themselves, in countries such as Finland, Switzerland, The Netherlands and Norway, a dedicated research directive has been actively advocated by national governments (Kyvik & Skodvin, 2003; OECD, 2003). In particular, practice-based research has been considered consistent with the professional orientation of UASs (Pratt, 1997). In these HEIs, education is enriched by enabling students to take part in R&D projects (Kajaste, 2018). Conversely, in universities, teaching staff enrich schooling by incorporating the latest scientific advances in the classroom.

The volume of research activity in UASs has increased significantly throughout Europe (Hallonsten, 2012; Hazelkorn, 2004; Kyvik & Skodvin, 2003; Lepori & Kyvik, 2010). Many UASs have established strategic plans to stimulate research and also to be recognized by the society at large as a research performing entity (Georgy, 2012). The self-image of UASs has in fact changed towards more research-oriented institutions (Strotebeck, 2014). The Bologna process contributed decisively to this since the degrees of universities and UASs now lead to identical qualifications. Also, the increase in the teaching staff academic qualifications, namely at the doctoral level, shaped a relevant context for intensified research and development, innovation, and the provision of qualified services not just to companies but also to the society at large. UASs have been progressively implementing interface infrastructures and delivering sophisticated scientific training. Enrolment of international students from different regions of the world has been growing. Moreover, international cooperation between HEIs, both universities and UASs, has evolved significantly, with the set-up of formal and informal networks of HEIs, and the joint application for international calls for research and innovation proposals.

In the case of Portugal, universities and UASs share some admission criteria: 1) similar tuition fees, 2) the number of allowed admissions is determined centrally by the government, and 3) common standards in the admission process. When applying for enrolment in a HEI, the selection criteria used by prospective students are the same regardless of whether intending to apply for a university or a UAS (Henriques et al., 2018). Job opportunities and the institution's reputation are the most important. The universities are mostly based in larger cities. Seven of the 15 public UASs are in ‘underdeveloped’ areas in the inner lands of Portugal. UASs mitigate demographic changes in these regions, as it was the intention, for example, of Norwegian or Finnish UASs (Taylor et al., 2008). Also, they contribute to local development and to raising the level of qualification of the population in those regions. UASs (*Institutos Politécnicos*) have access to competitive funding for both basic research (through the Foundation for Science and Technology, FCT) and applied research (through the National Innovation Agency). Currently, more than 50% of the faculty at UASs in Portugal hold a doctorate degree. Their research units have been systematically evaluated positively by FCT. Several are rated as excellent, and are active partners in several clusters, collaborative laboratories, scientific infrastructures, incubators and business accelerators, and science and technology parks.

In face of the above, the research question being pursued in this study is: does the formal status of HEIs in Europe influence research activity characteristics and performance indicators?

To answer this question, a mixed methods approach was used that combines a thorough literature search, the use of case studies and their analysis using combined qualitative and quantitative indicators. Two Portuguese ‘classical’ universities and one Portuguese UAS are studied and compared with two foreign examples (one technical university founded in the19th century in France, and an Italian university with applied/professional subject areas).

In the following section, a literature review on research assessment is critically addressed. This is followed by a description of the research methodology employed and of the selected case studies. The presentation of results follows and then a discussion on the findings is presented, including identification of limitations of the study. The paper ends with major conclusions and suggestions for future work.

RESEARCH ASSESSMENT

Assessment of scientific research quality is crucial for researchers, managers, funders, policy makers, and the society at large (Triggle et al., 2021). Academics can receive recognition and esteem by their peers, get career promotions, and obtain funding for further research (Fox, 1983; Gu & Blackmore, 2017; Sullivan, 1996). Thus, they look for publishing in ‘top journals’. However, there are no straightforward mathematical methods to objectively quantify individual contributions to the state-of-the-art (Figueredo, 2006). The global number of scientific journals published yearly has increased 3.5%/year over the past century (Bandt & Dacey, 2017). Within scientific outputs, articles have become the norm, although their relevance varies from one area to another (Vial et al., 2020). At the institutional level, publications can be quantified, and study programs can be appraised, but the fact is that there is no objective reference framework to determine the return on the resources’ investment.

Bibliometric Indicators

Bibliometric analysis is currently the most widely used approach to evaluate research results, by quantitative analyses of journals, their articles and corresponding citations (Mutschke et al., 2011). Over the past six decades, several bibliometric tools have been developed to quantify research performance. These include, for example, journal impact factors, h-indexes, along a multitude of their normalized versions (Bandt & Dacey, 2017; Vial et al., 2020). However, due to the multidimensional nature of research, multiple indicators are needed to develop a reliable portrait of the research performance of researchers, institutions, or countries. For example, the publication format strongly influences perceived productivity and impact. The information and computer sciences are recognized to publish more in conferences than other disciplines (Freyne et al., 2010; Wang, 2018). Social sciences, on the other hand, publish comparably more monographs and books (Sabharwal, 2013). Yet, in bibliometric studies, books are not appraised, largely because it is not possible to objectively assess the quality or relevance of books in an analogous way to that used to evaluate articles by quality of the respective journals (Kleck & Barnes, 2011).

Scientific productivity can be quantified using the volume of research outlets (e.g., papers). Naturally, this is a size-dependent metric that will favor scientific areas, institutions or countries with a larger research community. Furthermore, it will favor disciplines that are inherently more productive. Researchers in life sciences, medical sciences and engineering tend to publish more frequently than those in mathematics and business, whereas those in social sciences and in humanities have a tendency to publish less frequently (Gu & Blackmore, 2019). The volume of publications also depends on the collaborative habits. Research in physics have a propensity to be much more collaborative than research in arts and humanities.

Scientific impact is traditionally assessed using citation analysis. However, no research has determined that citations reveal the actual influence or quality of scientific work. High citation frequency cannot be directly linked with key scientific feats (Bloch et al., 2020; Tijssen et al., 2002). Also, there are significant differences in citation rates between scientific disciplines areas (Garfield, 1979; Hurt, 1987). In the humanities, a typical paper receives less than one citation in a decade, while this adds to more than 40 citations in certain biomedical areas. Moreover, citations are usually higher for larger collaboration networks (which are field dependent).

Complementary analytic methods include the use of a reference fraction of the most highly cited publications, to consider the skewness of citation distributions. For example, the 10% most highly cited publications can be used as an indicator of breakthrough articles (Schneider & Costas, 2017) and of scientific excellence (Wilsdon et al., 2015). The highly cited publications indicator has common traits with the h-index, but unlike the h-index it does not produce inconsistent rankings (Waltman & van Eck, 2012).

Size-normalized metrics can help assess research output quality of entities with varying sizes and scientific field profiles. Citations per publication, for instance, accounts for differences in the size of an entity's scholarly output, and is useful to reveal the efficiency of citations per publication (Gu & Blackmore, 2017). To account for different output and citation rate tendencies in different domains, field-normalized metrics, such as field-weighted citation impact metrics and journal metrics can be used. The field-weighted citation impact (FWCI), as defined by Elsevier, indicates the citation performance of a publication when compared to similar documents in a three-year period. It considers the publication year, the associated disciplines, and the document type. It allows the comparison of entities regardless of differences in their size, disciplinary profile, maturity, and publication-type structure. Example journal metrics include the SCImago Journal Ranking (SJR) and the Journal Citation Report (JCR, Clarivate). Gu and Blackmore (2017) report that SJR has wider coverage than JCR. The average SJR score of publishing journals has been used by these authors to quantitatively analyze relationships in Australian academic science, namely in three types of universities in Australia: a prominent university, a middle-tier university, and a non-thorough university.

Comparing Research Performance Across Institutions

Empirically comparing research performance across institutions and time is particularly challenging (Banal-Estañol et al., 2015; Seglen, 1997; Tue, 2020). In fact, research evaluation can be frequently distorted by 'gaming the metrics' (Biagioli & Lippman, 2020). Nevertheless, global university rankings are now commonly used to measure and compare institutional quality and excellence, including its research dimension (Hazelkorn, 2009). Since the appearance of the first international university ranking, the Academic Ranking of World Universities developed by Shanghai Jiao Tong University, in 2003, rankings are omnipresent when the role and impact of universities is on the table. Rankings compare HEIs using an array of indicators, which are weighed according to each specific ranking system. Information is generally collected from three sources: 1) survey data of students, employers or other stakeholders, 2) independent third parties e.g., government databases; and/or 3) directly from HEI sources. But essentially rankings depend on bibliometric data. Thus, they are often considered inaccurate and arbitrary (Diana Hicks & Wouters, 2015). Even though, the spread of university rankings has affected the academic publication system. It is suggested that their introduction has driven a significant increase in the number of publications and scholars (Marginson & van der Wende, 2007). Many universities define annual publication metrics to be more competitive in ranking lists (Sullivan, 1996). Regardless of what kind of HEI, the image is clear: research matters more now than ever (Hazelkorn, 2009).

METHOD

A two-stage methodology was followed. The first step concerns a through literature review. Next, deductive reasoning and reflective inquiry were used to derive findings from the case studies. A case study approach was chosen because it enables the in-depth investigation of phenomena. The selection of the case studies used the sense of ‘atypical cases’ to get a fuller dataset to create a greater insight of the research topic (Flyvbjerg, 2006). Both quantitative and qualitative data were used. Mixed methods are highly appropriate in this study because the integration of qualitative and quantitative research can provide a deeper understanding about the topic of research (Saunders et al., 2009), in this case the fulfilment of the second mission by UASs. A qualitative case-study research approach was used, as according to e.g. Patton (2002), it is appropriate for investigating issues that are complex and difficult to quantify, as well as identifying themes, patterns, concepts and insights that are needed to understand such issues. Quantitative, bibliometric data analysis was used to complement the qualitative research.

The literature search was conducted over the Scopus (Elsevier) database. It is the only database that automatically groups publications by a single affiliation (*Research Metrics Guidebook*, 2018). Besides the broader coverage of Scopus (Gu & Blackmore, 2017; Vial et al., 2020), including a wider spectrum of journals when compared with Web of Science (Clarivate) (Ghafoor et al., 2020), citation counts tend to be higher in the latter (Waltman, 2016).

Following the recommendations of notable international initiatives on research assessment (namely the Declaration on Research Assessment - DORA, and the Leiden Manifest for Research Metrics), a set of indicators was used (Diana Hicks & Wouters, 2015). This will give a balanced, multi-dimensional picture for evaluating research. Moreover, triangulating information from an evidence base, by using a combination of indicators, guarantees more consistent insights. When several complementary indicators lead to similar observations, more compelling substantiation about the research subject is attained.

The annual research, countries, media titles, authors, institutions, citation frequency, article and journal metrics were extracted. A citation window of 3 to 5 years is commonly used, being a sensible compromise between a short- and long-term citation timeframe (Aksnes et al., 2019). The analyzed period was 2016-2020.

The publication media included all the output types and was not limited to journal articles. However, for detection of ‘excellent’ articles, reviews were excluded as a document type and only research articles were considered (Schneider & Costas, 2017).

Four key analysis factors are considered: 1) multidisciplinarity, 2) collaboration patterns, 3) research productivity, and 4) ‘quality’ of publications. For assessing multidisciplinarity: a) the scientific areas and author keywords associated with published outputs were analyzed, and b) term mapping of the titles and abstracts was carried out using the VOSviewer software. The collaboration profile, at the country and institution levels, was assessed by clustering and mapping co-authored publications using the VOSviewer software. The HEIs´ productivity was studied by computing the growth in publication volume. The publication´s ‘quality’ was evaluated by computing the number of citations per publication as a measure of the research ‘impact’. Also, a weighted-average journal ranking score was calculated for the ten journals where each HEI publishes most of its research, and the field-weighted citation impact was compared for the 10 most cited publications for each HEI.

VOSviewer software version 1.6.16 was used to construct and display bibliometric maps, as well as to identify clusters, networks, and for automatic term identification in titles and abstracts (Rizzi et al., 2014; Xie et al., 2020). This allowed for a combined mapping and clustering approach (Waltman et al., 2010). Colors are used to indicate clusters (entities with strong links). The size of a circle shows the number of publications of the corresponding entity (topic, country). The distance between two circles approximately indicates the strength of the link (e.g., co-authorship) between the corresponding entities (Perianes-Rodriguez et al., 2016). The results from countries were subjected to co-authorship analysis in VOSviewer (Xie et al., 2020), using fractionalized counts (Aksnes et al., 2012). Terms are identified by examining the titles and abstracts using natural language processing techniques. The most relevant terms are selected by a term selection algorithm available in VOSviewer (Rizzi et al., 2014). General terms are not mapped (e.g., ‘conclusion’, ‘method’, and ‘result’). Full counting and a minimum of 10 occurrences of a term were used. Only the 60% of the most relevant terms are displayed.

The weighted-average SJR of publishing journals in 2016-2020 was determined by multiplying the number of papers published in each of the top 10 journals by the corresponding SJR value and dividing the corresponding sum by the total number of papers published in each year (Eq. 1). The total weighted-average SJR score corresponds to the average value for the considered period of time, as expressed in Equation 1, where *i* is the year number, *j* is the journal number, *n* the number of publications, and SJR the SCImago Journal Ranking indicator.

$$SJR_5^w = \sum_{i=1}^{5} \left(\frac{\sum_{j=1}^{10} (n \times SJR)_j}{\sum_{j=1}^{10} n_j} \right) / 5 \qquad (1)$$

The Case Studies

The Bragança Polytechnic University (IPB, Portugal) was used as the central case study. Its research profile and performance were compared with two public ‘classical’ universities located in the same region and sharing the fact that they were created in the last quarter of the 1900´s: the University of Minho (UMinho) and the University of Trás-os-Montes e Alto Douro (UTAD). Two other HEIs were selected for international comparison purposes. The HEIs selection criteria used were: 1) must be located in European countries and geographically close (to try to mitigate cultural biases as much as possible); 2) must be related with the ‘polytechnic’ concept; and 3) must have similar research performance in international rankings. This will allow to analyze specific research profile characteristics (multidisciplinary, collaboration patterns) and performance indicators (productivity, ‘quality’) of HE institutions with varied institutional profiles but similar ‘ranking’. To make this selection, the international ranks considered included the Scimago Institutions Ranking (SIR), developed by the SCImago research group (Spain), U-Multirank, developed by a consortium and supported by the European Commission, the CWTS Leiden Ranking, the Shanghai Ranking, the Times Higher Education World University Rankings, and WURI – World´s Universities with Real Impact ranking. Besides listing IPB, SIR was chosen because there is no reliance on data submitted by the universities themselves, and because it is a consolidated, internationally recognized HEI rank that facilitates the choice of HEIs based on their relative position. It includes both, size-dependent and size-independent indicators.

Using IPB´s position in the 2021 ranking (Table 1) as a reference, the closest HEIs from different European countries, that have in their designation terms related with the “polytechnic” concept are: the *Institut Polytechnique de Grenoble* (Grenoble INP, FR), and the *Universita Politecnica delle Marche* (UNIVPM, IT).

TABLE 1
SIR RESEARCH GLOBAL RANK 2021

HEI	Score
IPB	320
UTAD	381
UMinho	254
Grenoble INP	317
UNIVPM	334

IPB is a public HEI, founded in 1983, with Schools in the areas of Agriculture, Public Management, Communication and Tourism, Education, Health, and Technology and Management. UTAD became a public university in 1986, based on the Vila Real Polytechnic Institute, created in 1973. It is composed of the following Schools: Agricultural and Veterinary Sciences, Human and Social Sciences, Sciences and Technology, Life and Environmental Sciences, and Health. UMinho received its first students in the 1975/1976 academic year. Its Schools are the following: Architecture, Sciences, Law, Economics and Management, Engineering, Medicine, Nursing, Psychology, Social Sciences, Education, Arts and Humanities. UNIVPM, formerly known as the Free University of Ancona, is a public university in Italy, established in 1969, with Schools in Agriculture, Engineering, Economics, Medicine and Surgery, and Sciences. Grenoble INP is a 'technological university', officially founded in 1900 with the creation of the Electrical Engineering Institute, becoming the National Polytechnical Institute (INPG) in 1971. It is composed of the following Schools: Energy, Water and Environmental Sciences, Applied Mathematics and Computer Sciences, Advanced Systems and Networks, Industrial Engineering and Management, Paper, Print Media and Biomaterials, Physics, Electronics, Materials Sciences, Science and Engineering, Management. Relevant figures for these HEIs are summarized in Table 2.

TABLE 2
KEY 2019 FIGURES FOR THE STUDIED HEIS

	Annual Revenue (M€)	Teaching Staff (FTE)	Contracted Researchers (nr.)	Students (nr.)	Doctoral students (nr.)
IPB	33.69	460	21	9 000	90[a]
UTAD[3]	50.41	494	18	7 006	423
UMinho[4]	140.61	1 028	360	19 641	1 700
Grenoble INP[5,6]	113	393	235	6 000	730
UNIVPM[7]	141.35	350[b]	187[b]	16 645[b]	337[b]

[a] Enrolled in "classical" universities but carrying out research exclusively at IPB in most cases; [b] 2018.

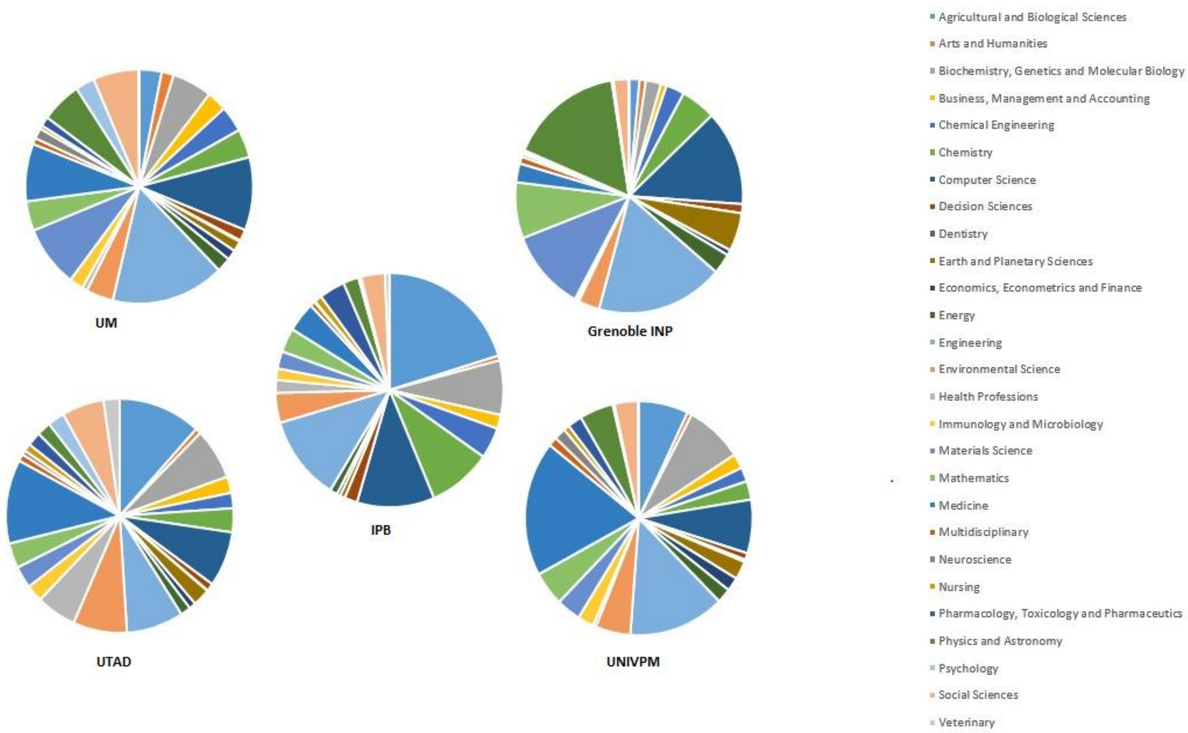
A first observation is that the HEIs have significantly varied sizes. The most striking feature is that FTE teaching staff, contracted researchers and doctoral students of UMinho are far greater than those of the other HEIs, while the number of students and the annual income are relatively similar to those of UNIVPM.

RESULTS

Multidisciplinarity at the Institutional Level

Figures 1 and 2 present the scientific areas associated with the publication output of each institution for the 2016-2020 period.

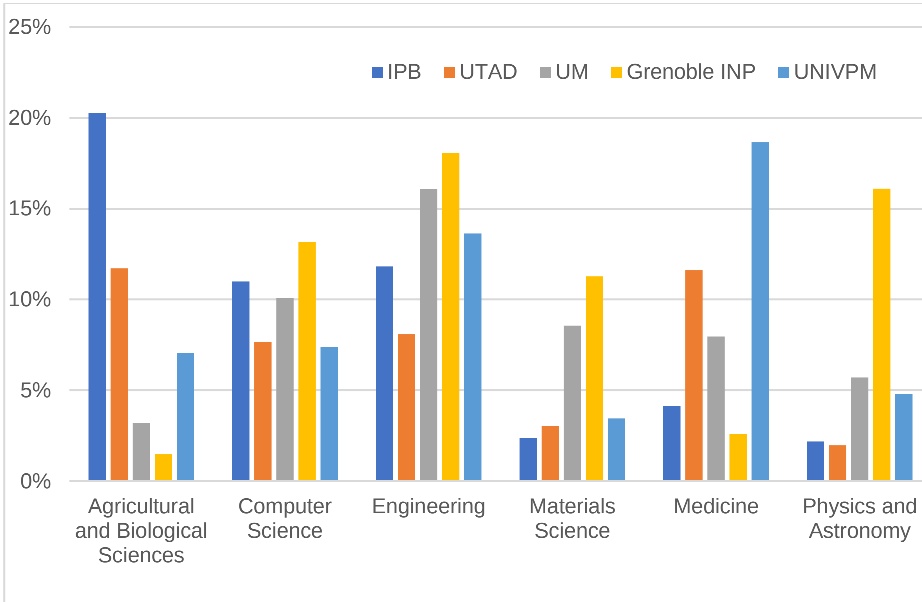
FIGURE 1
RELATIVE PROPORTION OF SCIENTIFIC AREAS IN EACH INSTITUTION



In Figure 1 it can be observed that all the institutions publish in a diverse array of scientific areas, although there are specific areas more prolific than others. Namely (Figure 2), agricultural and biological sciences (IPB, UTAD), engineering (IPB, UMinho, Grenoble INP, UNIVPM), medicine (UTAD, UNIVPM), computer science (IPB, UMinho, Grenoble INP), materials science (Grenoble INP) and physics and astronomy (Grenoble INP). In relative terms, Grenoble INP is particularly prolific in the physics and astronomy areas, UNIVPM in medicine and IPB in agricultural and biological sciences.

The relevance of, and relation between research topics was analyzed by term mapping the words utilized in the title and abstract of each paper. In the term map, each color indicates a cluster of related terms.

FIGURE 2
THE MOST PROLIFIC SCIENTIFIC AREAS ASSOCIATED WITH PUBLISHED OUTPUTS



Figures 3 to 7 show that in each institution clusters of topics can be clearly identified which represent active research areas. The use of data visualization tools allows for the identification of clusters that go beyond topics researched by the most prolific authors. A common trait of all the five institutions is the wide diversity of themes and the closeness of some clusters, which denotes relevant inter and multidisciplinarity. Thus, further evidence is provided of the wide scientific scope of these institutions.

FIGURE 3
TERM MAPPING FOR IPB

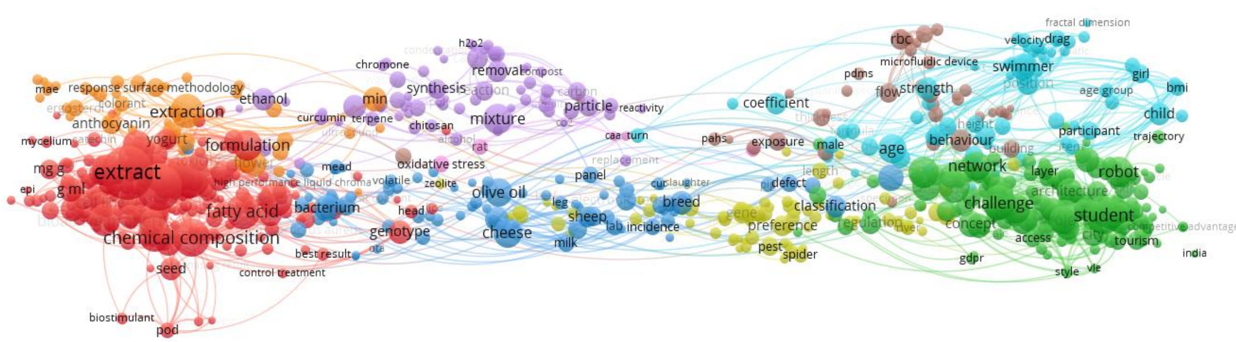


FIGURE 4
TERM MAPPING FOR UTAD

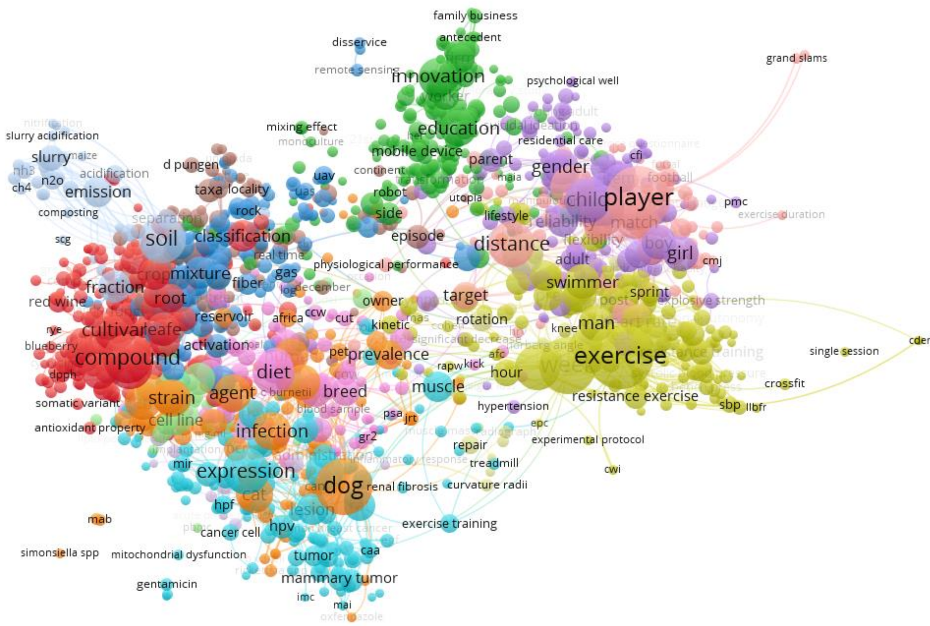


FIGURE 5
TERM MAPPING FOR UMINHO

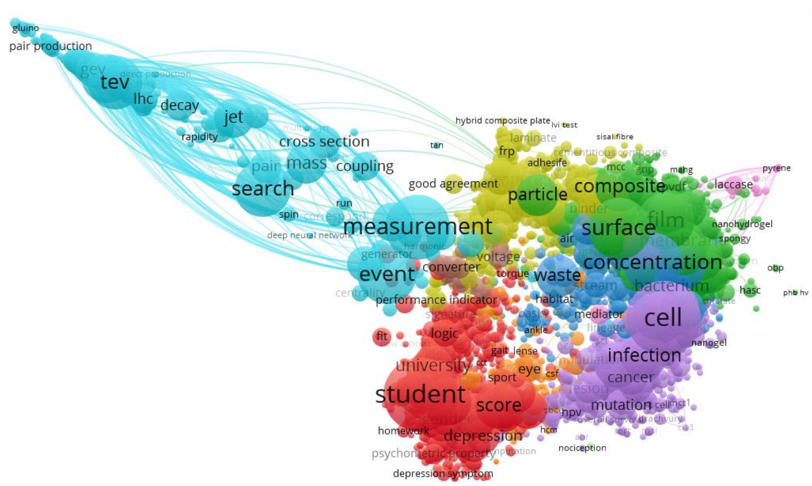


FIGURE 6
TERM MAPPING FOR GRENOBLE INP

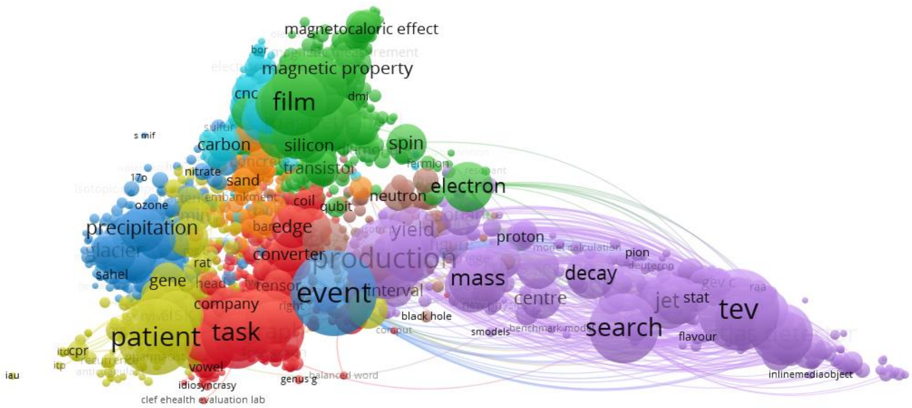
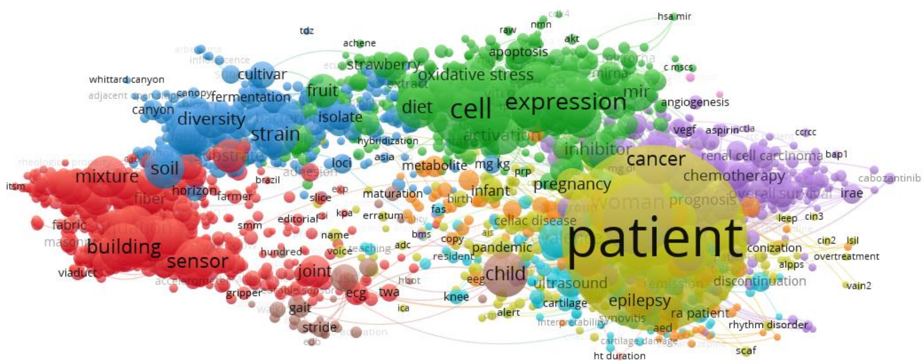


FIGURE 7
TERM MAPPING FOR UNIVPM



Collaboration Patterns

IPB, UTAD, UMinho, UNIVPM and Grenoble INP, published in the 2016-2020 period with authors from 141, 134, 156, 158 and 158 institutions, and from 81, 119, 151, 145 and 149 countries, respectively. The international networks were represented using the clustering functionality of the VOSviewer software (Figures 8 to 12). It can be observed that all the institutions present a wide international collaborative network. It is interesting to notice that United States, United Kingdom, Germany and Spain are countries shared by all the institutions. This correlates with the well-known research volume of these countries, plus the geographic proximity among all, except the United States.

FIGURE 8
COLLABORATION MAP FOR IPB

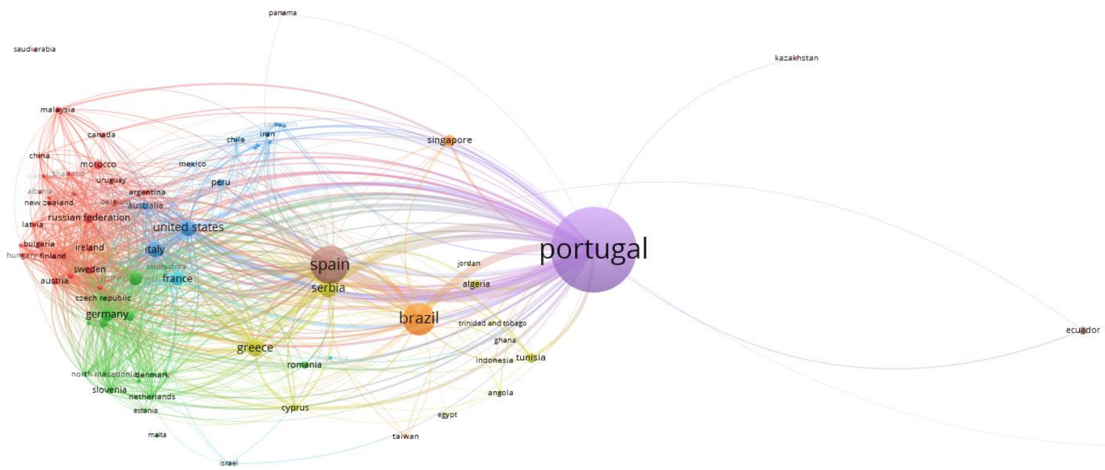


FIGURE 9
COLLABORATION MAP FOR UTAD

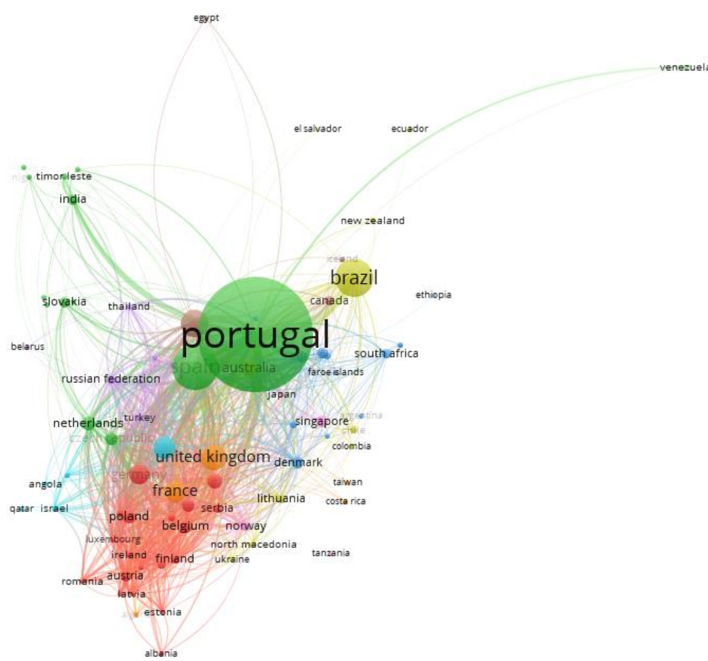


FIGURE 10
COLLABORATION MAP FOR UMINHO

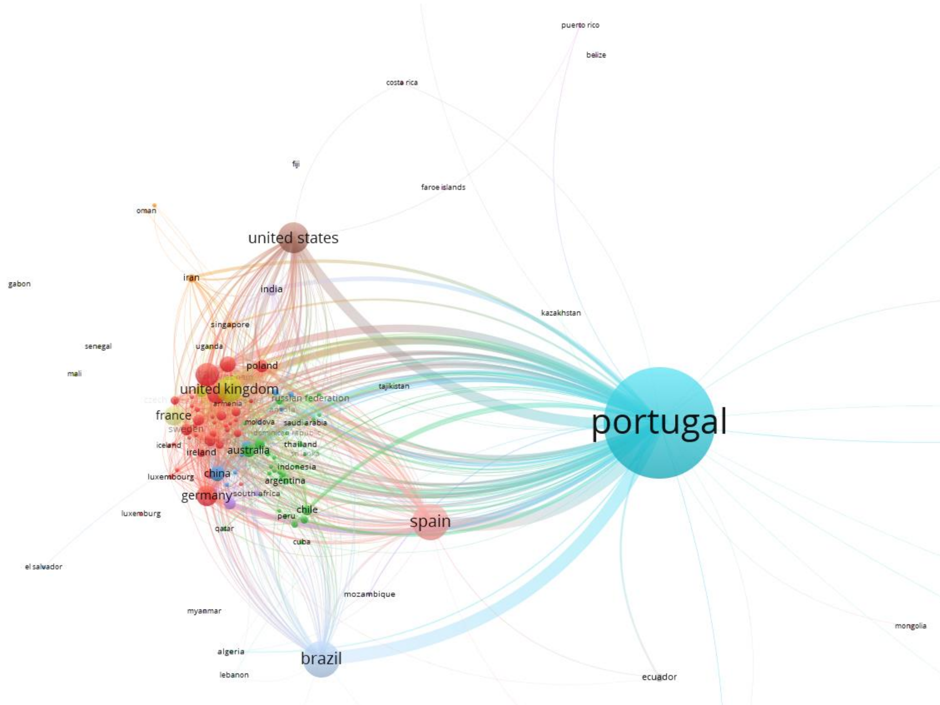


FIGURE 11
COLLABORATION MAP FOR GRENOBLE INP

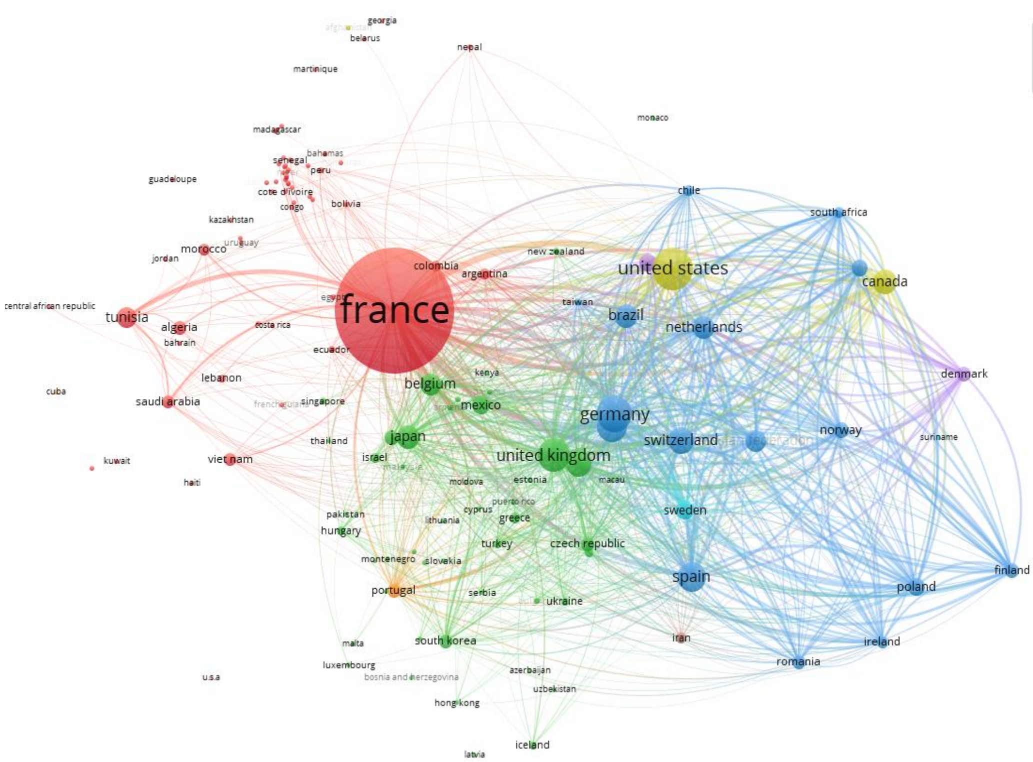


FIGURE 12
COLLABORATION MAP FOR UNIVPM

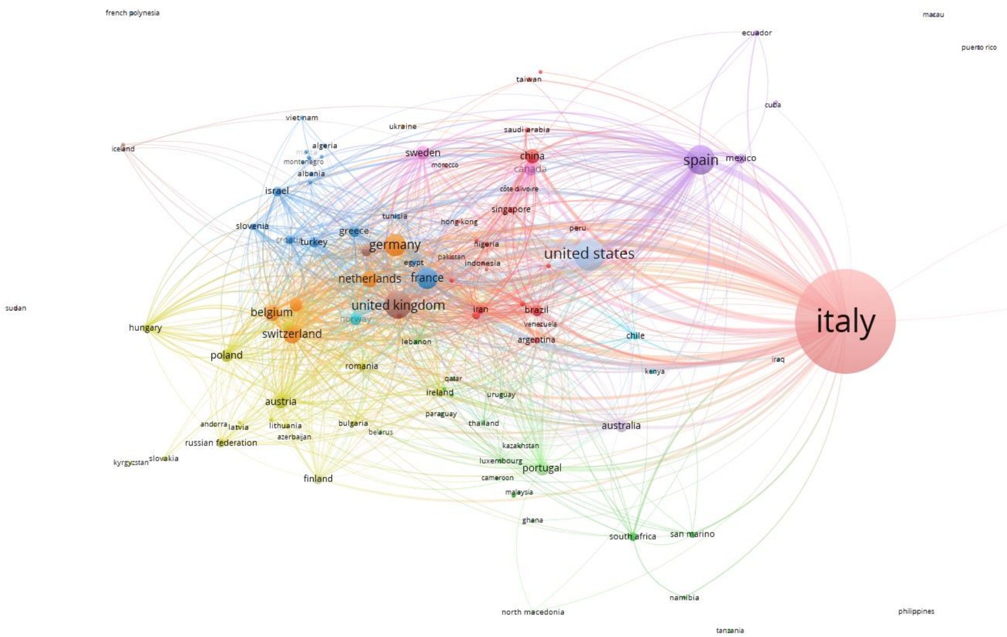


Table 3 presents the relative importance of the top 10 institutions that the HEI under study collaborate with. It can be observed that these are mainly organizations from the same country of each HEI, except for UMinho and IPB. This indicates that these HEIs have the more intense international profiles. The three Portuguese HEI collaborate significantly with the Universities of Porto, Coimbra and Lisbon, the oldest and biggest universities in the country. IPB and UTAD collaborate significantly with each other and with UMinho. This may be due to the close location and to professional links that go back to IPB´s staff academic period of academic qualification.

TABLE 3
TOP 10 PARTNER INSTITUTIONS

IPB		**UTAD**		**UMinho**		**Grenoble INP**		**UNIVPM**	
Univ. Porto	28.3%	Univ. Porto	21.9%	Univ.Coimbra	27.2%	Institut NÉEL	16.3%	Azienda Ospedaliera Universitaria Ospedali Riuniti. Ancona	18.8%
UTAD	17.7%	Univ. Lisboa	18.7%	Univ. Porto	17.6%	Grenoble Images Parole Signal Automatique	12.4%	Sapienza Università di Roma	14.6%
UMinho	12.4%	INESC TEC	11.6%	Univ. Lisboa	15.6%	Univ. Paris-Saclay	11.3%	Alma Mater Studiorum Università di Bologna	14.5%
Univ. Lisboa	8.3%	Univ.Coimbra	10.1%	Univ. Sao Paulo - USP	7.2%	Laboratoire de Physique Subatomique et de Cosmologie de Grenoble	11.0%	Univ. degli Studi di Napoli Federico II	8.7%
REQUIMTE	7.7%	UM	9.5%	Univ. degli Studi di Napoli Federico II	5.7%	IN2P3 Institut National de Physique Nucleaire et de Physique des Particules	10.1%	Univ. degli Studi di Padova	7.9%
Univ. Aveiro	7.4%	Univ. Beira Interior	7.2%	Consejo Superior de Investigaciones Científicas	5.4%	Laboratoire d'Informatique de Grenoble	9.1%	Univ. degli Studi di Milano	7.3%
Univ.Tecnologica Federal do Parana	5.6%	Univ. Aveiro	6.1%	Univ. Aveiro	5.4%	Sorbonne Universite	8.1%	Univ. degli Studi di Genova	7.2%
INESC TEC	5.2%	IPB	6.0%	Univ. Federal do Rio de Janeiro	5.3%	Institut des Géosciences de l'Environnement IGE	8.1%	Univ. degli Studi di Firenze	7.2%
Univ.Salamanca	3.8%	Univ. Nova de Lisboa	4.8%	The University of Sydney	5.3%	CEA Grenoble	7.0%	Univ. degli Studi di Torino	7.1%
Univ.Coimbra	3.7%	REQUIMTE	4.1%	The University of Manchester	5.2%	TIMC-IMAG	6.6%	Univ. degli Studi di Verona	6.8%

Productivity

The global volume of publications of each HEIs is presented in Figure 13. The absolute numbers reflect the age of each institution. In all the cases, an 'induction period' can be identified, corresponding to an initial number of years where the productivity is low and after which it takes off (less evident in the case of UNIVPM). The productivity dynamics varies significantly among organizations along the years. It can be noticed that from 2000 onwards UMinho presents a greater publication productivity growth than UNIVPM, while being younger. This is thought to have the contribution of several factors, such as a greater number of teaching/researching staff for UMinho and specificities of the dominant research areas. Nevertheless, Grenoble INP and UNIVPM produced in 2019 more than twice as many publications per staff member than the other HEIs (Figure 14).

FIGURE 13
SCHOLARLY OUTPUT FOR THE 2016-2020 PERIOD

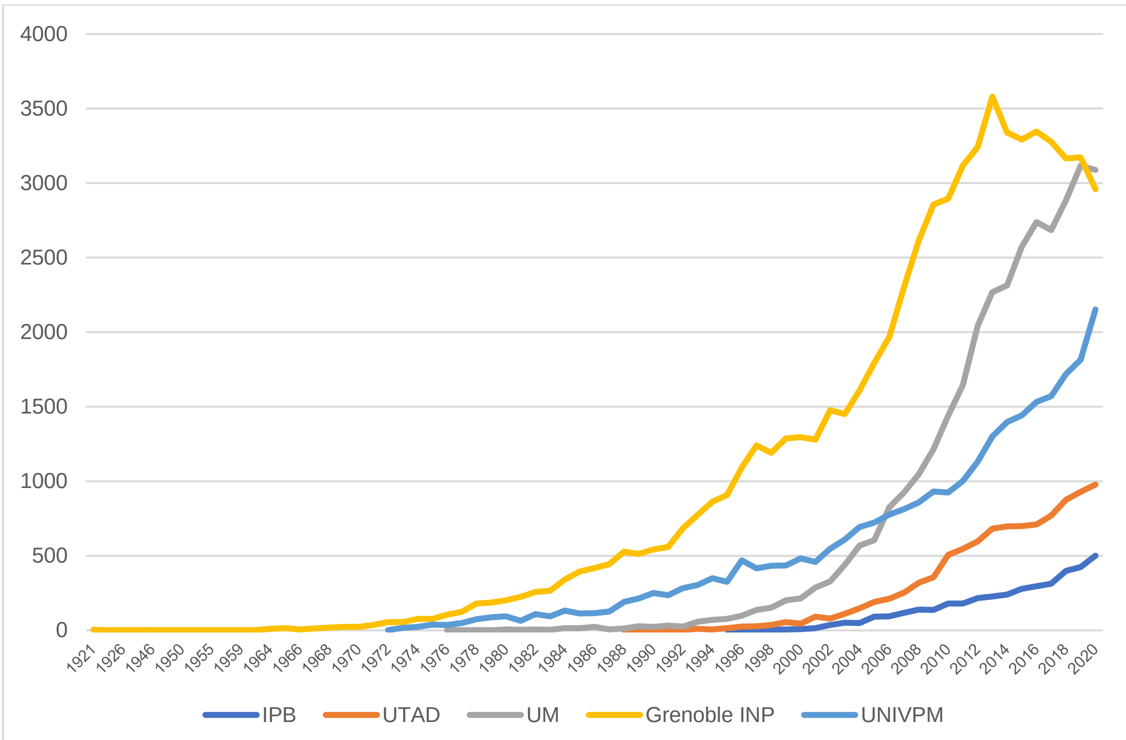


FIGURE 14
SCHOLARLY OUTPUT PER STAFF MEMBER IN 2019

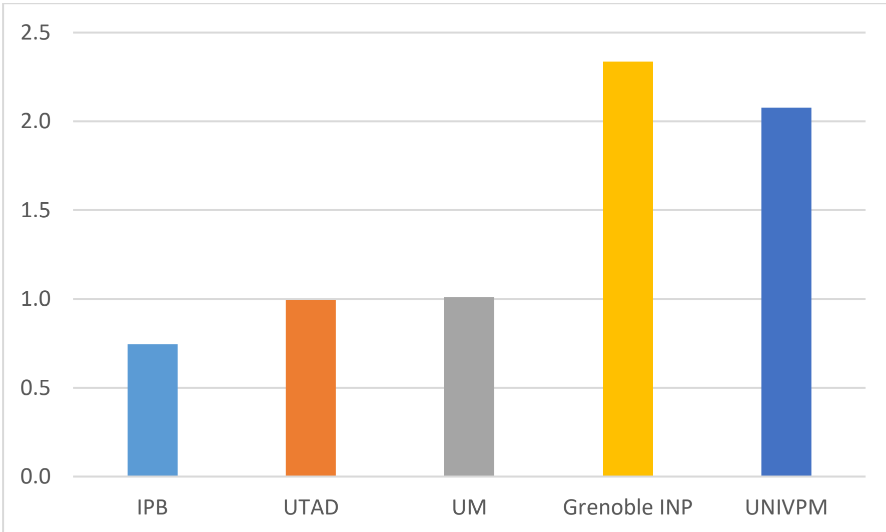
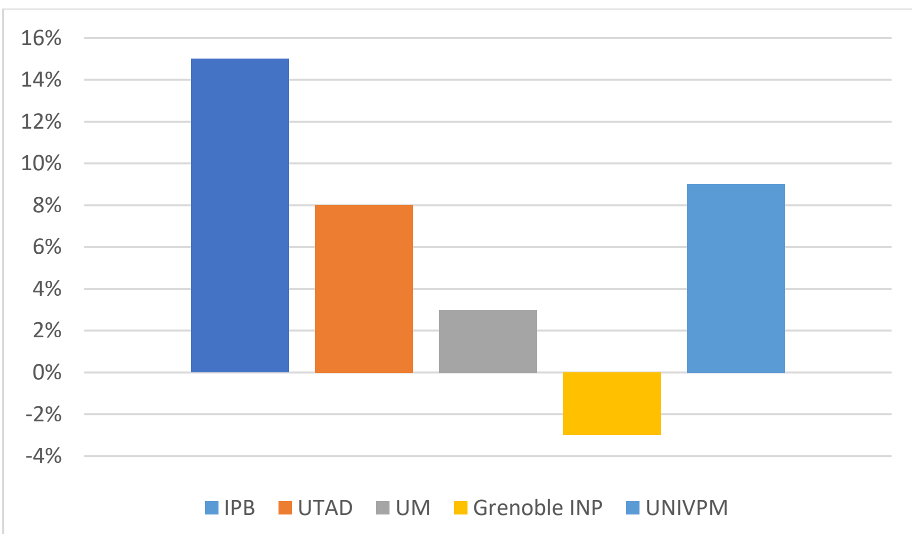


FIGURE 15
PRODUCTIVITY GROWTH FOR THE 2016-2020 PERIOD (AVERAGE %/YEAR)



Focusing on the period under scrutiny (Figure 15), it can be observed that for 2016-2020 the relative productivity growth is the greatest for IPB and presents negative values for Grenoble INP. Changes in the number and composition of research teams and in research funding volumes are thought to contribute to this trend.

When comparing the number of media titles with the corresponding citations, it is observed that 20% of the output media account for 85%, 74%, 77%, 78% and 89 % (average 80.6%) of the citations for IPB, UTAD, UMinho, UNIVPM and Grenoble INP, respectively. This is an interesting finding that follows the well-known 20/80 Pareto principle. Moreover, it indicates a tendency for publication in a relatively small number of journals. Several reasons could exist such as preference for titles connoted with higher 'quality' or greater 'accessibility'.

Impact

The scholarly output of IPB, UTAD and UMinho, Grenoble INP and UNIVPM in 2016-2020 has been cited (as of July 2021) by 16 092, 27 560, 127 478 and 171 575 documents, respectively. The average number of citations per document is presented in Figure 16, varying from 6 to 11 citations/document. The differences observed can be due, among other factors, to the different profile of the most productive areas in each institution (Wang, 2018).

FIGURE 16
AVERAGE NUMBER OF CITATIONS PER PUBLICATION

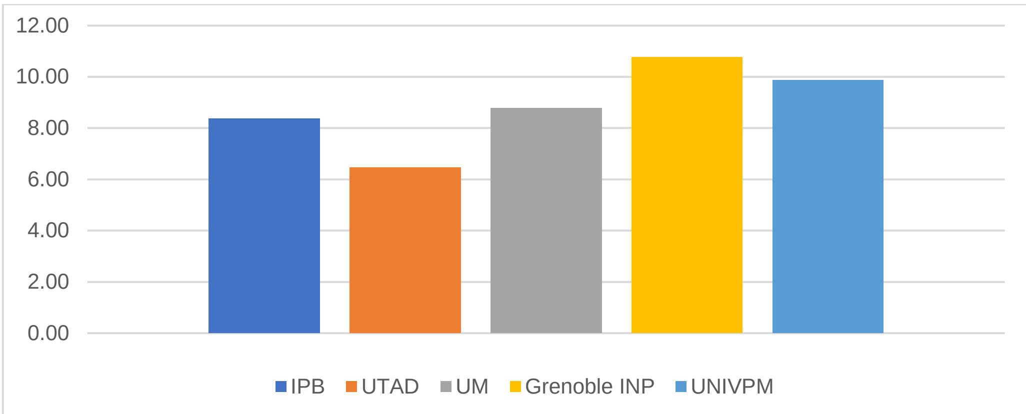
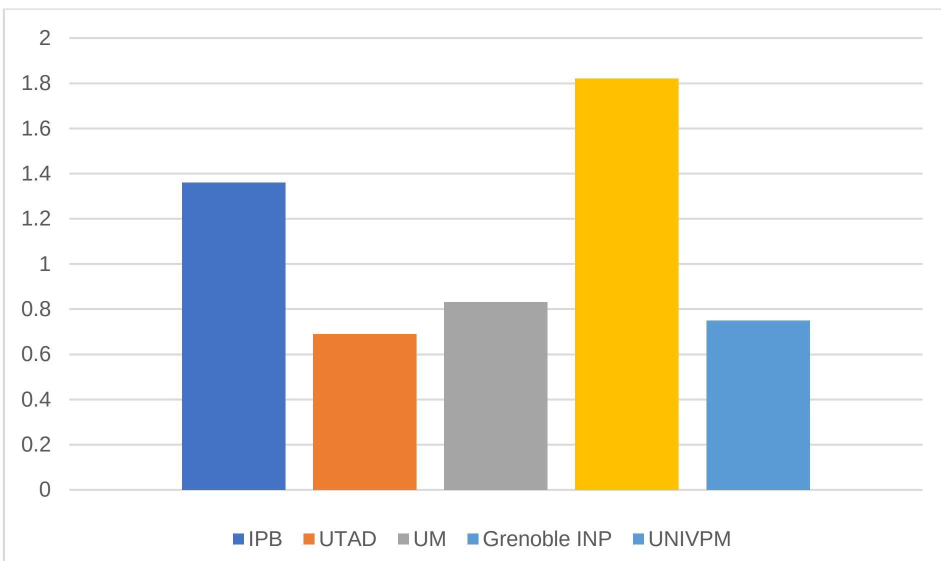


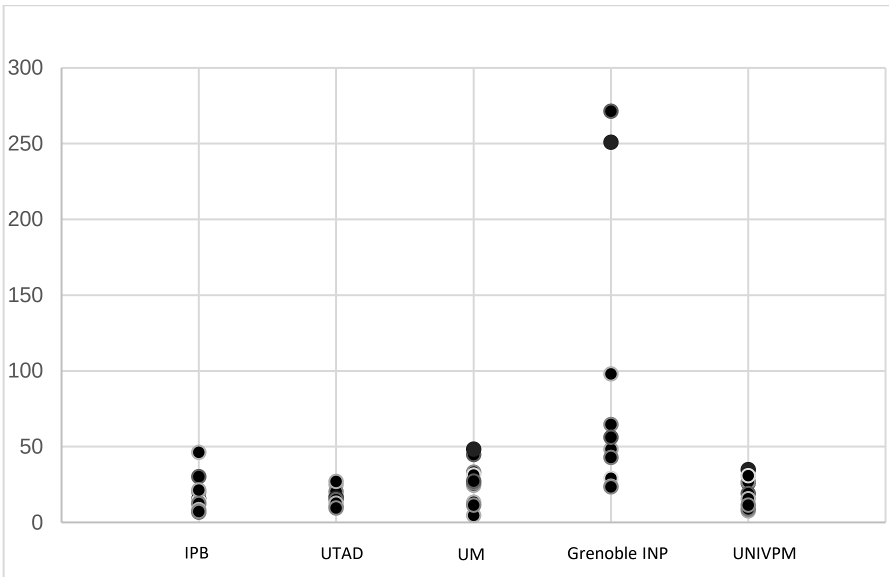
FIGURE 17
TOP 10 JOURNALS WEIGHTED-AVERAGE SJR SCORE FOR 2016-2020



The weighted-average SJR scores for the top journals are presented in Figure 17. This indicator provides a view on the impact/quality of the top 10 journals where each institution publishes the greatest number of papers. It reflects the existence of scientific areas prolific in terms of publication volume (e.g., computer science). So, it relates mainly to the impact/quality of an 'elite' group of scientific fields, not reflecting areas that traditionally have a lower publication volume/periodicity (e.g. social sciences and humanities). It can be observed that IPB and Grenoble INP have the highest performance, meaning that their elite groups have the greatest international quality/impact.

The FWCI values of the 10 most cited articles (excluding reviews) of each HEI are presented in Figure 18. Similarly to the weight-average SJR scores, it reflects the impact/quality of an elite set of papers, in this case from the citations point of view. It can be observed that Grenoble INP´s papers stand out, corresponding to articles in the areas of earth and planetary sciences, and physics and astronomy. The other HEIs show similar profiles but with varying dispersion levels: $FWCI_{IPB}$ = 18.22±11.62, $FWCI_{UTAD}$ = 16.31±5.84, $FWCI_{UMinho}$ = 26.51±13.26, $FWCI_{UNIVPM}$ = 21.18±9.45.

FIGURE 18
FIELD-WEIGHTED CITATION IMPACT



DISCUSSION

The HEIs under study are based in three geographically close European countries. In Portugal, where a HE binary system exists, one polytechnic HEI (IPB) and two ‘classical’ universities (UMinho and UTAD) are compared. UTAD evolved from an existing polytechnic institute. Grenoble INP is a polytechnic institute that has recently joined the ‘Université Grenoble Alpes’ group. UNIVPM is a ‘polytechnical university’ in the unitary Italian HE system, that changed its name from that of a ‘classical’ university to one typical of UASs. Thus, the case studies are composed of a variety of ‘atypical’ institutional profiles and contexts that allows for a rich perspective about how they excel in the pursuit of the HEI´s second mission.

A set of qualitative and quantitative indicators was used (as recommended by the Leiden Manifest for Research Metrics) to assess the characteristics and performance of the second mission of the higher education sector at the assessed institutions. In line with the DORA declaration, this study explores new indicators of significance of the research activity, namely at the multidisciplinarity and collaboration levels. The results are analyzed bearing in mind differences in publication and citation practices among scientific areas.

In what concerns the scope of research, all the studied HEIs show a varied portfolio of scientific disciplines and research topics. The predominance of hot-topics such as ‘antioxidants’ and ‘machine learning’ is interpreted to have the contribution of increased prospects of attracting funding for research on such themes, although, in general, researchers appear to be hard to influence in terms of research directions (Myers, 2020). The inter-institutional collaboration profile of these HEIs, namely at the international level, follows similar trends, although two (IPB and UMinho) show a more intense research internationalization than the other HEIs studied. The productivity indicators show that IPB has the greatest growth potential. This is thought to be related with it being a relatively younger institution.

The differences observed for the scientific impact of the research activities at these HEIs are interpreted as being a consequence of the existence of ‘elite’ scientific areas. These may be due to a combination of several factors that include publication and citation practices in specific scientific areas, the existence of highly productive scientists, and of topics favored by public policies. The creation of research critical mass is an argument commonly used to justify institutional support to these ‘elite’ groups, and funding focus on particular topics is reasoned to provide enhanced versatility to researchers, letting them take more risks and follow a more long-term research strategy. But, on the other hand, research diversity is recognized to nurture resilience in ever evolving research landscapes, backing a broader knowledge pool, creating adaptative capacity and supporting research-based education throughout all fields. Studies indicate that a healthful research ecosystem includes both small and large groups (Madsen & Aagaard, 2020).

In face of the above, it can be argued that the characteristics and performance of research activities in the ‘typical’ and ‘atypical’ HEIs studied: i) are comparable, namely in what concerns multi and interdisciplinarity, existence of ‘hot topics’ and ‘elite’ research groups, and internationalization and publication trends, and ii) do not reflect the complexity of binary and non-binary HE systems in Europe. In particular, despite its smaller size and available resources, the research activity characteristics and performance of the Bragança Polytechnic University, in the context of the strictly binary HE system prevailing in Portugal, are comparable with those of the ‘typical’ and ‘atypical’ universities analyzed. A particular difference among IPB and the other studied HEIs is that the number of researchers (contracted and doctoral students) is proportionally significantly lower, namely doctoral students. The availability of doctoral programs is a substantial predictor of research productivity for example in the tourism and hospitality areas (Lee & Law, 2011). Thus, by not being allowed to develop doctoral programs and, therefore, by hosting PhD students enrolled in ‘classical’ universities, UASs could be undesirably discriminated: 1) fees are charged by the ‘classical’ universities; 2) they expend own resources without compensation; 3) the productivity of the ‘classical’ universities increases artificially at UASs as publications include co-authors from the former; and 4) the fulfilment of the third and fourth missions of UASs is impaired due to decreased collaboration formats/options and opportunities with the society at large.

A global shift toward relevant, applied, and field-based doctoral studies has been observed in the last decade (Wildy et al., 2015). With this evolution, it was logical that, as they became more capable, UASs would be able to offer this level of training. This is the situation in countries such as Norway and Sweden, Ireland or Germany, and more recently in Portugal, where HE binary systems exist, although in other countries this possibility does not yet exist, as in the case of The Netherlands and Austria. In the USA, UK, Australia, and New Zealand, the professional doctorate is well established and has thrived (Servage, 2009). These doctorates are frequently defined in opposition to the conventional doctorates through their emphasis on interdisciplinary and applied knowledge, alignment with workplace competencies, and their options to the dissertation as the final result (Boud & Tennant, 2006; Neumann, 2005; Servage, 2009). Also, in Sweden, Denmark, and Norway, new doctorate programs are heralded as instruments for strengthening the links between researchers and practitioners. In some countries (e.g., Belgium, Denmark and the United States), PhD graduates in the business sector can amount to 30% (Patricio & Santos, 2020). According to official statistics data[2], only 8% of the Portuguese PhDs were employed in the business sector in 2020. UASs can play a decisive role in changing this situation. Thus, it can be argued that the full research potential of ‘non-university’ HEIs is far from being attained in countries where they are not allowed to deliver doctorates.

CONCLUSIONS

The combined use of a set of qualitative and quantitative indicators is shown to provide a fuller perspective of the research performance at HEIs than using solely bibliometric data. Term mapping the titles and abstracts of scholarly output allowed for a comparison of research areas that goes beyond the most productive groups, typically reflected in most bibliometric indicators used. All the institutions publish in a diverse array of scientific areas, although some are more prolific than others. A common trait of all the five institutions is the wide diversity of themes and the closeness of some clusters of topics, which denotes relevant inter- and multi-disciplinarity. The studied institutions present a wide international collaborative network but, except for UMinho and IPB, cooperate mainly with organizations from their own countries. The publication volume reflects the age of each institution, except for UMinho, which shows a greater productivity growth, probably due to the existence of specialty areas and greater investment in research resources, e.g. scientific personnel. In line with the Pareto Principle, 20% of the output media accounts for ca. 80 % of the citation volume. The most productive groups of IPB and Grenoble INP have the greatest international quality/impact.

The international comparison confirmed that convergence of 'polytechnic' institutions towards the research profile of universities is a general trend (Götze et al., 2021; Schüll, 2019), though in some cases without the benefit of being able to deliver doctorates. A practice drift towards more research-driven organizations is clear from the gathered data, as observed by Schüll (2019) for Austrian UASs, and towards practice-oriented R&D, as observed by Götze et al. (2021) for both universities and UASs in Finland and Portugal. This is thought to be due to 1) the Bologna process, that led to a harmonization of study structures and degrees, and, thus, diminished the distinctive characteristics of non-unitary national HE systems; 2) the importance of academics' societal engagement in HEIs´ mission (Götze et al., 2021); 3) international university rankings, that promote situations of comparison and competition, which ultimately leads to the convergence of institutional strategies towards better classifications; and 4) joint degree programs with foreign universities, programs for staff and student mobility, the recognition of foreign degrees and the active participation in international research consortia.

Thus, the main challenge for policymakers is concluded to be how to actively address the convergence of research at the 'non-university' sector towards a university profile, because in fact it is already happening, not only in Portugal but also e.g. in Austria and other European countries (Schüll, 2019). A common criterion used to distinguish existing sub-systems in the HE sector is the ability and legitimacy to award doctorates. However, successful doctorate programs exist, e.g., in Australia and the USA, that are adapted to the practice-based nature of UASs. Thus, the fact that in some countries UASs are not allowed to grant this degree level is argued to be ultimately an unjustified policy that inhibits the full impact that these HEIs may have in society at large. In UASs a model of doctoral students' supervision can be developed that involves mandatory co-supervisors from key stakeholders (e.g. sponsors). To a certain extent this is already being done at 'classical' universities (e.g., in industry sponsored doctorate programs). In this way, 'classical' universities are converging towards practice-based, applied sciences institutions through their doctorate programs.

In face of the above, it looks like UASs and universities are more often in analogous than in balancing positions within the HEI system (Strotebeck, 2014). The dynamic changes experienced in both sectors call for a re-evaluation of their individual profiles and of the current divide (Schüll, 2019). Bearing in mind that the European Higher Education Area (EHEA, launched in 2010) is meant to ensure more comparable, compatible and coherent higher education systems in Europe, it seems logical that the designation of 'non-university' HEI should be normalized (e.g., to UASs) and that all HEIs should have the same operating conditions (e.g., delivery of doctorate programs) for a healthy cooperative and competitive EHEA to be fully implemented.

The following limitations can be identified for this study. Being based on a set of case studies, if different cases had been selected, the results could have been somewhat different. However, it is believed that the general observations would still be valid. Also, if the set of metrics used had been different, the actual relative classification of the studied HEIs in each of them could have been different. Thus, care was taken not to rank these HEIs according to the quantitative indicators used, except where obvious patterns could be identified.

Future research avenues on the topic addressed in this paper could include an analogous comparative study of HEIs in regions outside Europe, followed by a comparison of the two sets of HEIs. Also, a longitudinal study could be done to provide a perspective of how the research questions validity and relevance may change over time. Moreover, network analysis such as centrality measures and other network parameters will be used to further elucidate for example the research characteristics and collaboration patterns of the studied HEIs.

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