



A BIBLIOMETRIC ANALYSIS OF TECHNOLOGY TRANSFER AND COLLABORATION BETWEEN SMES AND UNIVERSITIES

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Abstract:

This study aims to conduct a bibliometric analysis of technology transfer and cooperation between small and medium-sized enterprises (SMEs) and universities. In the study, the intellectual structure and trends of academic publications on the subject were mapped in detail by utilising bibliometric methods. In the data collection process, records obtained from the Web of Science Core Collection database were used and relevant documents were selected through specific keywords. In addition, VOSviewer software was used to visualise the relationships between key terms, institutions and research collaborations. The findings show that academic interest in SME-university collaborations has increased significantly in recent years, indicating that these collaborations play an important role in promoting innovation and enhancing economic competitiveness. However, the present results reveal that although the topic has gained importance in various academic circles, further research is needed to fill the gaps in the literature and to reveal new dimensions of university-industry collaborations.

Keywords:

Technology transfer, Research Collaboration, Research institutes, universities, technological progress, competitiveness, SME and Industry.

1. Introduction

The dynamic nature of the information society has facilitated the rapid growth of scientific research and academic publishing. In this context, analyzing the production, dissemination, and impact of academic knowledge plays a critical role in understanding the development processes of scientific fields. Bibliometric analysis, developed for the systematic evaluation and interpretation of scientific knowledge, has become a widely used approach in academic literature over the last century. Bibliometric analysis is an important methodology that enables the qualitative and quantitative examination of scientific studies within the context of a specific discipline or subject (Yang & You, 2017).

This study analyzes basic research trends, publication profiles, and citation patterns in academic literature using bibliometric analysis. The primary objective of the research is to determine the density of scientific studies on specific academic topics, the relationships between publications, and the impact of academic contributions. In this context, the analyzed literature focuses on key issues such as economic development, technology transfer, and research collaboration.

The research dataset was obtained from the Web of Science Core Collection, one of the world's most comprehensive academic databases. Following a literature search using predetermined keywords, appropriate academic studies were selected for analysis. VOSviewer versions 1.6.18 and 1.6.20, a widely used open-source software for bibliometric

analysis, were used during the dataset processing and analysis. This software allows for more in-depth analysis of the dataset by visually representing the relationships and network structures between academic publications.

This study aims to achieve the primary objectives of examining scientific trends in the selected academic fields, revealing the relationships between research topics, and identifying the most frequently cited studies. Furthermore, presenting research findings with figures and tables will enable a more comprehensible and systematic interpretation of scientific knowledge.

In conclusion, this study, which uses bibliometric analysis, provides important findings that will help understand the structure and development dynamics of existing scientific literature in the relevant academic field. In the light of the data obtained, an in-depth analysis of academic trends will be made and an inference will be made that can guide future research.

2. Methodology

The research methodology used in this study focuses on the application of bibliometric analysis. Developed in the last century (Havermann, 2016), this method uses statistical and graphical techniques to analyze and interpret the scope and impact of knowledge in a specific field of study (Robertson et al., 2020 as cited in Kraus et al., 2012). The dataset required for the analysis was obtained from the Web of Science Core Collection, a well-established and comprehensive database of academic publications. Keywords were used to filter and retrieve relevant documents from extensive search results. To support the bibliometric analysis, version 1.6.18 of the open-source tool VOSviewer was used. This software enables graphical representation of networks and relationships based on key terms identified in the academic literature (Robertson et al., 2020 as cited in Li and Rollins, 2018). The following diagram illustrates the procedure for selecting relevant documents required for the research analysis:

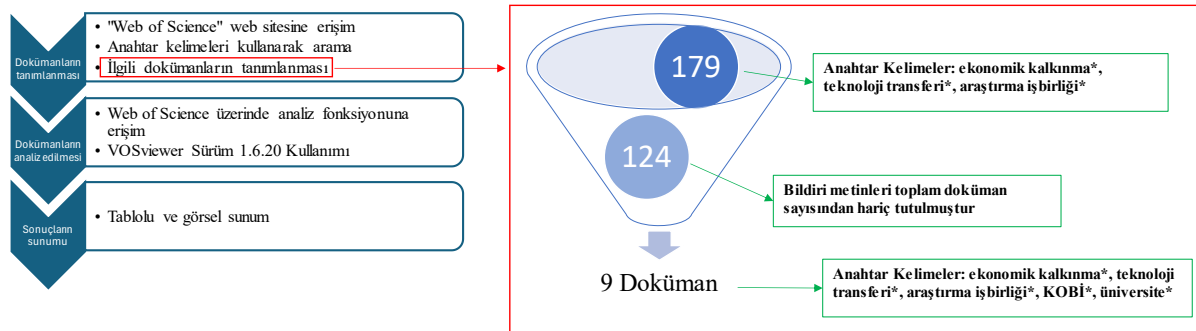


Figure 1: The methodological approach of bibliometric analysis, original design

The first phase focuses on selecting scientific articles to be used in the literature review. Searches were conducted in the Web of Science database using the identified keywords. The selection of specific keywords in the search process clearly identifies the core topics of interest: economic development, technology transfer, research, and collaboration.

The results obtained in the first stage are as follows:

- Search Date: 09.05.2024
- Total Number of Documents: 179
- Number of Documents Excluding Proceedings: 124

This data allows for the examination of core academic articles in the focused areas by eliminating shorter, preliminary literature sources such as proceedings. Furthermore, the "relevance level" criterion was used in the ranking of documents. This criterion allows for a more efficient literature analysis by evaluating the most relevant studies that align with the research objectives.

In the second stage of the study, the search scope was expanded to include keywords such as "SME" and "university." The findings of this expanded search are as follows:

- Total Number of Documents: 9

- Number of Articles: 2
- Other Documents: Proceedings

The results reveal that there are a limited number of academic studies in more specific areas of the topic. The limited literature on research collaboration and technology transfer between SMEs and universities demonstrates that this area requires further academic research and attention. After identifying relevant documents, a detailed analysis was conducted using Web of Science's analysis function and VOSviewer software (version 1.6.20). Finally, the results are presented both visually and in tables for comprehensive interpretation.

3. Analysis

The descriptive analysis comprehensively examines a variety of data, including publication years, research topics, document types, journals, and contributing countries. Figure 2 presents the distribution of documents and their citation counts, categorized by their respective publication years:

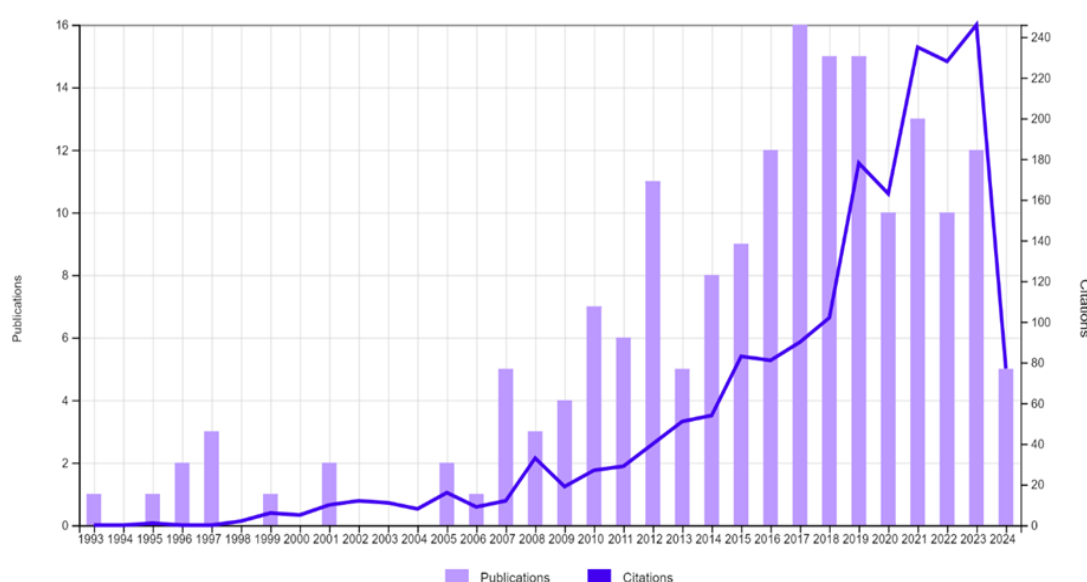


Figure 2: Development of publications and citations between 1993 and 2024

An examination of the publication years of the selected documents indicates significant fluctuations between 1993 and 2006. This finding suggests that the research topic under consideration received limited attention during these years. While the 1993-2006 period reveals that academic production in the literature was sporadic and sparse, it is important to consider the possible reasons for this lack of interest. The general academic trends of the discipline during that period may have contributed to the low level of research interest in the subject. However, technological advances and global events may also have contributed to this situation.

However, a significant increase in research was observed starting in 2007. This increase in the post-2007 period indicates increased awareness and interest in the field. This period can be attributed to factors such as the acceleration of global information flow, the integration of technological innovations into research, and the increase in international collaborations. This trend peaked between 2017 and 2019, with an increase in the number of publications, demonstrating an improvement in both the quality and quantity of research. This increase during this period indicates that academic production in the field has matured and become more systematic. However, it should be noted that this increase has fluctuated; these fluctuations may have been due to various external factors, such as economic conditions, political pressures, or changes in the allocation of academic resources.

While the 2017-2019 period represents the period of highest research intensity, a continuous growth trend has been observed since then, although minor fluctuations have been observed. This trend can be interpreted as a stabilization of academic production and a broader embrace of the research topic by the academic community. However, some differences emerged in this trend after the 2020 global pandemic.

The findings related to the pandemic period are particularly striking. The World Health Organization's declaration of the COVID-19 pandemic in 2020 had significant impacts on academic publishing, as in many other areas. The significant decline in research and publication numbers can be explained by factors such as the global uncertainties created by the pandemic, laboratory closures, the suspension of field research, and the diversion of academic resources to urgent research related to the pandemic. However, the steady increase in citation numbers during this period is a significant finding. This rise in citation figures demonstrates that, despite the challenges caused by the pandemic, academic communities are intensively referencing previous research on this topic and expanding their existing knowledge.

In this context, the increase in citation numbers indicates that, despite the pandemic, the topic is being followed with increasing interest within academic circles, and that this interest has deepened qualitatively. The pandemic, particularly as a global crisis, has led researchers to revisit previous studies, allowing for greater use of existing literature. This can also be explained by the increased demand for scientific knowledge and the greater integration of research into scientific decision-making processes. Consequently, the pandemic period can be considered a period in which academic production declined quantitatively but gained greater importance qualitatively.

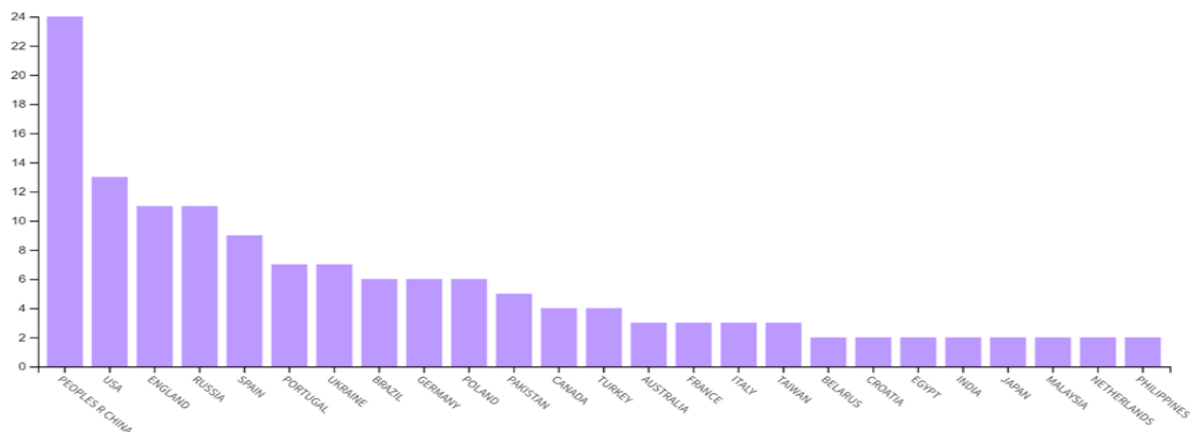


Figure 3: Number of researches on the subject by countries

An examination of the international dimension of research in Figure 2.8 clearly reveals that the People's Republic of China is one of the most active countries in this field. In particular, analysis of the number of scientific publications reveals that China is the country with the highest number of publications in this field, with a total of 24 scientific articles. This demonstrates not only China's research capacity but also the significant global reach of its scientific contributions.

This finding highlights the rising profile of the People's Republic of China in scientific productivity. China has significantly increased its influence in the academic field in recent years, becoming a leading actor in many disciplines. China's intensified research activities, particularly in fields such as science, technology, and engineering, support the country's increasing contribution to global knowledge production. In this context, China's rise to a leading position in this field highlights the country's leadership in both scientific productivity and knowledge transfer and innovation processes.

China's success is also linked to the country's extensive investments in scientific research. Strategic investments in science and technology policies have enabled China to increase its global competitiveness in these areas. The Chinese government has significantly increased its resources for R&D activities and strengthened its scientific infrastructure,

particularly over the last two decades. These developments have enabled Chinese researchers to contribute to a greater number of international publications and become more visible in the global academic community.

This rise in China's academic productivity can also be considered a harbinger of a significant shift in the global distribution of scientific contributions. The rise of countries like China to prominence in academic fields traditionally dominated by Western countries contributes to the diversification and globalization of knowledge production and scientific discussions. This also strengthens the interdisciplinary nature of academic collaboration and research, offering new opportunities for the global academic community. Consequently, the emergence of the People's Republic of China as one of the most active countries in scientific productivity demonstrates the country's positioning as a global academic power and its critical role in international knowledge production. China's leadership in this field directly impacts not only the academic world but also global economic and technological developments. (Yang & You, 2017)

Maintaining this strong position in academia will further enhance the global impact of its scientific contributions and shape the future of the knowledge economy. Figure 4 shows that a particular subject area has generated significant research interest. In particular, "Business Economics" stands out as the field with the highest academic resonance.

Among the scientific fields that hold a significant place in the academic community, Education & Educational Research (Education & Educational Research), with a total of 25 publications, and Environmental Sciences & Ecology (Environmental Sciences & Ecology), with 21 publications, stand out. Additionally, Environmental Sciences & Ecology (Environmental Sciences & Ecology) with 18 publications, Science & Technology – Other Topics (Science & Technology – Other Topics) with 16 publications, and Agriculture (Agriculture) with 11 publications represent three other disciplines with significant academic engagement. Remarkably, each of these research areas exceeds the ten-publication threshold, while the other fields experience relatively lower academic engagement. Business Economics is a branch of applied economics that examines the financial, organizational, market-related, and environmental problems faced by companies. It also encompasses fundamental economic concepts such as scarcity, factors of production, distribution, and consumption. The resonance rate for the other subject areas following this field drops to approximately 30%. This can be explained by Business Economics' broader approach to its research area.

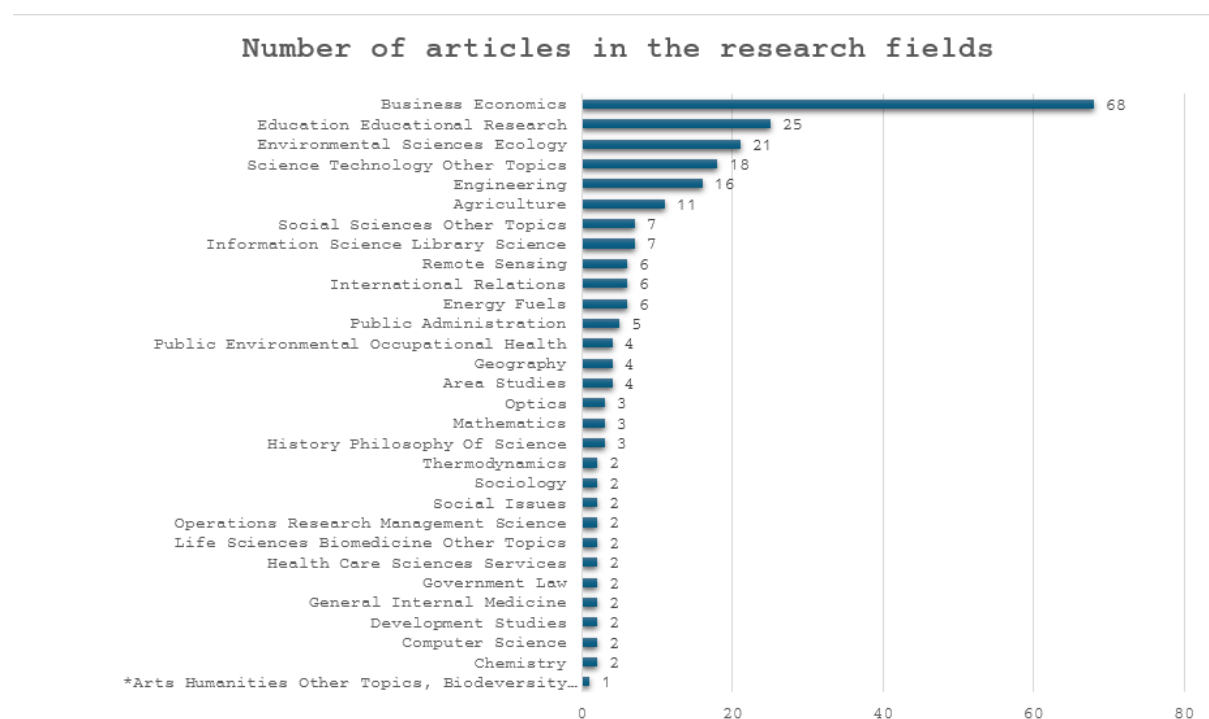


Figure 4: Visual of the Number of Articles in Research Areas

When examining the top 10 most frequently cited documents, two articles in particular stand out (Table 1). Lee's (1996) article received a total of 307 citations, with an average annual citation rate of 10.59. In contrast, Uyarra's (2010) article received a total of 191 citations, with an average annual citation rate of 12.73. The next two publications with over 100 citations were written by Papanastassiou, Pearce, and Zanfei (2020) and Harmon et al. (1997). In contrast, Wang, Lin, and Li () and Galan-Muros and Davey (2019) received citations in the seventies, while other academic contributions received fewer than 60 citations. An analysis of annual average citation rates reveals that the study by Galan-Muros and Davey (2019) has the third-highest rate, with a value of 11.83. This rate follows the study by Papanastassiou, Pearce, and Zanfei (2020), which had an average annual citation rate of 23.40, and the study by Uyarra (2010), which had an average annual citation rate of 12.73. These findings demonstrate the growing academic interest in Galan-Muros and Davey's contributions, resulting in a growing appreciation of the importance of their research within the scientific community.

These articles offer complementary perspectives on topics such as university-industry collaboration, technology transfer, innovation, and economic development. Each provides valuable contributions from different perspectives on the transition of academic research to practice, the dynamics of collaboration, and societal impacts. The following sections clarify the connections between the articles and systematically categorize them according to their respective research areas.

Table 1: Authors and Their Citation Counts

Authors	Citations	Average/year
Lee, YS	307	10,59
Uyarra, Elvira	191	12,73
Papanastassiou, Marina; Pearce, Robert; Zanfei, Antonello	117	23,4
Harmon, B; Ardishvili, A; Cardozo, R; Elder, T; Leuthold, J; Parshall, J; Raghian, M; Smith, D	110	3,93
Wang, Cassandra C.; Lin, George C. S.; Li, Guicai	75	5
Galan-Muros, Victoria; Davey, Todd	71	11,83
de Oliveira Neto, Geraldo Cardoso; Cardoso Correia, Auro de Jesus; Schroeder, Adriano Michelotti	56	7
Santamaria, Lluís; Surroca, Jordi	56	4
Yan, Zheming; Du, Kerui; Yang, Zhiming; Deng, Min	53	6,63
Garcia-Quevedo, Jose; Mas-Verdu, Francisco; Polo-Otero, Jose	47	3,62

(by Authors)

University-Industry Collaboration and Technology Transfer

Lee (1996) and Harmon et al. (1997) discuss the effectiveness and processes of university-industry collaboration while emphasizing the importance of technology transfer. Lee examines the impact on academic freedom and federal R&D funding, while Harmon and his team (1997) map technology transfer processes and offer suggestions on how to improve them.

Regional Economic Impact

Uyarrara (2010) examines the role of universities in regional economic prosperity and discusses the policy implications of this issue. In conjunction with Lee (1996), he offers reflections on how university-industry collaboration shapes the contribution of university-business collaboration to local development. Furthermore, Galan-Muros and Davey (2019) provide a framework for this issue by analyzing the impact of university-business collaboration.

Doctoral Graduates and Innovation

Papanastassiou, Pearce, and Zanfei (2020) and Garcia-Quevedo, Mas-Verdu, and Polo-Otero (2012) examine the impact of doctoral graduates on innovation. Both studies reveal the positive effects of collaboration between universities and the private sector on the employment of doctoral graduates. In this respect, they parallel the issues of university-industry collaboration discussed in Lee (1996)'s article.

Innovation Strategies and Conflicts

Santamaria and Surroca (2011) examine innovation performance by investigating the relationship between firms' technological objectives and partnership strategies. The political contradictions and conflicts discussed in Uyarrara's (2010) study offer important insights into how strategic partnerships can be managed.

Industrial Clustering and Technological Innovation

Wang, Lin, and Li (2010) examine the relationship between industrial clustering and innovation in China, revealing how local dynamics can produce different outcomes. This study aligns with Lee (1996) and Uyarrara's (2010) views on the contributions of universities to the local economy.

Low-Carbon Technologies and Global Cooperation

Yan et al. (2017) examine the development trends of low-carbon technologies, emphasizing the importance of technology transfer. This study demonstrates how collaboration between universities and industry is shaped at the global level, in relation to the international dimension of technology transfer discussed in Lee's (1996) article.

Electronic Waste and Environmental Impacts

Oliveira Neto et al. (2017) bridges the gap between environmental issues and technological innovation by conducting research on the recycling and reuse of electronic waste. This article provides a prime example of the sustainability impact of industrial collaborations and connects to the economic development and collaboration issues discussed in Lee's (1996) work.

Table 2: Journals and Impact Factors

Journals	Articles	Percentage Pay (179'dan)	Impact	Impact	JCR Category	Country
			Factor (2 Years)	Factor (5 Years)		
JOURNAL OF TECHNOLOGY TRANSFER	6	4,839%	4.8	5.5	Q2	ABD*

Journals	Articles	Percentage Pay (179'dan)	Impact Factor (2 Years)	Impact Factor (5 Years)	JCR Catagory	Country
ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	4	3,226%	5.8	5.4	Q1/Q2	Germany**
SUSTAINABILITY	4	3,266%	3.9	4	Q2/Q3	ABD*
COMPLEXITY	3	2,419%	2.3	2.3	Q2/Q3	Egypt*
MARKETING AND MANAGEMENT OF INNOVATIONS EQUILIBRIUM QUARTERLY JOURNAL OF ECONOMICS AND ECONOMIC POLICY	3	2,419%	1.3	1	Q3	Ukrain***
HELIYON	2	1,613%	4	4.1	Q2	Netherland*
JOURNAL OF CLEANER PRODUCTION	2	1,613%	11.1	11	Q1	England*
MGIMO REVIEW OF INTERNATIONAL RELATIONS	2	1,613%	0.2	0.2	Q4	Russia****

* academic-accelerator.com,

** scimagojr.com

*** <https://mmi.sumdu.edu.ua/>

**** https://www.vestnik.mgimo.ru/jour/index?locale=en_US

Conference proceedings were not included in the analysis of academic journals. A total of 105 peer-reviewed journals were included in the study. An examination of Table 2 shows that the Journal of Technology Transfer is the most productive publisher in this research area, with the highest number of published documents. Additionally, Environmental Science and Pollution Research and Sustainability journals were identified as the second and third most prominent publishers, each contributing four publications. One of the key metrics used to assess the importance of a journal in the academic world is the journal's impact factor. The impact factor reflects a journal's academic influence and reach within its field of expertise. A high impact factor indicates that the journal receives more citations and has a broader resonance within the academic community. Over the past two years, the journal

with the highest impact factor was the Journal of Cleaner Production with a value of 11.1. Other publishers on the list have impact factors ranging from 3.9 to 5.8. In particular, the journals Complexity and Marketing and Management of Innovations show the lowest impact factor over the two-year evaluation period. This data provides a detailed analysis of prominent journals in academic publishing in terms of both productivity and impact levels.

A 5-year evaluation reveals that the "Journal of Technology Transfer" achieved a significant increase in its impact factor within the academic community, approximately 1 point each. In contrast, the "Equilibrium Quarterly Journal of Economics and Economic Policy" reached values of 5.7 in the two-year evaluation, followed by a decrease to 3 when analyzed over a 5-year period. The remaining journals exhibit minimal variation when comparing the respective values. The search results were further analyzed, and inter-institutional collaboration data was examined. 233 institutional co-authorships were identified, demonstrating a collaborative research environment. The minimum requirement for institutional co-authorship was one document, and a total of 233 institutions were included in this analysis. Figure 5 shows a total of 97 clusters. It is observed that the connections between institutions are relatively weak and there are significant distances between them. In particular, only one cluster stands out significantly. Density visualization was applied to increase the interpretability of the inter-institutional network. As shown in Figure 6, a distinct cluster centered around the University of Beira Interior emerges as the most dominant among all identified clusters. A detailed ranking of these clusters is provided in Table 3. A total of 97 clusters were identified through the analysis of the inter-institutional network structure, and two main clusters stand out: Cluster 1 (11 institutions) and Cluster 2 (10 institutions).

Examining Table 3, the University of Beira Interior stands out in particular. With a total number of connections of 20 and a strength of 21, it holds a central position in the institutional network and acts as a major player. Within Cluster 2, each of the other institutions has produced only one published document, with the number of connections and strength of connections ranging from 1 to 3, respectively. In contrast, within cluster 1, QUT – the Australian Centre for Entrepreneurship Research holds a central position, with 11 connections and 12 connections. This ranks QUT as the second most influential institution within the entire network, behind the University of Beira Interior. The other institutions within cluster 1 exhibit similar metrics in terms of number of published documents, connections, and connection strength.

Finally, the "Enterprise Network - Clusters 1 and 2" data, presented in a 90-degree rotation in Figure 7, reiterates the central position of the University of Beira Interior within clusters 1 and 2. The network structure shown in Figure 7 provides a comprehensive framework for analyzing the depth and frequency of research collaborations between specific institutions and identifying the institutions that play a central role in these interactions.

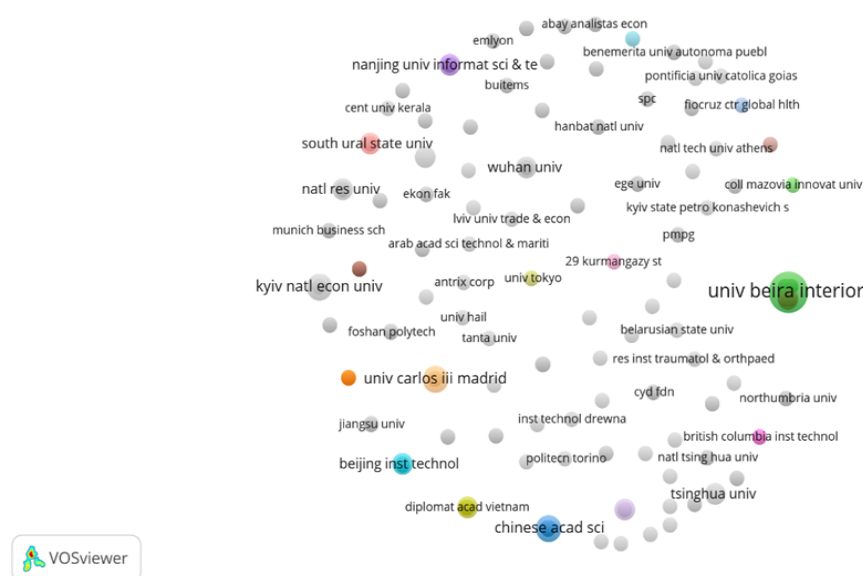


Figure 5: Corporate Network - All 233 institutions

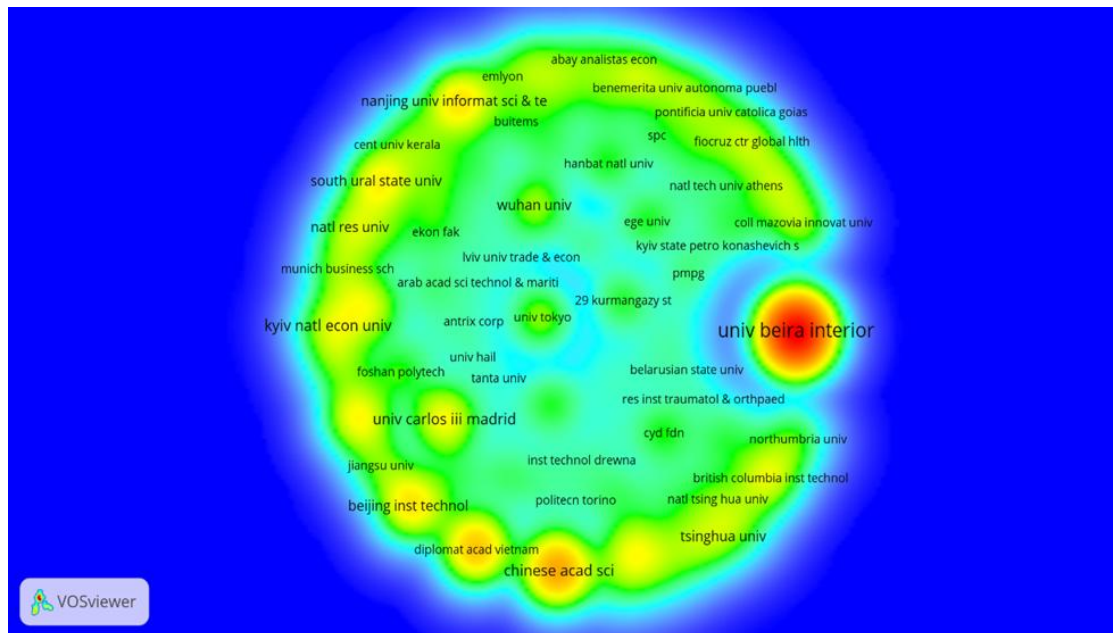


Figure 6: Corporate Network - Density

Table 3: Organization and the network information

Cluster	Organization	Articles	Link	Link Power
1	Cetrad	1	6	6
	School of Economics and Business			
	Administration – Ecobas	1	6	6
	Polytechnic Institute of Porto	1	6	6
	Polytechnic Institute of Tomar	1	6	6
	QUT - Australian Centre for			
	Entrepreneurship Research	2	11	12
	Universidade Católica Portuguesa	1	6	6
	University of Dubrovnik	1	6	6
	University of Ljubljana	1	6	6
	Universidade de Trás-os-Montes e Alto			
	Douro	1	6	6
	Universidade de Vigo	1	6	6
	University of Zagreb	1	6	6
2	Universidade Europeia	1	3	3
	Polytechnic institute of viseu	1	3	3

Cluster	Organization	Articles	Link	Link Power
	La Trobe University	1	1	1
	Polytechnic Institute of Bragança	1	2	2
	Polytechnic Institute of Castelo Branco	1	3	3
	ISAL Research Centre	1	3	3
	University of Applied Sciences of Jena	1	2	2
	University of Beira Interior	7	20	21
	University Institute of Lisbon	1	3	3
	University of Memphis	1	3	3

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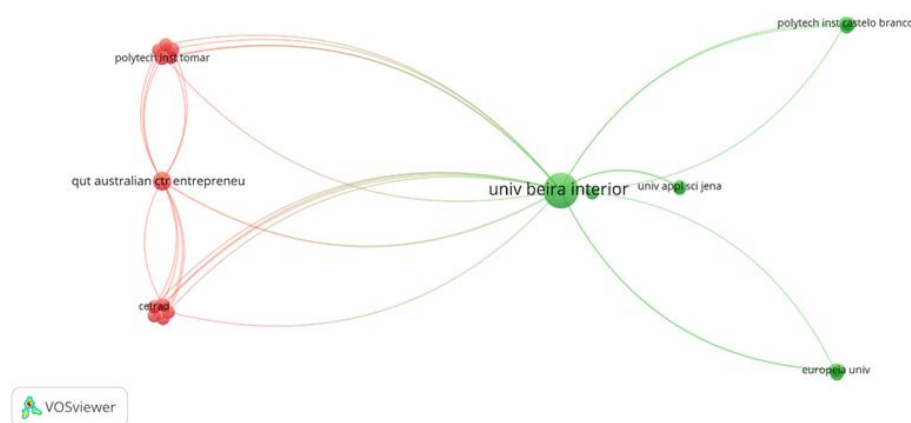


Figure 7: Organizational Network, Clusters 1-2

Table 4 below presents country-specific network data, including connections among 13 countries across four clusters. The table also shows that co-authorship relationships across countries were analyzed. The analysis found that 16 of the 49 countries with at least three published documents met this criterion; however, only 13 of these countries had connections. This suggests that academic collaborations are concentrated among specific groups of countries and that there is a need to develop broader global collaborations. Analysis of the results shows that China has both the largest number of published documents and the strongest network connections within the analyzed structure.

After China, the second most influential country in the network in terms of academic contribution is shared by the United States and Russia, with 11 published documents. However, in a direct comparison, the United States surpasses Russia in both the number of published documents and overall link strength. Turkey, positioned after Italy, exhibits a relatively limited academic distribution, with a total of four published documents, two links, and correspondingly low connection strength. In addition to these findings, Figure 8 provides a visualization of the country-specific network, revealing these interactions. The network image in Figure 8 has been rotated 90 degrees to accommodate the analysis process.

Table 4: Country Specific Network, 13 country connection Table consisting of 4 Clusters

Cluster	Country	Articles	Links	Link Power
1	England	10	6	7
	Germany	6	4	4
	Italy	3	2	3
	Türkiye	4	2	2
	USA	11	6	6
2	Australia	3	2	4
	Portugal	7	4	6
	Spain	9	3	4
3	Pakistan	5	2	5
	Chin	24	6	9
	Russia	11	1	1
4	Poland	6	3	3
	Ukrain	7	1	1



Figure 8: Country Specific Network Image. Image rotated 90 degrees

An analysis of the keywords used by the authors was also conducted to more clearly guide the research. Of the 516 keywords that met the minimum two-keyword requirement, 41 met this requirement. The connections between these keywords reveal how a knowledge network has formed around the key concepts of the study. The visualization "Historical development of author keywords" in Figure 9 graphically presents the relationships between these words, demonstrating the extensive interaction network within the research field.

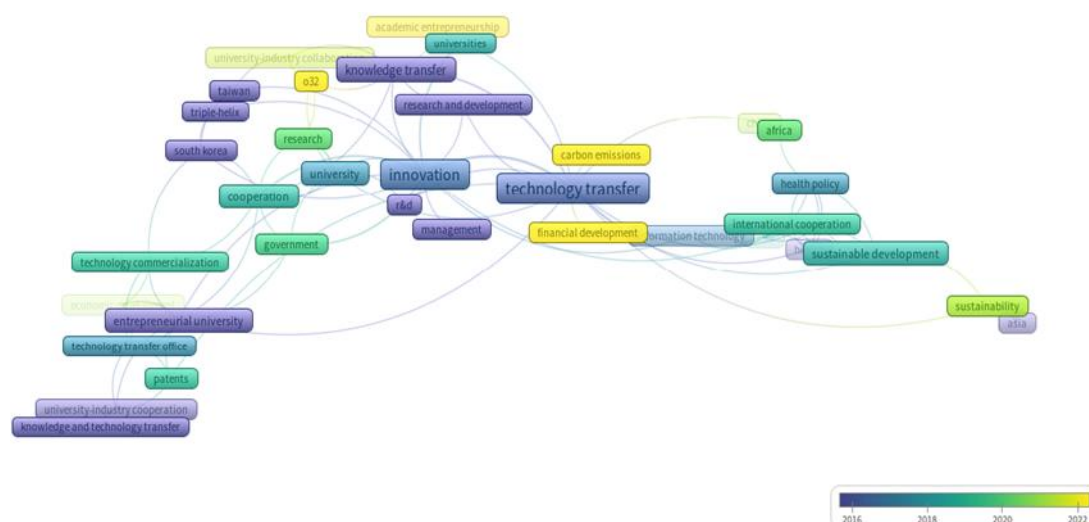


Figure 9: Historical development of Author Keywords

An examination of Figure 9 reveals that certain themes, such as "technology transfer," "management," and "knowledge transfer," have consistently attracted academic attention over time. In particular, collaboration between academia and industry, and the concept of academic entrepreneurship, have gained increasing prominence in academic discussions in recent years. This trend continues despite the long-established practice of such collaborations in various countries, such as Germany.

4. Conclusion

This bibliometric analysis comprehensively assesses the current status of university-SME collaborations and technology transfer in the academic literature, as well as the network structures underlying research collaborations. While there is a vast literature on economic development, technology transfer, and research partnerships, studies specifically focusing on collaborations between SMEs and universities are relatively limited. Furthermore, institutional and international collaborations appear to be concentrated within specific clusters and countries, highlighting the need for a broader global perspective.

The findings reveal that academic interest in university-SME collaborations has increased significantly over the years, and the number of structured studies that delve deeper into academia-industry dynamics is increasing. Key themes such as knowledge transfer, academic entrepreneurship, and joint innovation have emerged. However, despite this progress, further research is needed that focuses on under-addressed issues such as the role of policy frameworks, regional differences, and sector-specific challenges. The systematic bibliometric analysis conducted in this study not only deepens our understanding of the existing literature but also provides valuable insights into the distribution of research collaborations across scientific communities and countries. Strengthening collaborations, supporting interdisciplinary research, and addressing existing gaps are crucial for advancing this field and fostering more effective university-industry linkages.

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