



# An evolving international research collaboration network: spatial and thematic developments in co-authored higher education research, 1998–2018

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## Abstract

Co-authored research articles in the disciplinarily heterogeneous field of higher education have dramatically increased in this century. As in other fields, rising international co-authorships reflect evolving international collaboration networks. We examine higher education research over two decades, applying automated bibliometric topic identification and social network analysis of 9067 papers in 13 core higher education journals (1998–2018). Remarkable expansion in the volume of papers and co-authorships has, surprisingly, not resulted in a more diverse network. Rather, existing co-authorship patterns are strengthened, with the dominance of scholars from a few Anglophone countries largely maintained. Researchers globally seek to co-author with leading scholars in these countries, especially the US, UK, and Australia—at least when publishing in the leading general higher education journals based there. Further, the two-mode social network analysis of countries and topics suggests that while Anglophone countries have led the development of higher education research, China and Germany, as leading research-producing countries, are increasingly influential within this world-spanning network. Topically, the vast majority of co-authored papers in higher education research focuses on individual-level phenomena, with organizational and system or country-level analysis constituting (much) smaller proportions, despite policymakers' emphasis on cross-national comparisons and the growing importance of university actorhood. We discuss implications thereof for the future of the multidisciplinary field of higher education.

**Keywords** Higher education research · Social network analysis · Bibliometrics · International collaboration networks · Content analysis

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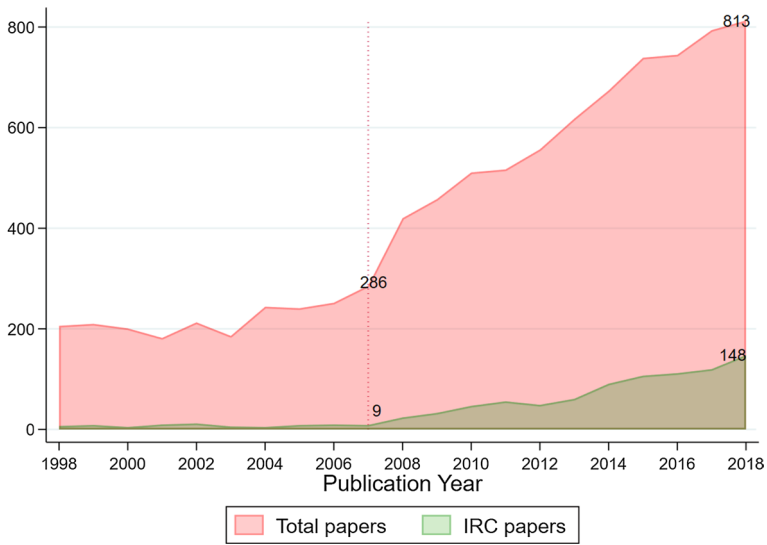
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## Introduction: developing higher education research through co-authorships

Contemporary science is marked by expanding and diverse forms of collaboration. Scientific publication generally has departed the age of scientific nationalism and entered an era of “global mega-science” (Baker and Powell, forthcoming): International teamwork has facilitated the unprecedented pure exponential growth in scientific knowledge. Currently, over a quarter of the world’s more than two million annually published scientific articles across all fields results from scientists affiliated with research organizations in at least two different countries, or what is referred to here as “international research collaboration” (IRC) (see Glänzel & Schubert, 2001; Adams et al., 2014). Growth in co-authored scientific publications worldwide across the sciences has been exponential, yet more slowly in the social sciences (Mosbah-Natanson & Gingras, 2013; Powell et al., 2017). If co-authorships across national and cultural boundaries are also increasingly prominent in higher education (HE), this multidisciplinary field, increasingly theoretically and methodologically sophisticated, has only become collaborative over the past two decades—with important, persistent regional and country differences (e.g., Akbaritabar & Barbato, 2021; Avdeev, 2021; Kwiek, 2020a; Marginson, 2021). Global networks increasingly connect higher education’s many organizational forms and researchers, especially those working internationally and comparatively (Kosmützky & Krücken, 2014). As the field professionalizes and utilizes advanced methodologies, collaborations that bridge disciplinary, cultural, linguistic, methodological as well as institutional and organizational boundaries extend the possibilities of discovery (see Hicks & Katz, 1996; Leahey, 2016; Choi et al., 2020). Yet to what extent does higher education research exemplify these broader scientific trends?

Delving more deeply into this context, recent bibliometric studies address the maturation of the increasingly global higher education field. Kwiek’s (2020b) analysis of an estimated twenty-one thousand articles (with 350,000 citations) since 1996 finds a quickly globalizing field—well beyond what was once a highly US-centric endeavor; the field’s leading contributions appear in English. Analyzing 34 co-authorship networks based on articles in 28 journals, Vlegels and Huisman (2020) find high fragmentation and increasing inequality resulting from the field’s hierarchical structure with a clear center and innumerable peripheral co-authorship teams. Akbaritabar and Barbato’s (2021) network analysis, based on Scopus data, confirms the divide between Europe’s internationalized higher education journals and the less open North American journals. Avdeev (2021), analyzing geographic and linguistic proximity also using Scopus data, shows major English-speaking countries, Western Europe, and China as key areas for higher education research.

Building upon, confirming, and specifying these findings, here we show how IRCs have significantly increased in the HE research field, as demonstrated by (co-)authorship information from our database of 9067 papers published in a set of key journals, based on Web of Science data (see Fig. 1; analyzed below). Barely existing in 1998, IRCs grew to represent over 15% of all articles twenty years later. Using a large, automated content analysis of HE research, Daenekindt and Huisman (2020) report that instead of topical concentration accompanying the maturation of the field, somewhat isolated clusters of topical research interests have grown since 1991. Thus, while co-authorships, especially international ones, suggest a spatial opening up and further evolution of this globalizing field, the presence of topical “islands” reflects the fragmentation of the thematic landscape, which inhibits the field’s coherence and strength.



**Fig. 1** Growth in international research collaboration (co-authored papers) within a set of key higher education journals, 1998–2018. *Source:* Project database ( $N=9067$  articles), data from Clarivate Analytics’ Web of Science

To further explore the dynamics between spatial and thematic patterns and their implications for the evolving field of HE, we build upon such recent studies in our investigation, based on Web of Science data, and then apply a two-mode network analysis. We formulate the following research questions: Firstly, how did the international research collaboration network (country) affiliations evolve over two decades (1998–2018)? Secondly, what topical preferences do these growing international research collaborations exhibit? We explore the implications of these co-authorship patterns for the increasingly globalized higher education research community.

After a brief review of general globalization trends and the increasingly-collaborative nature of research on HE, we conduct a network analysis of a large sample of publications across two ten-year periods (1998–2008/2009–2018). These analyzed patterns of IRC confirm the strong influence of particular countries in higher education research. Next, we employ automated bibliometric topic identification among publications to demonstrate thematic convergence. Then, we integrate these analyses through a two-mode social network analysis of IRCs and research topics.

### Higher education research becoming more global and more collaborative

Educational research, and social and natural sciences more generally, have become much more collaborative over time (see Aman & Botte, 2017; Güneş et al., 2017; Powell, 2020). The dominance of a few authoritative voices in HE studies has also decreased. However, the tremendous rise, across fields, of internationally co-authored scientific contributions (Wagner, 2018) has not yet been matched in (higher) education studies, which continue to focus overwhelmingly on national cases and contexts; indeed, often at the micro-level,

as we will show. While IRCs are time-consuming, requiring coordination and exchange among teams (Beaver, 2001), the motivations to collaborate are diverse and clear (Dusdal & Powell, 2021), especially for researchers seeking to better understand their country through comparison (Kosmützky & Krücken, 2014). Co-authorships increase the diffusion of ideas—ideally understanding as well—not only enhancing the potential for discovery but also producing the most influential science (see e.g., Katz & Hicks, 1997; Glänzel & Schubert, 2004). This is especially true for mobile researchers, as circulation networks reveal the importance of the US, the UK, France, Canada, and Germany as prominent nodes in global science (Sugimoto et al., 2017).

Along with the expansion of education systems, higher education research has grown, with its evolution relying increasingly on regional and worldwide theoretical paradigms; on investments and funding schemes, such as the European Union's Framework Programs (Marques, 2018); and on methodological advances. Distinct spatial and social patterns across countries and colonial legacies may endure, as Europe and North America continue to lead in producing natural and social science research, with a more recent shift to East Asia (Marginson, 2021; Mosbah-Natanson & Gingras, 2013). Indeed, East Asian higher education systems' rapid, yet diverse, development demands conceptual frameworks adequate to understand varying values and system characteristics (Horta & Jung, 2014; Horta et al., 2015). Yet, does this evolving IRC network in higher education research lead to more density and integration as well as topical convergence?

To set the context for the analysis here, Fig. 1 shows the research articles published in the selected 13 prominent journals in the field (methodological details described below) indicating that, in the two decades since 1998, higher education research has grown exponentially (confirming Vlegels & Huisman, 2020). And similar to scientific research generally, accompanying this expansion is a steady increase in higher education researchers working together across country boundaries (Akbaritabar & Barbato, 2021; Avdeev, 2021). In 2018, nearly one-fifth of all papers in these journals resulted from international collaboration. What is less known about patterns in higher education research are the main features of this growing international co-authorship trend, the development over time of a sustained field-specific network, and the associations of this global network with the substantive, topical development of this diverse, multidisciplinary field. If collaborations and the resulting co-authorships have importantly facilitated this overall process of globalization, we examine this through detailed analysis of the historical development of the international collaborative knowledge network of higher education research using this large sample of articles published in leading journals.

## International collaboration in the social sciences

The exponential rise in international co-authorships has been studied within single countries and world regions (e.g., Heilbron & Gingras, 2018; Kwiek, 2020a; Melin & Persson, 1996), in and across disciplines (e.g., Akbaritabar et al., 2020; Beaudry & Allaoui, 2012; Hou et al., 2008), and research fields longitudinally and worldwide (Marginson, 2021; Powell et al., 2017), also in the social sciences (Leydesdorff et al., 2014). Such studies confirm the pure exponential rise in co-authorships across all world regions, although with important spatial and temporal variations (see Powell et al., 2017; Baker and Powell, forthcoming). In their analysis of the global production of social sciences by world regions between 1980 and 2009 through analysis of journals in the Social Science Citation Index (SSCI), Mosbah-Natanson and Gingras (2013) show that every major world region

displays exponential growth in the production of internationally co-authored research. All world regions almost doubled the number of co-authored publications, especially Europe and Asia, with the exception of North America. Nonetheless, North America and Europe account for almost 90% of the worldwide research production in the three decades studied, showing disparities in social sciences research production by region. The proportion of worldwide IRC articles grew from 14 to 23% (2000–2018), with most major producers highly collaborative: the UK (62%), Australia (60%), France (59%), Canada (56%), Germany (53%), Spain (53%), and Italy (50%) all exhibit (very) high international collaboration rates (see NSB, 2020: Fig. 23).

This expansion in social science publication rates was followed by dramatic increases in international co-authorships, confirmed by studies analyzing single countries (Wang et al., 2013), disciplines (Aman & Botte, 2017), world regions (Adams et al., 2014) and research fields (Leydesdorff & Wagner, 2008; Ribeiro et al., 2017; Wagner & Leydesdorff, 2005). Mosbah-Natanson and Gingras (2013) show that at the end of the 2000s, 1/6 to 1/3 of articles in social sciences were produced by researchers from at least two different regions. Interestingly, North America and Europe, which have numerous higher education and science systems with autonomous capacity, exhibit the smallest proportion of interregional collaboration. Africa and Latin America show the highest percentage of such collaborative work, as these world regions are more dependent on others for collaboration opportunities, especially when aspiring to publish in leading, largely Anglophone, journals.

In fact, with several European funding instruments incentivizing intra-regional collaboration in science, the intra-European collaborations have increased substantially, both in number and in the size of organizations participating (Heilbron & Gingras, 2018; Marques, 2018). Moreover, while scholars in North America tend to collaborate strongly with European researchers, European researchers tend to collaborate more evenly with other regions of the world, including Oceania and Africa (Glänzel et al., 1999). Taking into consideration these international patterns in the social sciences generally, we ask whether international collaboration in higher education studies have evolved similarly.

## Higher education as a multidisciplinary research field

The development of higher education research itself is continuously of interest to field members (Bedenlier et al., 2018; Daenekindt & Huisman, 2020; Peng et al., 2013; Tight, 2007; Vlegels & Huisman, 2020). Yet scholars in a variety of fields study the development of HE as the system in which they work. Key methodologies applied to explore global patterns of development include expert judgment and scientometrics. The first approach relies on field knowledge to identify those key research topics and the connections among theoretical branches and empirical foci. Tight (2004) analyzed 17 journals and 284 books published in 2000 and concluded that higher education had not developed an independent theory because most higher education research just applies theories from other academic fields. Later, Tight (2007) identified eight core research topics in higher education: (1) teaching and learning; (2) course design; (3) student experience; (4) quality; (5) policy; (6) institutional management; (7) academic work; and (8) knowledge and research. Recently, Tight (2018) discussed the top 28 HE journals, arguing for more synthesis, as the field generates ever more articles that are weakly linked to existing studies. Pioneering studies reconstruct multiple frameworks to study HE, yet limitations in the range of methodologies and methods applied abound (Tight, 2007, 2008, 2012, 2018).

As recently argued by Daenekindt and Huisman (2020), reliance on expertise in HE studies suffers from three pitfalls, including narrow scope, limited content-related analysis, and lack of an inductive approach. To tackle these, the authors use topic modeling to map research topics in HE through analysis of 17,000 articles published in 28 HE journals. They classified articles into 31 topical categories on three levels: individual, organization, and macro. Relatedly, using co-word analysis—content analysis matching word co-occurrence in a corpus of texts—in 15 selected HE journals, Liu et al. (2019) also documented 361 themes divided into 20 clusters.

The application of content analyses and bibliometrics to study higher education extends the scope and enhances our understanding of the dynamic collaborations driving the field and the contents of HE research. However, the global HE community still has limited knowledge regarding how its international knowledge network has evolved, particularly across regions. The study of the driving forces behind this evolution may be divided into two streams.

The first stream of inquiry is the divergence or convergence of HE research interest shown by scholars working in different countries. Based on publications that appeared in the 2000s, Tight (2007) points out that North American scholars focus more on student experiences, whereas scholars from other regions prefer comparative study at more meso and macro levels. Daenekindt and Huisman (2020) trace publications (1991–2018) to uncover trends of specialization, finding increasing diversity of HE research, while leaving the field “scattered”.

Examining methods applied and topic selection, Tight (2007) found that North American scholars are more apt to use quantitative methods and have diverse topic selection because North America first experienced HE expansion, achieving massification earlier. The scale and differentiation of HE there provides vast material for North American scholars to study. The other countries, as followers, tend to learn from North American’ experience through (different forms of) comparative study. Countries with contrasting HE systems may well present different patterns in methods used and research topics.

The second thread of inquiry focuses on cross-national collaboration patterns. Collaboration across institutional, disciplinary, organizational, and cultural boundaries expands the possibilities of discovery, despite incontrovertible costs of collaboration (see Hicks & Katz, 1996; Leahey, 2016). Both international comparative and collaborative research projects are more complex than the non-comparative because the principles of ideal research designs are more difficult to achieve (Kosmützky, 2018). Data from different national contexts must be gathered and compared, taking contrasting national contexts into account, diverse languages spoken, and oftentimes research team members with dissimilar cultural and disciplinary backgrounds (Dusdal & Powell, 2021). Studying the evolution of the neuroscience community from 1991 to 1998, Barabasi et al. (2002) found that scientific communities evolve through the participation of new members and are driven by the formation of new collaborations. However, currently, empirical studies to document such worldwide changes in terms of changing collaboration patterns specifically in HE research in cross-national networks are rare (but see Kuzhabekova et al., 2015; Chen et al., 2019; Vlegels & Huisman, 2020); thus, we address this gap and extend the analysis to 2018 here.

Social network analysis (hereafter SNA) has proved useful in addressing such issues, as a very powerful tool to depict structural changes and shifting relationships in complex HE networks (Dusdal et al., 2021; Kezar, 2014). Horta and Jung (2014) investigated the social network of HE researchers in Asia and found that researchers in that region have interests shifting from policy toward teaching and learning. Vlegels and Huisman (2020) found that the growth of publications and authors in the global field leads to increased clustering,

creating a dense core of well-connected author clusters—and the Matthew effect in opportunities to co-author for the field’s most prolific researchers wherever they are based.

International collaboration is an important driver of science dynamics around the world (Leite & Pinho, 2016; Wagner, 2018). Following network analysis, cross-national collaboration patterns in HE research represent the structure of information exchange within the network and reflect the influence of the involved scholars, organizations, and countries (Borgatti & Everett, 2000). The longitudinal investigation of the network structure facilitates our understanding of how strong the connections among scholars in various countries have become. Further, such analyses locate countries—at the core, semi-core or periphery. Core actors always serve as opinion leaders and are likely to influence the contents of HE research, especially in leading journals. Next, we discuss our data and methods applied.

## Data and methods

This paper joins bibliographic and network analysis to investigate the rise of HE as a global multidisciplinary field and to conduct a longitudinal analysis of co-authorship patterns.

### Data collection and cleaning

To build our database, we searched and downloaded publication records from Clarivate Analytics’ Web of Science (WoS), alongside Scopus one of the two key citation databases. Since “higher education” is not an independent field in the WoS classification, we considered the 243 journals in the “Education & Educational Research” category of 2018 Journal Citation Reports for initial selection. Instead of selecting the journals based solely on author’s judgement (Liu et al., 2019), we use the Content Analysis Toolkit for Academic Research (CATAR)<sup>1</sup> to apply agglomerative hierarchical clustering and multi-dimensional scaling based on bibliographical coupling similarity for cross-validation. Because the relatedness between scientific publications is multidimensional, no single measurement captures it perfectly; however, automated ways to analyze the semantic contents of articles are crucial as an effective response to the above-shown exponentially-increasing volume of scientific research articles (see Kozłowski et al., 2021). This method allowed us to double-check the topical relatedness of the overall 243 educational journals by analyzing the degree of overlap among the large volume of papers’ references in all these educational journals (Small & Koenig, 1977; Tseng & Tsay, 2013; Yan & Ding, 2012). Our results revealed that 17 journals initially clustered together within three groups. Among them, 3 journals (*Croatian Journal of Education*, *Eğitim ve Bilim*, and *Journal of Social Work Education*) were least related to other journals. And 1 journal (*Studies in Educational Evaluation*) does not predominantly focus on HE topics. Therefore, we eventually chose 13 journals for closer analysis (see Appendix 1).

Once the selected journals were identified, we made queries using the WoS website interface. We limited coverage of publication years from 1998 to 2018 and the document type as “Article”. The resulting database includes a total of 9067 papers in the 13 selected journals. All the papers in these 13 journals were collected via a customized crawler program on May 15, 2019. The highest number of articles (1573) were found in the leading

<sup>1</sup> See <https://github.com/SamTseng/CATAR>.

**Table 1** Journals and articles analyzed, descriptive statistics, 1998–2018. *Source:* Project database ( $N=9067$  articles), data from Clarivate Analytics' Web of Science (see below)

Journal	Papers	Percent
Assessment & Evaluation in Higher Education	761	8.39
Higher Education	1573	17.35
Higher Education Policy	252	2.78
Higher Education Research & Development	768	8.47
Journal of College Student Development	1104	12.18
Journal of Diversity in Higher Education	232	2.56
Journal of Higher Education	594	6.55
Journal of Higher Education Policy & Management	184	2.03
Journal of Studies in International Education	286	3.15
Research in Higher Education	756	8.34
Review of Higher Education	412	4.54
Studies in Higher Education	1325	14.61
Teaching in Higher Education	820	9.04
Total Articles	9067	100

journal *Higher Education*, the lowest number was 184 articles in the *Journal of Higher Education Policy & Management*. Summary statistics of the sampled journals are presented in Table 1.

Next, we collected the publication information for each of these 9067 papers published over two decades (1998–2018). We limited the period of investigation because before 1998 the author's affiliated country information demonstrated considerable missing data, which would bias the estimation, since our main research interest is to explore country-level networks. Among these 9067 papers, 83 papers did not have affiliation country information. We therefore excluded them when conducting the network analysis.

Since 2009, there has been dramatic growth in HE publications. Thus, in order to understand the evolution and collaborative dynamics of the international knowledge network in HE, we evenly divided this twenty-year time frame into two periods: 1998–2008 and 2009–2018. CATAR can extract the “organization host country” from the unstructured “Affiliation” text as well as the affiliated authors from the C1 field of the WoS records using a regular expression technique to resolve the name ambiguity to some extent (see Appendix 2 for an example). Eventually, our database included author names and affiliations, organization host country, paper title, paper abstract, publication year, and cited references (see Appendix 3). The analyzed data consist of structural and non-structural information: The former includes publication year and host organization(s), enabling us to calculate publications by year and country; the latter includes the abstract text and keywords that were used in our topic identification analysis.

## Data limitation

Of the two key citation databases, Scopus covers more journals and proceedings than does WoS. However, Scopus allows far fewer data records (up to 2000 full records) to be manually downloaded per query session. Also, in the downloaded records from Scopus, there can be considerable variation in the way in which cited references are formatted, e.g., the cited references are not well normalized (Van Eck & Waltman, 2020; see also Akbaritabar & Barbato, 2021). It would be less reliable to use the cited references for bibliographic



coupling computation based on Scopus data, which is crucial for grouping journals and papers for the purposes of this study, as we do not have access to disambiguated Scopus data. Therefore, we chose the WoS database, while aware of its somewhat narrower coverage of HE journals.

## Methods

*Topic identification* The open-source toolkit CATAR, recognized for its reliability in scientometrics (Tseng & Tsay, 2013) and previously utilized for the case of educational research generally (Chang et al., 2010; Tseng et al., 2013), is used to analyze HE publications in Clarivate Analytics' Web of Science (WoS) database. The task of topic identification was completed in two steps. First, CATAR implemented paper clustering based on bibliographic similarity, differentiating the papers with similar citation patterns into small groups. Then, these small groups were recursively merged into larger groups to produce a topic tree of global HE research.

Second, CATAR applied text mining techniques to extract the key terms from each paper title and abstract. CATAR then calculated the correlation coefficient between the key terms and the cluster by referring to the formula:

$$\text{Co}(T, C) = \frac{(\text{TP} \times \text{TN} - \text{FN} \times \text{FP})}{\sqrt{(\text{TP} + \text{FN})(\text{FP} + \text{TN})(\text{TP} + \text{FP})(\text{FN} + \text{TN})}}$$

where TP (True Positive), FP (False Positive), FN (False Negative), and TN (True Negative) denote the number of papers that (do not) belong to cluster C while containing or not containing term *T*, respectively. When *T* only appears in the C cluster and FP and FN is equal to zero, the correlation coefficient between C and *T* is equal to 1; on the contrary, when TP and TN equal to zero, the correlation coefficient is equal to -1. We choose key terms with the highest correlation coefficients among each cluster as the cluster descriptors and refer to those descriptors for the cluster naming.

*Network Analysis* To examine the global HE research community and the evolution of its relationships, we analyze the internationally co-authored publications in the HE journals that were identified. The author country affiliations were analyzed in terms of key network measures, namely network diameter, average degree, average path length, density, modularity, and clustering coefficient (Newman, 2010; Scott, 2017). The calculation of measures was conducted using the social network analysis software Gephi (Cherven, 2015). This set of measures enables us to better understand the patterns of international co-authorship in the field of HE research and changes in that globalizing network over two decades. Network diameter indicates the longest of all shortest paths between the two most 'distant' countries in the network. Average degree shows the average number of relationships between individual countries. Average path length refers to the average number of steps from one country to reach another country with which its scholars currently have no active collaborations (Scott, 2017). Density shows the proportion of all possible ties between countries. Modularity measures partition the network into sub-communities (Newman, 2006), while clustering coefficients measure the probability of nodes to cluster together, or simply the idea that "a friend of a friend is also my friend" (Watts & Strogatz, 1998).

Finally, we calculate the important *node-measure* of degree centrality—the number of relationships of countries—to understand which countries have become central in this global research network. An increase in the diameter indicates that, over time, new

contributors have joined the network, indicating expansion of IRC in HE. Similarly, an increase of average degree shows how countries expand their collaboration relationships. In contrast, when the average path length increases, this suggests dispersion of relationships in the network. If density increases, this implies that countries become aware of other countries in the network, showing signs of consolidation of relationships across space. If the network increases its modularity value, it shows a strong internal division between groups and weak relationships between countries in different groups. Increases in the clustering coefficient show a tendency of countries' authors to collaborate. Core-periphery network structure is a ubiquitous form evidenced in numerous studies (Borgatti & Everett, 2000; Cattani & Ferriani, 2008; Csermely et al., 2013). Vlegels and Huisman (2020) also show such a core-periphery structure in the HE co-authorship network. Thus, we expect to find a similar pattern in the international research collaboration network based on our data. However, we additionally seek to understand associations between collaboration patterns and topics as well as level of analysis.

Thus, the second aim of this analysis is to employ a two-mode network to analyze the relationship of countries while simultaneously considering the topics that co-authors from these countries have contributed (Newman, 2001). Two-mode network analyses use two sets of units (in this case, authors' country affiliations *and* the topic of co-authored research) to see the relative country contributions to each HE topic. Two further measures—in-degree and weighted in-degree (incoming connections to a node, multiplied by their weights) (Barrat et al., 2004; Newman, 2001)—show the extent to which countries have contributed, in their various collaborations, to the range of topics identified (Latapy et al., 2008). To visually show the country contributions to each HE topic, we create a heatmap by using ggplot 2, specifically, `geom_tile`. We focus on the articles' different levels of analysis—individual, organizational or system.

## Results

### Increasing but narrow international collaboration patterns

Above, we emphasized the exponential rise in the production of HE research and in international research collaborations. If in the period 1998–2008 the total number of contributing countries was 36, in the following period, 2009–2018, that number more than doubled, to 85 countries. While in 1998 only 3% of HE publications were international co-authorships, a negligible amount, by 2018 the proportion had risen strongly to 18%. Now, nearly a fifth of HE studies are written by international co-author teams, aligning with overall publications patterns (NSB 2020). Increasing research output overall is related to the growing number of countries contributing. Examining collaboration patterns, social network analysis provides an important method to uncover the evolving geography of global knowledge production in HE research. Table 2 exhibits common network measures of network diameter, average degree, average path length, density, modularity, and clustering coefficient defined above.

Such results can be confirmed with the measures of the average degree and average path length. The average path length—how close countries are to each other in terms of collaboration—confirms a stabilizing collaboration between countries, but more importantly, shows that collaboration between countries has gotten somewhat tighter

**Table 2** Network measures of international collaboration in higher education, 1998–2018. *Source:* Project database ( $N=9067$  articles), data from Clarivate Analytics’ Web of Science (see below)

	1998–2008	2009–2018	1998–2018
Network Diameter ( $\mathcal{A}$ )	6	4	4
Average Degree ( $k$ )	3.421	7.91	8.022
Average Path Length ( $l_G$ )	2.415	2.235	2.234
Density ( $D$ )	0.092	0.09	0.09
Modularity ( $Q$ )	0.295	0.192	0.175
Clustering Coefficient ( $C$ )	0.577	0.72	0.724

(1998–2008  $IG=2.415$ ; 2009–2018  $IG=2.235$ ). This aspect is also confirmed by the average degree: the average number of country collaborations. Of all the network measures, the average degree is the measure that best displays the sturdy growth in collaboration between researchers in different countries over two decades (1998–2009  $k=3.421$ ; 2009–2018  $k=7.91$ ). The diameter of the network—the longest-shortest path between two countries—displays a decrease from one period to the other (1998–2008  $\mathcal{A}=6$  to 2009–2018  $\mathcal{A}=4$ ), showing that HE researchers from all contributing countries are gradually collaborating more.

While we observe an increase in collaboration among countries, the density measure—the proportion of all possible ties that are presented—not only exhibits a rather stable measure, but more importantly, a very low density across the entire period ( $D=0.09$ ). This measure shows that while more countries have joined the network in co-authoring HE research, there is not much variation in collaboration propensity across the entire network. Moreover, the clustering coefficient—the tendency of countries to cluster together—also shows stability in the network, with researchers in particular countries repeatedly co-authoring with others in the same countries instead of branching out to explore new comparisons or joining other constellations of researchers (1998–2008  $C=0.577$ ; 2009–2018  $C=0.72$ ).

Therefore, the results indicate that the overall increase in collaboration has not resulted in more diversity in collaborations but rather in the strengthening of existing collaborations. This result confirms the co-author-level analysis by Vlegels and Huisman (2020). Next, we explore the internal sophistication of the network through the modularity measure—the structure of the network and the strength of the internal division in communities. We find that the modularity measure of the network decreases over time, which shows a lack of internal division in the network in specific sub-communities of researchers (1998–2008  $Q=0.295$ ; 2009–2018  $Q=0.192$ ). This result indicates that the international knowledge network in HE research in these journals is not composed of dense connections between countries but rather composed of a small group of central countries (and their world-leading scholars as well as journals) that constitute the core around which other countries’ scholars continuously gravitate.

Therefore, we analyze the degree centrality to uncover the evolution of this network of HE researchers. The results show a small number of countries collaborating to produce HE research from 1998 to 2008, with a clear dominance of the English-speaking countries, such as the United States (USA, 23), Australia (AUS, 14), Great Britain (GBR, 12), Canada (CAN, 7), New Zealand (NZL, 5), Hong Kong (HKG, 5), and South Africa (ZAF, 4). Outside of this group of English-speaking countries, only two European countries—the Netherlands (7) and Sweden (6), with their internationalized universities and strong English language skills—very successfully co-author with the leading Anglophone countries.

China (CHN, 3) also shows a relatively stronger degree centrality measure than many other countries, yet cannot compete with the Anglophone group.

In the next period, 2009–2018, we find a dramatic expansion of international collaboration in HE research. We observe the consolidation of the English-speaking countries: the United States (53), Great Britain (46), Australia (34), Canada (21), and Hong Kong (20). Yet we also find the enhanced centrality of European countries like Germany (29), the Netherlands (26), Spain (25), and Portugal (22). China (29) is the only Asian country that has become a key producer of HE international collaborative research in Western journals.

The expansion of international collaboration in HE research occurred in a highly stratified manner, resulting in a clear division between the leading contributing countries and many others more sporadically collaborating internationally. Nevertheless, this result should be read carefully for two main reasons. The first is related to the overrepresentation of English-language journals in the WoS to the detriment of other languages (Mongeon & Paul-Hus, 2016) and by the fact that our dataset is exclusively based on English journals. Thus, it does not seem surprising that Anglophone countries show a higher degree of centrality over non-Anglophone countries. Moreover, looking at the rate of published articles per million inhabitants (see Appendix 5), while Australia (1998–2008, 1.3; 2009–2018, 6.98) and New Zealand (1998–2008, 1.03; 2009–2018, 8.91) show a high rate of internationally co-authored articles and have a high centrality degree measure in international collaborations, the United States (1998–2008, 0.108; 2009–2018, 0.658) and Great Britain (1998–2008, 0.441; 2009–2018, 3.063), for instance, which have a strong centrality score, show a relatively small rate of internationally co-authored articles in comparison with other countries. By contrast, countries such as Norway (1998–2008, 0.368; 2009–2018, 8.116) and Finland (1998–2008, 0.541; 2009–2018, 3.790) have relatively low centrality in the network but a significantly high rate of internationally co-authored articles, which reflects national research policies that favor English language publication and strengthened global networks. While not being the focus of the paper, our results show complex relationships at the nexus of collaboration/research production that deserve closer attention in further research.

The network is composed of a core dominated by the research outputs of scholars based in Anglophone countries, with numerous other countries that continuously gravitate around that center—unsurprisingly given the focus on English-language journals. Yet the patterns are not only related to language, as more sporadic contributors tend to collaborate with central ones and over time increase their collaboration activities. We do not find many new collaborations between peripheral actors, but rather an increase in activity in those countries that engage to collaborate with the central ones. This confirms the hierarchical structure in the field and resulting inequalities among countries (Vlegels & Huisman, 2020).

### Shifts in main research themes

We turn now to shifts in the main research themes since 1998 derived from topic modeling. We extracted the most prominent key terms from the abstracts of those papers that best represent the theme of the cluster (based on the formula presented above). We generated a set of candidate models with different themes (i.e., 3, 13, and 62). Since topic modeling is an exploratory technique and will give researchers any number of topics they request (see Daenekindt & Huisman, 2020), we opted for 62 themes, providing detailed results of topic classification.

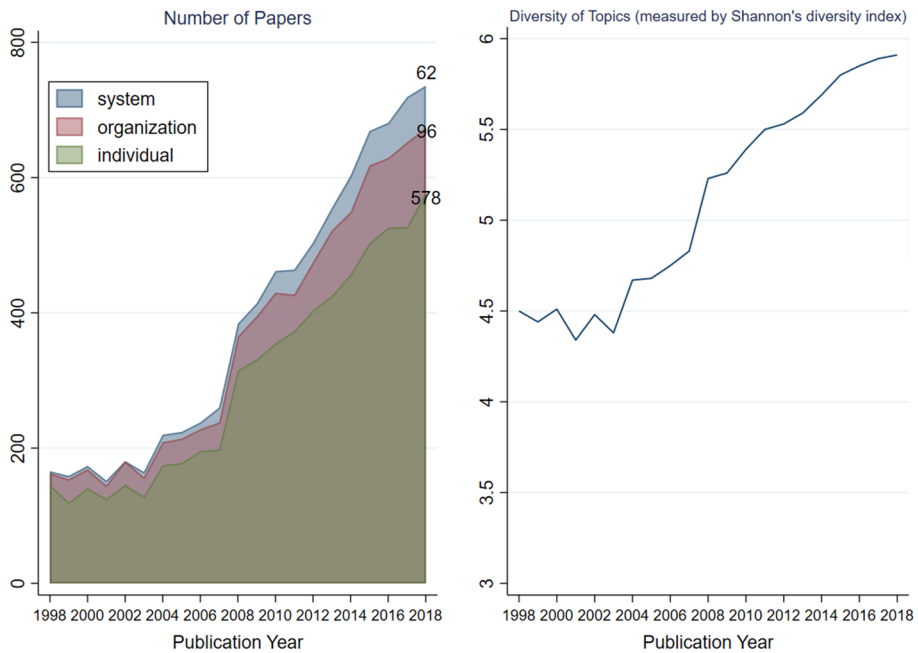
Among 9067 papers, 8130 papers could be classified into one of 62 themes, accounting for 90% of total articles in these HE journals. For those papers impossible to classify, their topics are relatively unique and have not yet formed an overarching theme. To enhance the interpretability of our two-mode network analysis, we assigned these 62 themes to three levels: individual, organization, and system—analogous to the analysis by Daenekindt and Huisman (2020). For example, “A structural model for predicting student retention” (Sass et al., 2018) is classified under college student at the individual level; “The role of the associate dean in UK universities: distributed leadership in action?” (Floyd & Preston, 2018) is classified under leadership at the organizational level; “Equity in higher education and graduate labour market outcomes in Australia” (Li et al., 2017) is classified under labor market at the system level. Appendix 4 presents the themes and the number of papers classified at each level. However, we acknowledge that such classifications may be somewhat arbitrary since some of the papers might conduct analysis from the standpoint of the individual as the unit of analysis, but the application of the empirical findings could be relevant to the organizational or system level(s) or vice versa. This scenario might create an overlap in categories, creating a further set of themes. To tackle this concern, we chose to interpret the results from the standpoint of units of analysis only.

Emphasizing the dominance of the individual level, there are 43 themes that were centered on analysis of characteristics and activities by students, faculty members, and other actors. Assigning these themes to the individual level, the total number of papers was 6348, accounting for 70% of total publications in the sample. At this level, the key theme of “college students” has most publications (2185), followed by “learning” (1990) and “engagement” (474). The total number publications of these three themes accounted for 73.2% of HE research focusing on individual level.

At the organizational level, 1246 papers in 12 themes accounted for 13.7% of total publications sampled. The topics focus on the internal operations of HE organizations. The top three key themes are “leadership” (854), “quality assurance” (107) and “culture” (72). At the system level, 536 papers in 7 themes accounted for only 5.9% of all papers. The topics at this level emphasized the broader cross-boundary interaction between HE and other social sectors, including the economic returns to HE (i.e. labor market benefits, knowledge transfer). Alongside the output of “labor market benefits” (155), the impact of competition, governance, and external forces on HE were leading topics, including “ranking” (144) and “world-class university” (116), finance, performance-based budgets, and globalization.

To visualize the differential growth of these thematic levels and the diversity of topics, we chart the number of papers appearing over time (Fig. 1). To capture the diversity in this sample of HE research since 1998, we calculate the Shannon diversity index to measure the steadily increasing diversity within the 62 themes since 1998. Our findings differ from Daenekindt and Huisman (2020), who found the diversity of topics decreasing and some topics becoming more disparate as specialization proceeds. The themes at the individual level have continued to attract the vast majority of attention among HE researchers over the past 20 years. Although the publications focused at the organization and system levels have also increased, their growth has been rather modest. During the period of 1998–2008, the organization and system level accounted for 18.3% and 6% of all classified papers, respectively; by the period of 2009–2018, the percentages of these two levels only slightly increased to 19.5% and 9.7%, respectively, showing their modest growth.

The growth of research at these levels and overall have been rising similarly over the past decade (left side of Fig. 2). Measured by Shannon’s diversity index, thematic diversity increased, especially after 2003, with individual level topics still dominant (right hand side of Fig. 2).



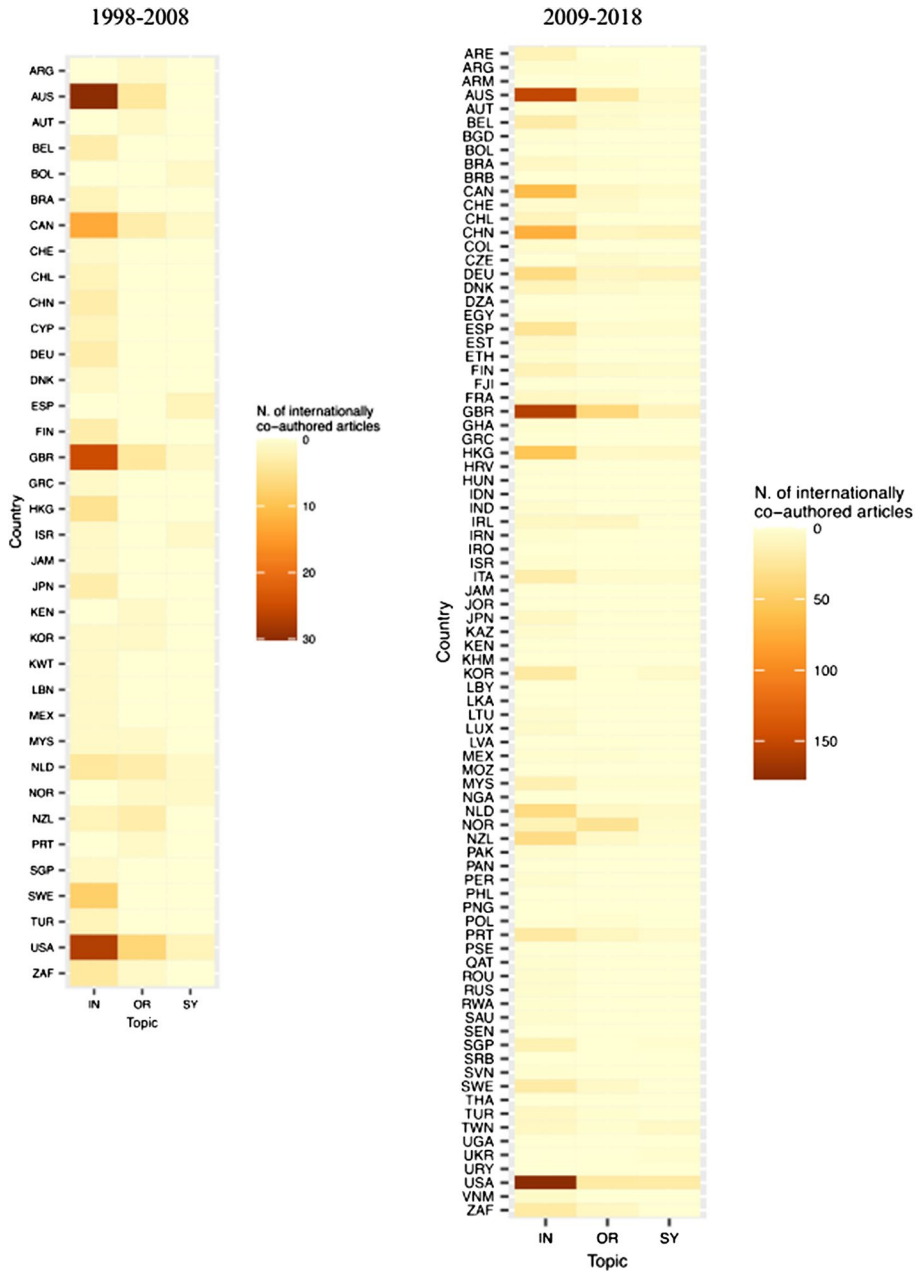
**Fig. 2** Higher education research: Growth of papers published by level (individual, organization, system), and diversity of topics, 1998–2018. *Source:* Project database ( $N=9067$  articles), data from Clarivate Analytics' Web of Science

**Table 3** International co-authorships in higher education research (1998–2018), levels of analysis (in-degree and weighted in-degree). *Source:* Project database ( $N=9067$  articles), data from Clarivate Analytics' Web of Science

1998–2008			2009–2018		
Topic	In-Degree	Weighted In-Degree	Topic	In-Degree	Weighted In-Degree
Individual	29	152	Individual	79	1195
Organizational	15	33	Organizational	46	261
System	7	9	System	40	135

Turning now to the two-mode network analysis, this also confirms the importance of the individual level of analysis as preferred in this sample of HE research, followed by the organization and system levels (see Table 3 and Fig. 3). More importantly, looking at the contributions of countries on each level, we see two interrelated aspects.

On the one hand, our analysis shows that all countries contribute somewhat to the individual, organization, and system levels. Through the in-degree and weighted in-degree measures, we observe that international co-authorship in HE research was accompanied by a strong development of the three levels, especially the individual. The organization and system levels, while exhibiting increased attention by international co-authors, still lag behind in comparison to the predominance and growth of



**Fig. 3** Internationally co-authored higher education articles, by country and level of analysis, 1998–2018

themes primarily addressing the individual level. The country-topic heat map (Fig. 3) again shows the continued dominance of English-speaking countries on all three levels of analysis, although their predominance has been relativized by substantial increases of other countries, noticed in the last period analyzed. Such results confirm that

**Table 4** Topic coverage and diversity of the top 10 paper-producing countries. *Source:* Project database ( $N=9067$  articles), data from Clarivate Analytics' Web of Science

Period	1998–2008					2009–2018					
	Country	Total	IN	OR	SY	S	Country	Total	IN	OR	SY
USA	42	64%	17%	5%	2.49	USA	253	70%	8%	8%	2.56
GBR	34	74%	12%	3%	1.65	GBR	240	66%	17%	4%	2.38
AUS	36	83%	11%	–	1.72	AUS	190	80%	12%	2%	2.54
CAN	18	72%	17%	6%	1.87	CHN	99	74%	9%	12%	2.39
NLD	9	44%	33%	11%	1.67	CAN	84	75%	10%	5%	2.29
HKG	7	71%	–	–	1.33	HKG	74	74%	8%	9%	2.45
NZL	5	40%	60%	–	0.67	NLD	60	60%	15%	18%	2.29
CHN	3	100%	–	–	0.64	DEU	54	67%	13%	9%	2.85
DEU	3	100%	–	–	1.1	NZL	53	66%	11%	4%	2.22

international co-authorships in HE are highly fragmented, without cohesive communities of countries contributing to a particular level of analysis.

While for the first period (1998–2008), English-speaking countries extensively contribute to all three levels of analysis, we observe a more diverse picture in the following period (2009–2018). On the individual level, six Anglophone countries appear to contribute most: United States, Great Britain, Australia, Canada, Hong Kong, and New Zealand. China (73), Germany (36), and the Netherlands (36), are also major contributors. At organization level, Norway, China, Germany, and Portugal strongly contribute research, alongside Great Britain, Australia, the United States, Ireland, and Canada. At the system level, the United States, Great Britain, China, and Germany contribute the most articles. Thus, as in other research fields, such as Science, Technology, Engineering, Mathematics, and Health (STEM+), we see the dominance of the three main science regions—Europe, North America, and East Asia (see Powell et al., 2017)—albeit with the addition of Oceania (Australia, New Zealand).

Furthermore, Table 4 presents the evolution of the top 10 paper-producing countries across the two periods in terms of topic coverage and diversity. As expected, the leading countries, including the United States and Great Britain, have broader topic coverage and diversity. However, it is noteworthy that compared to the first period, emerging countries in global HE research like China, Germany, and the Netherlands not only increased their IRC but also diversified and broadened their topic coverage.

These results reflect contemporary developments of HE systems in different world regions, such as the organization and system level themes attended to by researchers in European countries that receive EU funds to collaborate and participate in the Bologna process that has the harmonized European HE that facilitate cross-country comparisons (Marques, 2018).

The results from the two-mode network analysis, in which we globally explore the country-topic relationship, highlight and reinforce the international collaboration network results. As shown, this network is characterized by strongly expanding collaboration, yet relatively modestly compared with other more globalized fields, such as many of the STEM + fields, but that expansion occurs with limited diversity in terms of countries collaborating as well as in the variety of themes and levels of analysis. The modularity measure shows that the partition into sub-communities of the network indeed decreased



from one period to the other. These results, in line with the two-mode network analysis, seem to indicate that the central group of countries also guides the direction of the field in terms of what themes and levels are of greatest interest to the field's researchers who collaborate internationally. While networks with low modularity are characterized by stable group thinking, they also do not necessarily promote diversity, innovation, and creativity among their constituents (Cattani & Ferriani, 2008; Collins, 2004; Fleming et al., 2007). And if authors outside the center may explore divergent ideas with more freedom and without pressures to conform, they nevertheless lack visibility and recognition (Perry-Smith & Shalley, 2003). Such results raise important questions related to the evolution of the multidisciplinary field of HE as well as to the role of international collaboration in reinforcing established dynamics as well as in establishing new ones.

## Discussion and conclusion

With respect to international co-authorships, we find clear divisions between the countries we identify as dominant producers and those who have only more recently joined the global HE knowledge network. Our joint bibliometric and network analyses show dynamic patterns of collaboration among countries, yet the expansion is mediated by the narrow structure of international co-authorships. While (many) more countries have joined the network, especially over the latter decade analyzed (2008–18), they tend to gravitate around a small group of central, largely Anglophone, countries—where the leading researchers are based—and this reflects the field's persistent stratification (see also Vlegels & Huisman, 2020; Akbaritabar & Barbato, 2021; Avdeev, 2021). Such results should be read carefully since our sample of journals and articles is based on English language journals. Authors in Anglophone countries do not suffer trade-offs between visibility in domestic vs. international scientific communities based on publication language, one of the main drivers of centrality within this network, and they profit from journals that are often based within their domestic scientific communities.

Gradually, the field's boundaries have extended and important new contributors to leading HE research have emerged. However, we find relatively uniform patterns of collaboration, measured in co-authorships, and maintained disparities in contributions among countries and world regions. Yet scholars from peripheral countries have begun to contribute more to the dynamic and diversifying field of HE research. Indeed, as Kwiek (2020b) shows, the overall share of publications produced by the scholars based in major Anglophone countries is decreasing. If HE research has become vastly more collaborative over these twenty years, the power of scholars in major Anglophone countries remains extremely strong. This field is characterized by global stratification, with increasing returns to core countries long advantaged in HE research, not least via control over the journals sampled here. These countries not only have influential journals, but also have very long histories of HE research, leading research universities and other relevant organizations, and professional associations. They are the key platforms for today's burgeoning collaborative research—and they have many leading researchers guiding the field's global development.

Reviewing the evolution of HE research in these journals across these two periods (1998–2008/2009–2018) reflects broader challenges facing globally networked science, including disciplinary divisions of labor; data selectivity and methodological nationalism; lack of synthesis; and few systemic longitudinal analyses. The meso and macro levels remain, we find, underemphasized in contemporary research conducted by international co-authorship

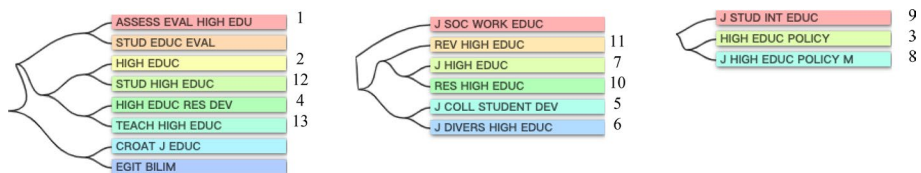
teams, despite their relevance for policymaking. In-depth comparative research is needed to extend our knowledge beyond dominant science-producing regions and countries and improve our understanding of cultural and disciplinary diversity. For HE research to thrive and maximize its potential, the continuously-evolving network of individuals, teams, projects, and organizations—and their contexts—demands attention. Bibliometric social network analyses, such as the one presented here, demonstrate spatial shifts and global flows, but also regional embeddedness and persistent dominance of a few countries, at least in terms of leading journal publications. As Tight (2021) argues, if regional influences have reshaped the landscape of HE research, we do not yet find a fully integrated global scientific network in higher education research.

In terms of data and methods, exploring the developments of co-authorship and thematic focus as well as levels of analysis suggests the importance of multi-level approaches and mixed methods to extend the possibilities for analysis and explanation of the dynamic global field of HE research. This remarkable expansion of scientific output reflects contrasting trends: rising competition at all levels matched by diverse forms of collaboration among scientists working in different disciplinary contexts and countries. The future of HE research is indeed global, but many studies remain parochial and particularistic. More internationally and inter-culturally comparative research is warranted—as is enhanced attention to organizational and system levels and especially multi-level analyses.

The establishment and maintenance of a truly global scientific network devoted to HE research will, as scientific dialogue moves increasingly into virtual worlds, need to be actively supported, especially to counteract the existing stratification of authors, organizations, and countries that skews our knowledge with its focus on a few dominant contexts. We confirm that HE research remains scattered spatially and in thematic focus. Attention is needed to develop deeper understandings of the drivers of dynamics within intercultural teams and inter-organizational research collaborations that lead to co-authorships. Co-authored HE research has expanded considerably globally, increasingly reflecting wider trends. The field's international research collaboration network has yet to transform into an integrated and diverse scientific community that could best address contemporary global challenges at individual, organization, and system levels.

## Appendix

### Appendix 1: Higher education-related clusters based on journal bibliographical coupling



Note: Only three clusters from the clustering result of 243 journals are shown. The numbers beside the journal titles correspond to the positions of the journals in Table 1.



## Appendix 2: Demonstration of data extraction using CATAR

PT J
AU Meng, Q Zhu, C Cao, C
AF Meng, Qian Zhu, Chang Cao, Chun
TI Chinese international students' social connectedness, social and academic adaptation: the mediating role of global competence
SO HIGHER EDUCATION
LA English
DT Article
DE Chinese international student; English proficiency; ...
ID CROSS-CULTURAL ADAPTATION; ACCULTURATIVE STRESS; ...
AB This study examined ...
C1 [Meng, Qian; Zhu, Chang; Cao, Chun] Vrije Univ Brussel, Pl Laan 2, B-1050 Brussels, Belgium. [Meng, Qian; Cao, Chun] Changchun Univ Sci & Technol, Changchun, Jilin, Peoples R China. ...
Meng, Qian: Vrije Univ Brussel
Meng, Qian: Changchun Univ Sci & Technol
Zhu, Chang: Vrije Univ Brussel
Cao, Chun: Vrije Univ Brussel
Cao, Chun: Changchun Univ Sci & Technol

The above row indicates a snippet of a WoS record. The second row shows the extracted author names with their affiliations from the C1 field by CATAR.

## Appendix 3: Data collected on articles published in leading higher education journals

Item	detail	Example
AU	Author	Pike, GR; Saupe, JL
TI	Title	Does high school matter? An analysis of three methods of predicting first-year grades
SO	Journal	Research in Higher Education
DE	Keywords	enrollment management; college grade; high school
ID	Description	Catholic schools; college; student; achievement; dropout; model
AB	Abstract	This research evaluated the usefulness of 3 approaches for predicting college grades: (a) traditional regression models, (b) high-school-effects models, and (c)...
C1	Country	USA

Item	detail	Example
CR	Cited reference	Adelman C, 1999, ANSWERS TOOL BOX ACA; ALWIN DF, 1977, SOCIOL EDUC, V50, P259, <a href="https://doi.org/10.2307/2112499">https://doi.org/10.2307/2112499</a> ; ...
NR	No. of references	50
PY	Publication year	2002
SC	Academic field	Education & Educational Research
UT	WOS id	WOS:000,179,601,700,003

## Appendix 4: Key themes in higher education research by level, 1998–2018

### Individual (6348 | 70.0%)

college student (2,185); learning (1,990); engagement (474); international student (271); bisexual (267); racial identity (217); adjustment (165); psychological (152); academic dishonesty (137); academia (123); reflective (114); inquiry-based learn (94); mental health (80); college choice (69); minority (68); problem-based learning (67); collaborative (62); sexual harassment (55); assessment (50); rape prevention (45); disabled student (42); portfolio (42); student affair (42); satisfaction (39); skill (39); grade inflation (38); indigenous student (38); teacher (37); adult higher education (36); social work (35); student identity and sense of place (29); value-added (29); cultural-historical (28); social activism (28); apprentice (28); feminist (23); mentor (22); foreign doctorate (22); doctoral candidate (22); excitement (22); computer-based supported collaborative (21); teacher-intensive (18)

### Organization (1220 | 13.5%)

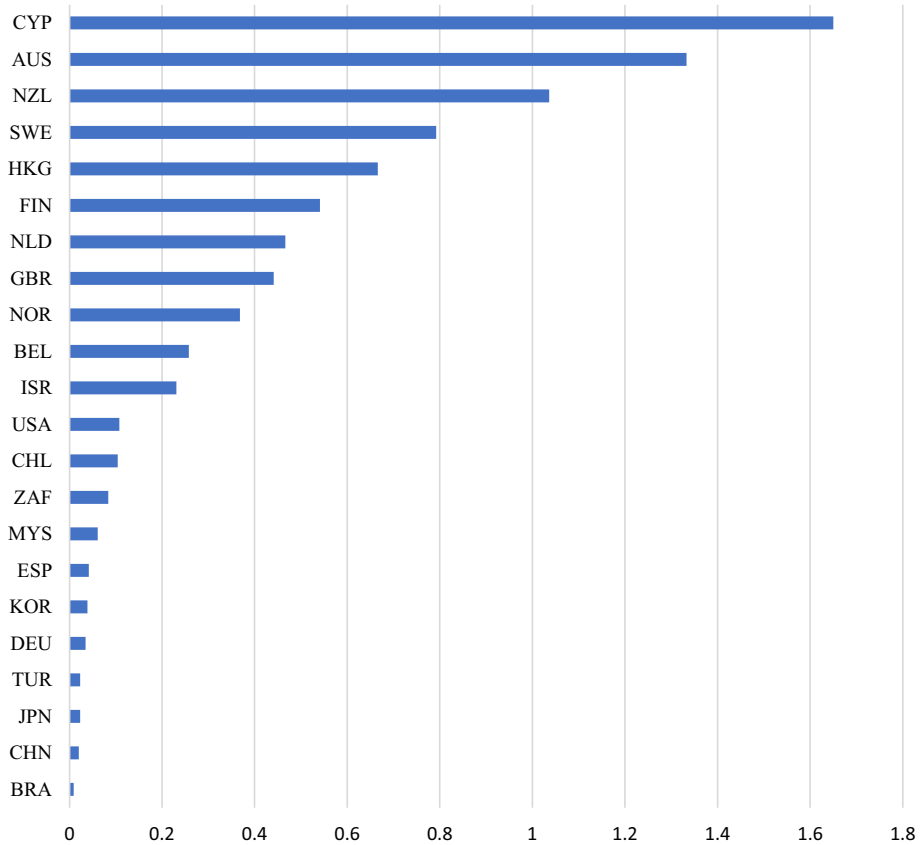
leadership (854); quality assurance (107); culture (72); private higher education (62); governmentality (56); amalgamation (56); strategic (52); accountancy (44); Taylorism (42); institutional research (28); benefit-cost (21)

### System (562 | 6.2%)

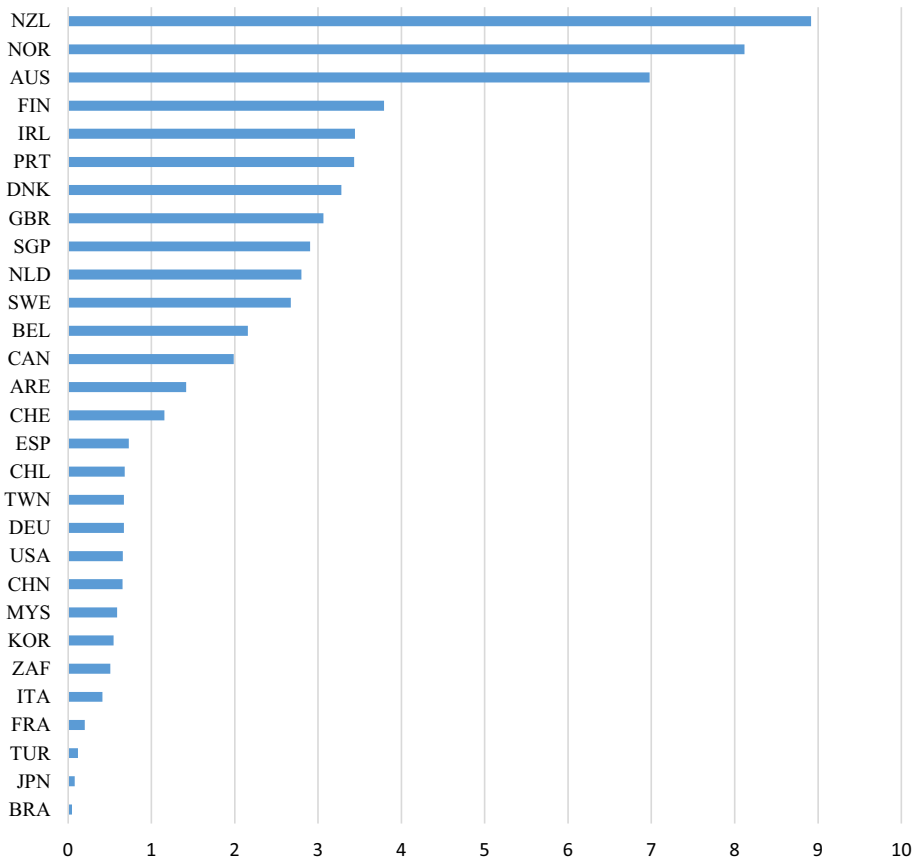
labor market benefit (155); rank (144); world-class university (116); globalization (64); knowledge transfer (36); performance-based budget (28); Truman commission (26); financing higher education (22)

**Appendix 5: Rate of international co-authored articles**

Rate of internationally co-authored articles (per million of inhabitants), 1998-2008 (>1 articles)



Rate of internationally co-authored articles (per million of inhabitants), 2009-2018 (>10 articles)



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**Data availability** Downloaded from Web of Science, as described in the section Data and Methods.

**Code availability** The code used for this project is available at <https://github.com/SamTseng/CATAR>.

**Declarations**

**Conflict of interest** The authors declare that they have no conflicts of interest.

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