DISCIPLINARY LEADERSHIP, COLLABORATION AND SCIENCE DIPLOMACY IN THE TURKIC WORLD: AN LLM-ENHANCED BIBLIOMETRIC ANALYSIS

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Abstract

This study presents a novel, LLM-integrated bibliometric approach to comprehensively analyze the dynamics of scientific collaboration and research leadership, with a specific focus on the Turkic World States. In an increasingly interconnected world, it is crucial to understand how and why researchers collaborate, particularly within new geopolitical and cultural groups. This knowledge can stimulate innovation and help regions enhance their scientific achievements through science diplomacy. This research addresses a significant gap in the literature by employing advanced computational methodologies to dissect the intricate layers of collaborative research in an underexplored yet strategically important region. The methodology adopted herein combines traditional bibliometric techniques with state-of-the-art text mining and Large Language Model (LLM) capabilities. Initially, a robust dataset of scientific publications from the Turkic World States will be compiled from reputable scholarly databases. This raw data will then undergo a rigorous text-mining process to extract key information such as author affiliations, keywords, abstract content, and citation networks. A crucial innovation of this study lies in the strategic integration of LLMs. These models will be leveraged for advanced thematic analysis, enabling the identification of nuanced research topics, emerging trends, and the classification of complex collaborative patterns that might elude conventional bibliometric methods. Furthermore, LLMs will assist in discerning and categorizing the roles of various entities within collaborative networks, thereby providing deeper insights into the mechanisms of research leadership. The analysis will specifically investigate the extent and nature of intra-regional and inter-regional scientific collaborations involving Turkic World States, identifying key collaborative hubs, prolific institutions, and influential researchers for science diplomacy. The study aims to map the evolution of research themes over time, pinpointing areas of strength and potential growth. Through a meticulous examination of co-authorship networks and citation flows, patterns of leadership, both institutional and individual, will be identified and quantified. By integrating the interpretive power of LLMs, the research seeks to move beyond mere quantitative metrics to offer qualitative insights into the characteristics that define effective research leadership and successful collaborations within this unique geopolitical context. The findings are expected to provide valuable insights for policymakers, funding agencies, and research institutions seeking to enhance scientific cooperation and elevate the research standing of Turkic World States on the global stage.

Keywords

Large Language Models (LLM), Text Mining, Bibliometrics, Scientific Collaboration, Research Leadership, Turkic World States

Organization of Turkic States (OTS): Historical Development and Structure

The foundations of the Organization of Turkic States (OTS) are based on the summits that started in 1992. These summits aimed to promote cooperation among the independent Turkic states, allowing leaders to come together to discuss common problems and evaluate opportunities for cooperation (Akçapa, 2023; Bayramol, 2025). In this process, a common identity and sense of purpose have developed, and the ground has been prepared for the creation of more formal institutional structures. A wide range of issues such as economic development, cultural exchange and security cooperation, were discussed at the summits. This reflected the different interests and priorities of the participating States. The first steps have demonstrated the determination of the Turkic states to establish stronger relations and to seek solutions to common problems together. This structure gained an institutional identity with the Nakhchivan Agreement signed in 2009 and became official under the name of "Turkic Council" (Özsoy, 2023). The Nakhchivan Agreement was an important turning point in the institutionalization of cooperation between the Turkic states. With this agreement, the official charter and organizational structure of the organization were determined. Thus, a more stable and predictable cooperation framework has been established. The Turkic Council has served as a permanent platform for dialogue and decision-making; It has enabled member states to coordinate their policies and engage in joint initiatives. The agreement also defined the main objectives aimed at promoting political, economic and cultural cooperation (Baki, 2014).

The main objective of the OTS is to develop and strengthen comprehensive cooperation among member states (Tarçın, 2025). This comprehensive approach reflects the necessity of cooperation in various fields to achieve sustainable development and support regional stability (Kireçci & Biltekin, 2022). By creating a common space for the Turkic states, OTS aims to produce solutions to common problems together and to achieve common goals. Fields of activity of the organization; It covers a wide range of areas such as trade, investment, transportation, energy, education, culture and security. This multifaceted understanding of cooperation of the OTS reveals its vision of becoming a leading power in regional integration and development in the Turkic world (Alizada, 2025)

Member States and Observer Status

The founding members of the OTS are Azerbaijan, Kazakhstan, Kyrgyzstan, and Türkiye (Alizada, 2025; Terzioğlu, 2013). Uzbekistan became a full member of the OTS in 2019. These states share a common Turkic heritage and have a strong will to promote regional cooperation and integration. Differences in their geographical location, economic structures and political systems contribute to the richness and multifaceted structure of the OTS. Each member state contributes its unique knowledge and perspective to the organization, enriching the dialogue and increasing the effectiveness of its activities. The founding members played an important role in shaping the agenda and priorities of the OTS and ensured that the organization developed in a way that was sensitive to the needs of the member countries.

As of July 2025, the observer states of the Organisation of Turkic States (OTS) are Hungary (since 2018), Turkmenistan (since 2021), the Turkish Republic of Northern Cyprus (TRNC) (since 2022), and the Economic Cooperation Organisation (ECO) (since 2023) (Çınar & Uzun, 2023). The granting of observer status to these countries reflects the OTS's commitment to the principle of inclusivity and its desire to expand its cooperation network. Observer countries participate in the activities of the organization and contribute to the dialogue processes. However, they do not have the right to vote on the decisions taken. This status makes it possible for these countries to gradually integrate into the OTS structure and evaluate opportunities for closer cooperation with member states.

This expansion has increased the geographical and cultural impact of the organization and expanded its reach and sphere of influence (Akçapa, 2023). The inclusion of new members and observer states has expanded the geographical scope of the OTS, allowing it to reach wider communities and regions. At the same time, the cultural diversity of the organization has increased; Different perspectives and traditions have come together. The expanding geographical and cultural influence has increased the capacity of the OTS to produce solutions to regional problems and contributed to the creation of a more comprehensive cooperation environment. The Organization's growing partnership network and expanding field of activity show that its importance in the international arena is increasing.

Structure and Functioning of the Organization

The OTS carries out its activities through various committees and working groups; these structures focus on specific areas to cooperate (Uzunaa, 2025). Committees and working groups enable experts and officials from member countries to come together to share information and develop joint initiatives. These structures play an important role in identifying problems, developing policies and implementing projects in their areas of expertise. These groups, organized around key sectors such as economy, culture, education, transportation and energy, reflect OTS's multifaceted cooperation approach. The effective operation of these structures is decisive in the implementation of the OTS's agenda and the achievement of its objectives.

These structures support comprehensive development by encouraging cooperation in many areas such as economy, culture, education, transportation, and energy (Manaflı, 2021). Economic cooperation, aims to increase trade, investment and economic integration. Studies in the cultural field strengthen the sense of shared identity and promote understanding and respect between different communities (Şeker & Yalçın, 2024, p. 94). Educational projects aim to improve the quality of education and support student-lecturer exchange. Transportation projects facilitate trade and tourism by improving regional connectivity (Özdemir, 2021). Energy cooperation, on the other hand, contributes to the safe and sustainable energy supply of member states. This multidimensional approach enables OTS to directly contribute to the welfare and general development of the Turkic world (İpçioğlu & Petek, 2024)

The decision-making processes of the organisation involve the member states, with policies determined in line with common interests, based on inclusiveness and mutual benefit (Akçapa, 2023). The OTS's decision-making structure is based on the principle of consensus. This means that all member states have a say in shaping policies and priorities. Decisions are made through consultations and negotiations between member states. Different interests and points of view are taken into account. This inclusive approach strengthens the member states' sense of ownership and increases the applicability of the decisions taken. A focus on shared interests strengthens regional stability and cooperation, ensuring that OTS policies benefit all members.

In addition to fostering political and economic cooperation, the OTS reflects significant diversity in research and development (R&D), which has strategic implications for regional innovation and economic growth. Among the organisation's member and observer states, Türkiye recorded R&D expenditure of 377.5 billion TRY ($13.9 Billion) in 2023, accounting for 1.42% of its GDP, a substantial increase compared to previous years (Turkish Statistical Institute, 2024). Meanwhile, in Azerbaijan, R&D expenditure accounted for just 0.18% of GDP in 2023 (World Bank, 2025). Meanwhile, Kazakhstan's R&D expenditure accounted for 0.14% of its GDP in 2023, and Uzbekistan reported 0.13% for the same year. Kyrgyzstan's R&D expenditure accounted for 0.06% of its GDP in 2023 (World Bank, 2025). Turkmenistan reported R&D expenditure of 0.17% of GDP in 2023 (United Nations Economic Commission for Europe, 2025). Among the observer states, Hungary recorded R&D expenditure equalling 1.39% of its GDP in 2022 (World Bank, 2025). These figures illustrate the varied levels of commitment to research and innovation across the region, highlighting both the challenges and opportunities of collaborative projects under the OTS framework.

Although the institutional framework and R&D ecosystem of the OTS are primarily associated with the political, economic, and cultural domains, they also have the potential to yield tangible results in the fields of scientific cooperation and science diplomacy, and to contribute significantly to regional integration. In our study, we conducted a multi-perspective analysis to evaluate the growth of scientific activities among member and observer states and examine the reflection of multidimensional cooperation, as promoted by the OTS, in academia, supported by empirical data.

Data and Method

To closely examine the reflection of the multidimensional cooperation encouraged by the OTS in the academic field, it aimed to conduct a study on the scientific publications published with the contributions of the member and observer countries of the OTS. For this purpose, an online search of the Web of Science (WoS) database [1] examined a

[1] Refine results for (CU=(Türkiye or Azerbaijan or Kazakhstan or Kyrgyzstan or Uzbekistan or Hungary or Turkmenistan or "Turkish Republic of Northern Cyprus") and TS=(Biochemistry Molecular Biology or Cell Biology or Physics Applied or Physics Multidisciplinary or Physics Condensed Matter or Physics Particles Fields or Physics Atomic Molecular Chemical or Physics Nuclear or Physics Mathematical or Physics Fluids Plasmas or Chemistry Multidisciplinary Or Chemistry Physical Or Chemistry Analytical Or Chemistry Organic Or Chemistry Inorganic Nuclear or Biophysics or Genetics Heredity or Immunology or

significant dataset covering the period between 1972 and 2026. A total of 69487 scientific documents obtained from 7925 different sources (journals, books, etc.) were analyzed. The obtained data were processed using the R programming language and in this context, bibliometric analyses were carried out through the Bibliometrix package. The number of citations, h-indices, keyword distributions and international cooperation rates of the publications were examined in detail within this framework. In addition, the Python programming language and Scikit-learn library were used for text mining, clustering and relational analysis. In this way, scientific interaction networks between countries and institutions have been revealed; Thematic structures, cooperation patterns and citation relationships are modeled numerically. In the study, natural language processing (NLP) and an artificial intelligence-based text classification method were used in order to make interdisciplinary classifications based on the content of scientific publications. The abstract sections in the bibliographic records obtained via WoS were processed using the Python programming language and each text was classified within the framework of four main science disciplines (Social Sciences, Natural Sciences, Formal Sciences, Applied Sciences). In this process, the LLaMA 3.2 large language model (LLM) was used, which works through the Ollama library; Each abstract text was given to the model and the relevant discipline category was determined. In order to increase efficiency in the classification process and to prevent repetition of transactions, the checkpointing method was adopted, and the processed records were stored in JSON format, allowing the algorithm to continue from where it left off. In addition, the classification results were both momentarily printed on the screen and permanently exported to an external text file. In the whole process, the progress of the transactions was monitored with the tqdm module, thus providing visual feedback to the user. This methodological approach has allowed for the discipline-based separation of large volumes of bibliometric data with high accuracy. These methods contributed to the depth of the study in terms of both visualization and analytical accuracy.

When the number of publications is evaluated, the annual growth rate. The exponential growth observed in the number of publications shows that the number of academic publications addressed to the member countries of the OTS has increased. The average age per document is 9.87 years, suggesting that the literature reviewed is relatively up-to-date. The average number of citations was calculated as 20.9 per document, which gives an idea of the scientific impact of the documents. The presence of 2156289 references in total indicates the intense citation relationships in the literature. In terms of document content, 84695 keyword phrases were identified under Keywords Plus (ID)

Microbiology or Virology or Neurosciences or Mathematics or Mathematics Applied or Mathematics Interdisciplinary Applications or Statistics Probability or Astronomy Astrophysics or Geology or Geochemistry Geophysics or Oceanography or Evolutionary Biology or Agronomy or Ecology or Biodiversity Conservation or Materials Science Multidisciplinary or Materials Science Characterization Testing Or Materials Science Coatings Films or Materials Science Composites or Materials Science Textiles or Materials Science Ceramics or Materials Science Paper Wood or Materials Science Biomaterials or Nanoscience Nanotechnology or Crystallography or Optics or Spectroscopy or Quantum Science Technology) and Publication With Expression of Concern or Retraction or Retracted Publication or Correction (Exclude – Document Types) and Türkiye or Hungary or Türkiye or Kazakhstan or Azerbaijan or Uzbekistan (Countries/Regions)

and 121287 keywords provided by the author (DE). This shows that the dataset has been extensively indexed. At the level of authors, there are contributions of 189649 different authors and 4290 documents consist of single-author studies. The number of single-authored documents is 6102, with an average of 9.36 authors per document. International collaborations, on the other hand, have a significant rate of 37.44%, which shows that there is a global interaction in the field of research.

Evaluations in terms of Countries and Publication Performance Indicators

The analysis based on WoS data provides the opportunity to comparatively evaluate the scientific production capacities of the member and observer countries of the OTS and their international academic impacts.

Table 1

Countries and Publication Performance Indicators

h-index	Country	Citation sum within h-core	All citations	All articles
193	**TURKIYE**	**60925**	**590869**	**36879**
166	**HUNGARY**	**63537**	**262620**	**11022**
144	USA	69671	128796	2695
49	**KAZAKHSTAN**	**4941**	**14371**	**1773**
98	GERMANY	21245	51453	1702
90	UK	17638	38135	1182
35	**AZERBAIJAN**	**2532**	**6424**	**991**
35	**UZBEKISTAN**	**3789**	**7623**	**852**
69	FRANCE	14263	26505	786
50	RUSSIA	6784	13232	776
70	ITALY	12353	23386	737
58	JAPAN	29261	35355	476
44	SAUDI ARABIA	3736	8142	449
56	PEOPLES R CHINA	8466	13840	441
53	SPAIN	5744	10810	412
53	IRAN	5545	10511	391
42	POLAND	5089	8349	373
42	ROMANIA	5388	8810	348
43	INDIA	4088	7187	334
50	SWEDEN	5507	9080	304
44	AUSTRIA	5238	8629	299
48	CANADA	5973	9345	281
45	BELGIUM	5606	8328	275
55	NETHERLANDS	9317	12546	268
44	SWITZERLAND	5568	8376	262
28	PAKISTAN	1461	2911	231
29	CZECH REPUBLIC	2445	4034	210
30	EGYPT	1599	3206	207
44	AUSTRALIA	4489	6737	196
40	SOUTH KOREA	4469	6338	193

In this context, Türkiye, which is among the founding members of OTS, has a remarkable academic performance with an h-index of 193. Türkiye has received a total of 590,869 citations with 36,879 scientific articles and 60,925 citations within the scope of h-core. These data reveal that Türkiye successfully maintains its regional leadership role not only

in the political and economic arena, but also in the scientific field. The other OTS members, Kazakhstan, Azerbaijan and Uzbekistan, have a relatively low number of publications and citations, but they are important actors with the potential for regional scientific cooperation. Kazakhstan has 49 h-indexes, 1,773 articles and 14,371 total citations, while Azerbaijan has 6,424 citations with 35 h-indexes and 991 publications. Similarly, Uzbekistan continues its scientific contribution with 7,623 citations in 852 publications. These indicators show that the research capacity of these countries is developing and can be moved to a higher level with scientific collaborations. Hungary, which is among the OTS observer countries, has a remarkable scientific production capacity with 166 h-index and 11,022 publications. The fact that Hungary has received 63,537 citations within the scope of h-core shows that it offers important opportunities in terms of academic collaborations that can be carried out with the OTS despite its observer status. The fact that the TRNC is not independently included in the WoS data reveals that the scientific production potential of this country should be made more visible under the umbrella of the OTS. Turkmenistan, on the other hand, still has limited data in terms of scientific production, and it should be made to increase this capacity with existing cooperation mechanisms. The indicators reveal that the strengthening of scientific networks under the umbrella of OTS is of strategic importance in terms of improving regional knowledge production and joint research capacity. Both the effective use of the existing scientific potential and the support of countries with low production levels will contribute to the institutionalization of science diplomacy in line with the long-term development vision of the OTS.

Evaluations in terms of Publication and Performance Indicators of Institutions

From the point of view of the members and observers of the OTS, academic performance indicators should be evaluated not only at the level of countries but also in terms of leading academic institutions. In this context, academic institutions in OTS member countries have significant potential to increase international scientific impact and cooperation opportunities.

Table 2
Evaluations of Institutions in terms of Publication and Performance Indicators

h-index	Unit	Citation sum within h-core	All citations	All articles
92	HUNGARIAN ACAD SCI	16654	46576	1665
71	UNIV SZEGED	10916	29178	1204
70	MIDDLE E TECH UNIV	9048	20770	689
69	EOTVOS LORAND UNIV	14170	29535	1203
69	ISTANBUL TECH UNIV	9072	23992	1124
68	HACETTEPE UNIV	7795	25407	1386
62	BILKENT UNIV	8362	16460	534
56	CUKUROVA UNIV	6932	12310	497
56	UNIV DEBRECEN	7921	15308	672
55	ANKARA UNIV	5322	16179	987
53	BUDAPEST UNIV TECHNOL & ECON	5504	13418	727
52	ISTANBUL UNIV	4847	14215	928
51	EGE UNIV	4938	15042	1003
50	GAZI UNIV	4384	13939	920
50	SAKARYA UNIV	4370	10428	539
48	DOKUZ EYLUL UNIV	4434	9937	664
48	MARMARA UNIV	4053	10100	608
47	YILDIZ TECH UNIV	4051	11375	822
47	SELCUK UNIV	4855	11051	570
47	KOC UNIV	6233	10400	389
47	ERCIYES UNIV	3949	8355	460
46	KARADENIZ TECH UNIV	4428	10470	534
46	ATATURK UNIV	3610	9940	655
46	FATIH UNIV	4110	7132	229
45	SEMMELWEIS UNIV	5508	10697	503
44	FIRAT UNIV	2961	6314	434
43	AKDENIZ UNIV	4228	6830	340
43	BOGAZICI UNIV	4943	8058	350
42	ESKISEHIR OSMANGAZI UNIV	3555	8325	532
42	ANADOLU UNIV	3582	6446	288

Scientific Performance of Institutions in Türkiye

Universities in Türkiye have the potential to strengthen an important academic network within the OTS. Istanbul Technical University (ITU) is a Turkish university with the highest academic performance with an h-index of 9.072 and has 1,124 publications with 23,992 citations. Hacettepe University and Bilkent University also have significant scientific production capacity with h-indexes of 7.795 and 8.362, respectively. In particular, Hacettepe University's 1,386 articles and 25,407 citations reflect its strong academic profile in the field of health and life sciences. Remarkable results are also seen among other Turkish universities. Ankara University occupies an important place in scientific production with an h-index of 5,322 and a total citation of 16,179. In addition, foundation universities such as Koç University and Sabancı University, although they have a lower number of publications, carry out studies of higher quality and are expanding their international impact. These data indicate that Türkiye has a significant capacity for academic cooperation and establishing scientific networks within the OTS. However, it is obvious that smaller universities such as Firat University, Akdeniz

University and Anadolu University need to develop more international cooperation. Increasing the academic production of these institutions can make the scientific interaction of OTS more efficient.

Institutions in Hungary

Although Hungary is among the OTS observer countries, it exhibits a very strong profile in terms of scientific performance. The Hungarian Scientific Academy stands out as the Hungarian institution with the highest scientific impact, with an h-index of 92 and 16,654 citations. In addition, the University of Szeged (h-index 71) and Eötvös Loránd University (h-index 69) also have significant scientific production capacity. These institutions enable Hungary to assume a regional leadership role in terms of academic cooperation. The contribution of these institutions in Hungary to the scientific projects to be carried out within the framework of the OTS will allow regional knowledge production to be strengthened.

Cooperation Potential of OTS Member and Observer Countries

The data reveal that universities in the OTS member countries show remarkable diversity in the level of scientific production and international influence. While Türkiye stands out as the country with the highest number of scientific publications, it is observed that other member countries such as Azerbaijan, Kazakhstan and Uzbekistan have a more limited but increasing academic production capacity. Universities of these countries can strengthen scientific cooperation within the OTS by increasing their research in different disciplines such as health, engineering and social sciences. The academic institutions of Hungary and other observer countries can carry out scientific projects and joint research between Türkiye and the member countries of the OTS. Such collaborations will contribute to creating a scientific impact on a global scale by increasing the knowledge production capacity of the Turkic world. In order to strengthen OTS in the scientific field, the interactions between these institutions need to be further deepened.

The academic institutions of the OTS member countries have the potential to create a strong and effective scientific network. This will not only support regional development but also strengthen scientific cooperation at the global level and increase the knowledge production capacity of the Turkic world.

Thematic Evolution Map

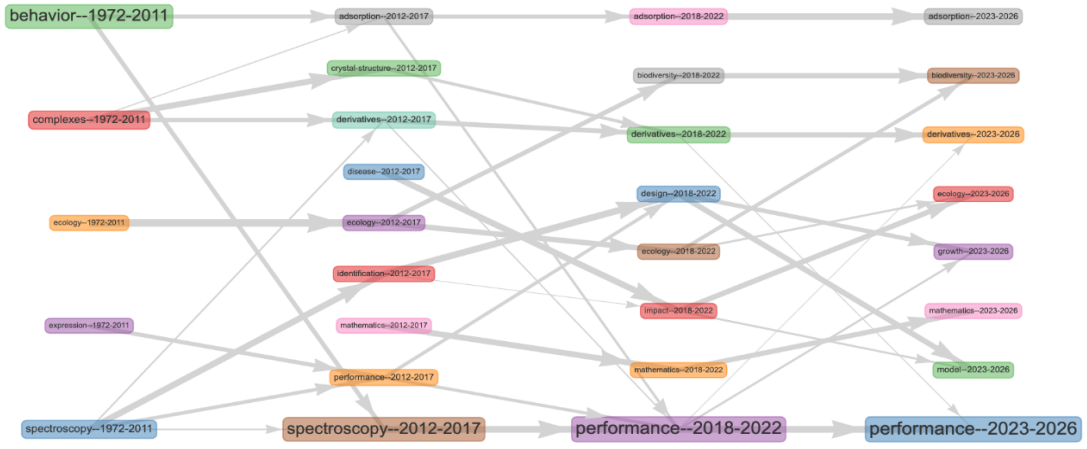
In this part of the study, in order to evaluate the thematic structure of the research area, the process from the beginning to the present day is discussed in four periods in terms of publication years: 1972-2011, 2012-2017, 2018-2022, 2023-2026. A conceptual network map has been developed showing the relationships and evolution of keywords in

different time intervals for these determined periods[2]. When evaluated in the context of scientific cooperation between the member countries of the Organization of Turkic World States and Hungary, this map shows which thematic cooperation alanlarda yoğunlaştığını ve bu temaların zaman içinde nasıl bir değişim gösterdiğini anlamak için değerli bir araç sunmaktadır.

It is seen that the relationship of the keyword "performance" with other keywords has become stronger from the 2012-2017 period to the 2023-2026 period. This may indicate that scientific cooperation between these countries is increasingly oriented towards performance-oriented research and that joint studies in this field are increasing. Similarly, the fact that the keyword "spectroscopy" has existed for a long period of time and has established relationships with different themes shows that cooperation in this field is permanent and diverse. On the other hand, the fact that some keywords appear at certain time intervals and then disappear or their relationship weakens indicates that collaboration is dynamic and has changing interests. For example, the keyword "behavior" is evident in the early periods, but less associated in later periods, suggesting that the focus of cooperation changes over time (Figure 1).

Figure 1

All Periods



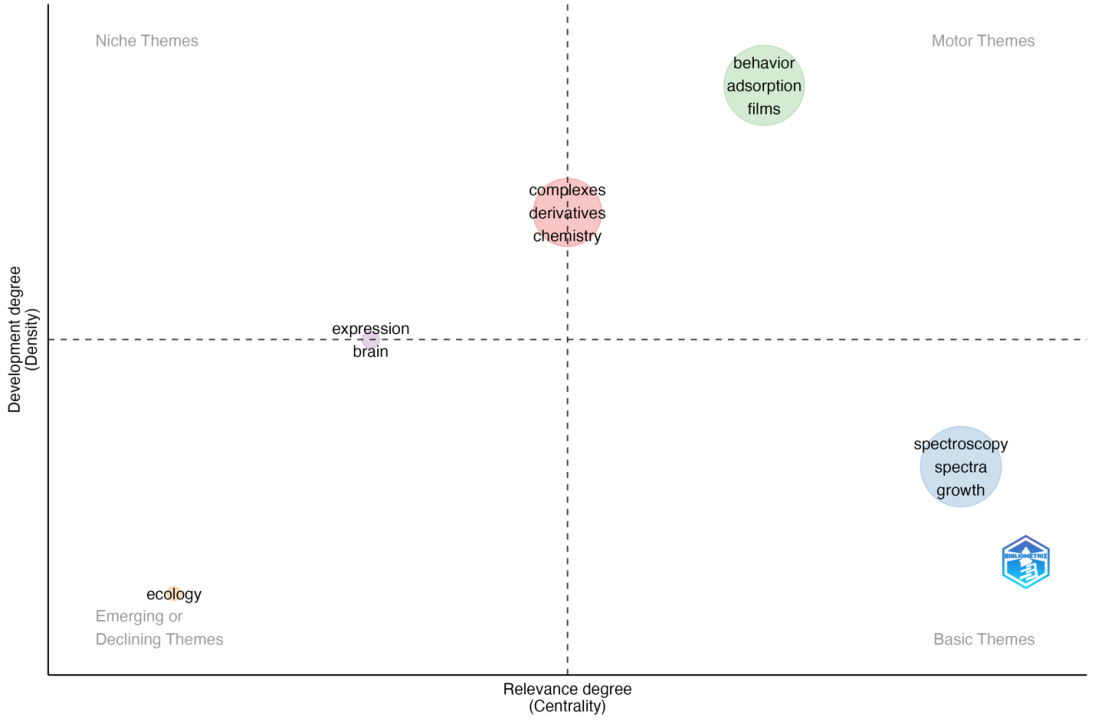
[2] It is a strategic diagram created using a bibliometric analysis technique called thematic mapping. The diagram allows the themes in a particular area of research to be positioned according to two basic dimensions: Relevance degree: It shows the strength of a theme's connection with other themes within the field and its importance in the overall structure of the area. High centrality implies that the theme is strongly associated with the key concepts of the field and plays a central role. It is positioned on the horizontal axis. Development degree - Density: Indicates the level of development and maturity of a theme within itself. High density implies that the theme has a well-defined conceptual structure, strong research, and a coherent literature. It is positioned on the vertical axis. These two dimensions divide the diagram into four quadrants and allow us to interpret the strategic significance and developmental status of the themes in each quadrant in different ways:

Analysis of the 1972-2011 Period

In this period, the thematic structure of the research area is shaped as follows (Figure 2).

Figure 2

Strategic Diagram for the Period 1972-2011



Motor Themes (upper right quadrant) shows that the keywords "behavior", "adsorption" and "films", which have high centrality and high density, were the main drivers of the research area of these subjects between 1972 and 2011. It can be interpreted that these themes are strongly related to the research focuses of the member countries of the OTS and that they have an intense research activity within themselves. In terms of Niche Themes (upper left quadrant), it is possible to say that the keywords "complexes", "derivatives" and "chemistry", which have low centrality but high density, interact less with their general structure, but are highly specialized and in-depth topics in themselves. When the Basic Themes (Lower right quadrant) are examined, it is observed that the keywords "spectroscopy", "spectra" and "growth", which have high centrality but low density, find their place in this quadrant, and it can be said that these themes are of central importance for the field, but they may not yet have as mature or scattered literature as motor themes. These themes will be flagged as potential areas of growth in the future. When the Developing or Declining Themes (Lower left quadrant) are evaluated, it is seen that the keyword "ecology", which has low centrality and low density, is found in this quadrant. This theme also has a weak connection with other themes in the field and is at a low level of development. In addition, the words "expression" and "brain", which are located close to the center but at a low density, represent topics that have not yet received enough attention or development in this period, while their location close to the center

indicates topics that will include Transition Themes (Near the Center Themes) that can potentially become important for the field or establish connections between different thematic areas in this period.

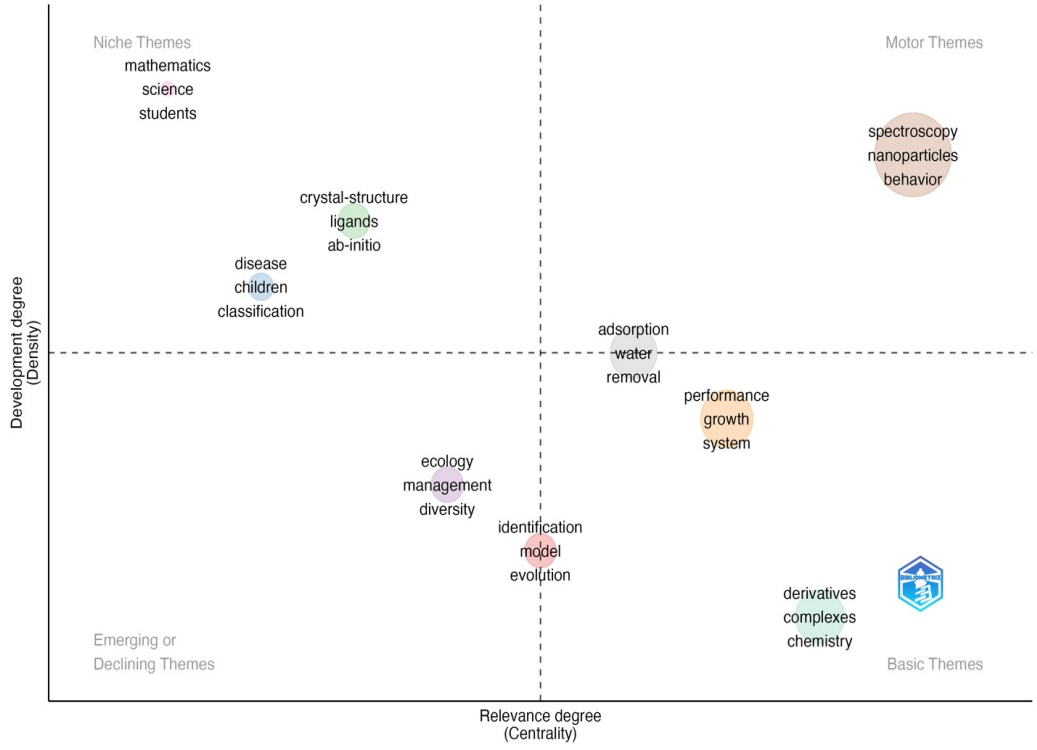
When the period of 1972-2011 is evaluated in general, topics such as "behavior", "adsorption" and "films" formed the basis of the research area and attracted great attention. Areas such as "complexes", "derivatives" and "chemistry" have continued to exist as more specialized niche research areas. Key themes such as "spectroscopy", "spectra" and "growth" seem not to have yet reached their full potential, although they are of central importance. "Ecology", on the other hand, seems to be a more marginal subject in the field during this period. Topics such as "expression" and "brain" can be considered transition themes that point to possible future developments.

2012-2017 Period Strategic Diagram Analysis

When the strategic diagram analysis of the 2012-2017 period is examined, significant changes are observed in the thematic structure of the research area (Figure 3).

Figure 3

Strategic Diagram for the Period 2012-2017



While the keywords "spectroscopy", "nanoparticles" and "behavior" still exist in terms of motor themes, it is observed that concepts such as "adsorption" and "films", which we call motor themes in the 1972-2011 period, are not included in this quarter in this period. This can be interpreted to mean that "spectroscopy" and "nanoparticles" remain important as the main drivers of the field, while "adsorption" and "films" have become

relatively less central and dense. The fact that the theme of "Behavior" remains the motor theme indicates that this issue continues to be important in the field. While the keywords "mathematics", "science" and "students" remain niche themes, more specific topics such as "crystal-structure", "ligands", "ab-initio", "disease", "children" and "classification" also found their place in this quarter. This continues to increase the existence of various specialized research areas in the field. When we look at the basic themes, it is possible to say that the concepts of "derivatives", "complexes" and "chemistry" maintain their central importance for the field, but they have not yet reached the level of motor themes. When we consider the developing or decreasing themes, it has been determined that in addition to the "ecology" theme in this quarter in the 1972-2011 period, the concepts of "management" and "diversity" also showed low centrality and low density in this period. This situation suggests that the issues have not yet received enough attention in the field or have started to lose their importance. The words "identification", "model" and "evolution" are among the other concepts that are close to this quadrant. When we examine the transition themes, "expression" and "brain", which can be considered as transition themes in the 1972-2011 period, maintain their positions close to the center in this period. However, new themes such as "adsorption", "water", "removal", "performance", "growth" and "system" are also located close to the center. From this point of view, it can be said that related topics can have an increasing importance for the field and they can establish connections between different thematic areas. In particular, it is observed that "performance" and "growth" have the potential to move towards motor themes.

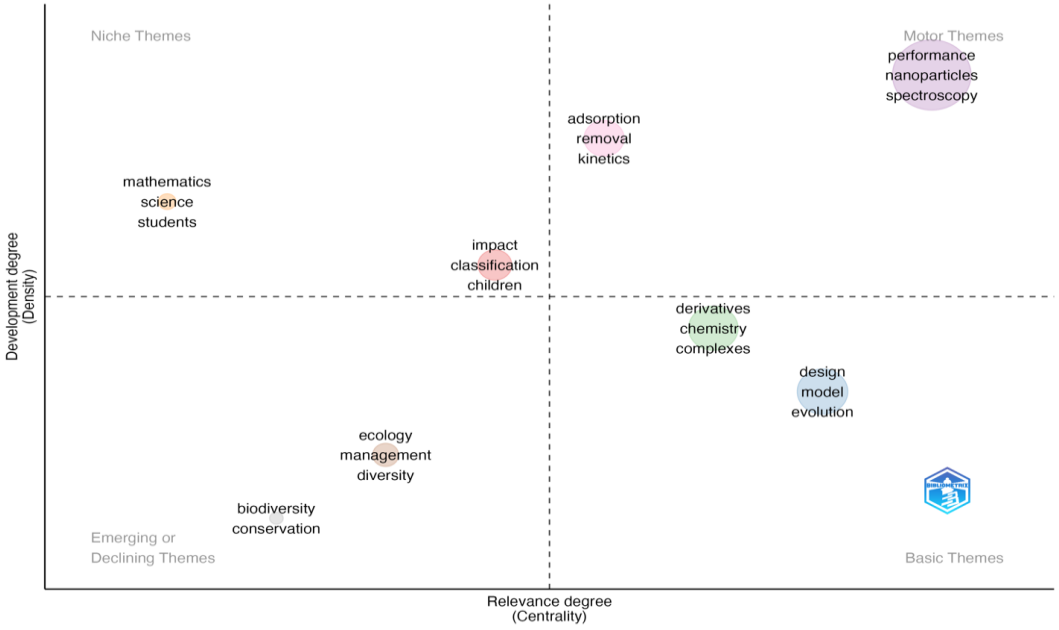
When we compare the transition process from the 2012-2017 period to the 1972-2011 period, it is determined that the themes of "adsorption" and "films" are among the motor themes in the context of change in motor themes, and the concepts of "spectroscopy" and "nanoparticles" maintain their importance. This is important in that it shows that there has been a shift in research focus between the two semesters and that nanoscience and spectroscopy have become the main areas of interest in the field. The continuity of the theme of "Behavior" over the periods is also remarkable. When we evaluate it in terms of the diversification of niche themes, an increase in the number of themes is observed, and it can be said that this indicates an increase in specialization in the field. In terms of the continuity of the basic themes: derivatives, "complexes" and "chemistry" can be said to remain fundamental, but not yet fully mature. It is noteworthy that while the theme of "ecology" continues to receive low attention when the state of ecological themes is observed, related topics such as "Management" and "diversity" have a similar tendency. The emergence of new themes such as "performance", "growth", "water" and "removal" in the context of new transition themes points to the potential and increasing interest of these topics in the field.

2018-2022 Period Strategic Diagram Analysis

In this period, changes in the thematic structure of the research area become evident (Figure 4).

Figure 4

Strategic Diagram for the Period 2018-2022



The keywords "performance", "nanoparticles" and "spectroscopy" continue to strengthen their position as motor themes. It is noteworthy that "performance", which appeared as a transition theme in the 2012-2017 period, joined the motor themes in this period. The absence of the "Behavior" theme in this quadrant may indicate that this topic has lost its relative centrality and intensity. Niche Themes include "mathematics", "science" and "students". This quadrant also contains the words "adsorption", "removal" and "kinetics". This is noteworthy in that it shows that these topics, which were among the transition themes in the 2012-2017 period, evolved into more specialized niche areas during this period. While "derivatives", "chemistry" and "complexes" remain the main themes, the words "design", "model" and "evolution", which are close to this quarter in the 2012-2017 period, are also among the main themes in this period. This suggests that these topics remain central to the field but have not yet reached the level of motor themes. In terms of evolving or declining themes, the words "ecology", "management", "diversity", "biodiversity" and "conservation" continue to appear in this quarter. This suggests that these topics continue to have a trend of low interest in the field. The words "impact", "classification" and "children" are also located close to this quadrant. As transition themes, there are the words "impact", "classification" and "children" close to the center in this period. This suggests that these topics may be of increasing importance to the field and can establish links between different thematic areas.

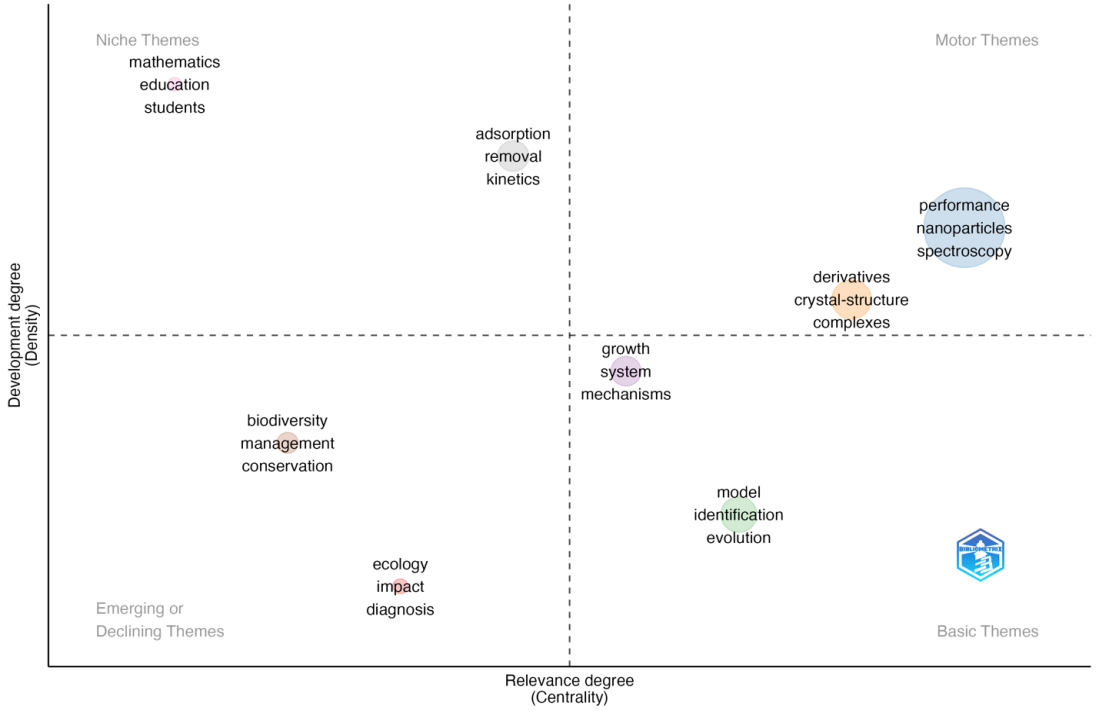
When we compare it with the 2018-2021 period and previous periods, "performance", "nanoparticles" and "spectroscopy" became stronger as motor themes in terms of consolidation of motor themes. The emergence of the theme of "Behavior" from motor themes is an important change. When we closely examine the evolution of niche themes, it is noteworthy that topics such as "adsorption", "removal" and "kinetics" have shifted from transition themes to niche themes, showing that these topics are concentrated in more specific sub-areas. The concepts of "derivatives", "chemistry", "complexes", "design", "model" and "evolution" remain important in terms of the stability of the basic themes. The continued low relevance of ecological themes is striking. The fact that topics such as "impact", "classification" and "children" are approaching the center as new transition themes point to the future potential of these topics.

2023-2026 Period Strategic Diagram Analysis:

This most recent thematic structure illustrates the following features (Figure 5).

Figure 5

Strategic Diagram Analysis for the Period 2023-2026



Recently, "performance", "nanoparticles" and "spectroscopy" continue to maintain their importance as motor themes. This is important in terms of showing that these topics are currently the main focuses of the research area and the most active research areas. While "mathematics", "education" and "students" continue to exist as niche themes, the words "adsorption", "removal," and "kinetics" also continue to appear in this quadrant, indicating the persistence of these topics as specialized interests. "Derivatives", "crystal-structure," and "complexes" remain the main themes. This is indicative that these topics continue to be of central importance to the field but have not yet reached the level of

motor themes. It is noteworthy that the words "growth", "system" and "mechanisms" also appear in the position close to this quadrant, which may indicate that these issues have the potential to gain fundamental importance. Evolving or declining themes. The words "biodiversity", "management," and "conservation" continue to appear in this quadrant, indicating that interest in these topics is relatively low. The words "ecology", "impact" and "diagnosis" are also close to this quadrant. The words "growth", "system", "mechanisms", "model", "identification" and "evolution" are located close to the center. This suggests that these topics may be of increasing importance to the field and can establish links between different thematic areas. In particular, it can be said that "growth", "system" and "mechanisms" tend to move towards basic themes.

This diachronic thematic analysis, which is carried out through scientific publications between the member countries of the Organization of Turkic World States and Hungary, offers a unique perspective on the dynamics of scientific cooperation in this geographical and cultural context. "Performance", "nanoparticles" and "spectroscopy", which stand out as continuous motor themes, point to the scientific fields that form the basis of this collaboration and are of great interest. This confirms the existence of strong scientific interaction and joint research activities between these countries, especially in areas such as materials science, nanotechnology and spectroscopic methods. The fact that the theme of "Behavior" has lost importance over time suggests that cooperation focuses more on concrete scientific and technological outputs. The niche themes "mathematics", "education" and "students" reflect the basic scientific background and educational dimension of this collaboration. While mathematics functions as a universal language and tool for joint scientific studies, the themes of education and students constitute an important dimension of cooperation in terms of training future scientists and knowledge transfer. The continuity of themes such as "adsorption", "removal" and "kinetics" in niche areas indicates the scientific commonalities that have intensified and deepened in certain areas of expertise.

In the context of core themes, concepts such as "derivatives", "crystal-structure" and "complexes" demonstrate the strong commitment of this collaboration to core scientific disciplines such as chemistry and materials science. The evolution of the themes of "growth", "system" and "mechanisms" into the core themes indicates that joint research shows a tendency toward understanding and modeling more and more complex systems. The low interest of ecological themes in all periods suggests that this cooperation network has not yet focused sufficiently on the issues of environmental sustainability and ecological impacts. This situation reveals that potential cooperation opportunities in this field should be evaluated in the future.

Dynamic shifts in transition themes offer clues about the possible future directions of this scientific collaboration. The fact that themes such as "expression" and "brain" lose their clarity after their transitivity in the early periods may indicate that common interests have changed over time. The recent rise of concepts such as "growth", "system", "mechanisms", "model", "identification" and "evolution" as transitional themes indicates that this cooperation has taken on an increasingly interdisciplinary character and that the search for common solutions to complex problems is increasing. In particular, the prominence of modeling and system approaches shows that scientific cooperation is evolving towards a more strategic and result-oriented structure.

This analysis, based on scientific publications between the member countries of the Organization of Turkic World States and Hungary, shows that the current collaboration is based on strong foundations and focuses on certain scientific fields. Future cooperation potentials can be further enhanced, especially by supporting interdisciplinary approaches and the search for common solutions to global problems.

Methodology for Quantitative Analysis of Publication Output and Disciplinary Leadership Among OTS Countries

Within the scope of this research, a systematic data processing procedure was adopted to integrate information derived from multiple data sources and prepare it for subsequent analysis. The study utilized two primary datasets: firstly, a main dataset serving as the foundation for the core analyses, assumed to contain essential research metrics and Unique Technology Identifiers (UTIs); and secondly, an auxiliary dataset providing information regarding the associated "leading country" for each specific UTI. The procedure for identifying leading countries was underpinned by the precise linking of information from the auxiliary dataset to the main dataset. This process primarily involved assigning a single country attribution for each unique UTI present in the auxiliary dataset. This attribution was based on the principle that the first recorded country within the list of associated countries for each given UTI was designated as the "leading country". This derived correspondence was subsequently organized into a key-value pair structure (a dictionary). In the final stage, this constructed mapping of leading countries was employed to query the UTI for each record within the main dataset, and the corresponding leading country information was appended as a new attribute to the main dataset. This methodology facilitated the consolidation of related information from disparate data sources into a single, unified dataset, thereby establishing a robust foundation for the in-depth statistical analyses to be conducted in subsequent stages. Such integration enables a more comprehensive understanding of complex relationships and the derivation of holistic conclusions.

Research Leadership of the OTS Countries by Discipline

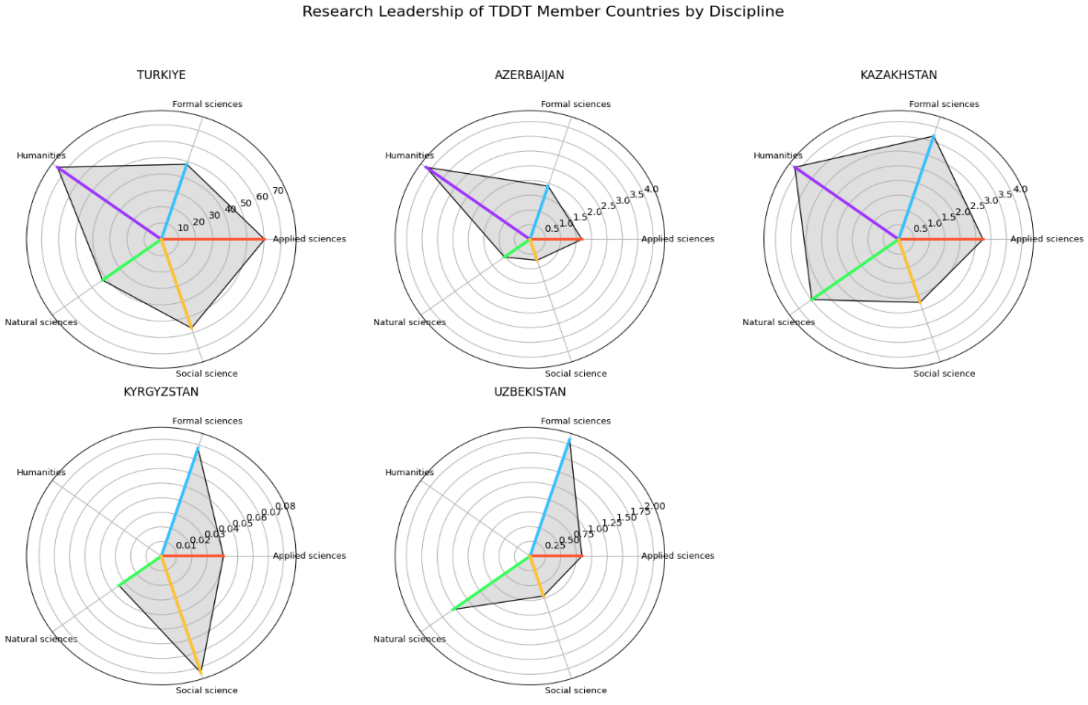
This part of the study, aims to reveal the scientific publications of the countries that are members of the OTS and especially in which fields of science they stand out. We have noticed that records about Türkiye are sometimes written in different ways (such as "TURKEY"); they are put together in the form of a single correct spelling, "TURKEY". Then, publications with a confidence score above 0.7 were selected to ensure the reliability of the data. During the analysis phase, only the publications of the current member countries of the OTS were focused. It is possible to say that one of our most important innovations in the method we consider to measure research leadership is not only to look at which country publishes how much, but also to examine in which branches of science (i.e. disciplines) each country is more active and in a leading position. This has given us an important insight in terms of showing the general scientific power of the countries, as well as which areas they specialize in and on which issues they can cooperate in the future.

As a result of all these processes, regular tables were obtained showing both the total number of publications of each member country and how many publications they made in which disciplines. In this way, while having the opportunity to concretely evaluate the scientific contributions of the countries of the Turkic World and in which fields they can be pioneers, a perspective on how academic collaborations in these regions can be more efficient was also reflected. A specific methodology was followed in determining the status of research leadership. The author list of publications within the scope of the study was examined. Unless otherwise noted, the first author in a publication is assumed to be the leader of that research. However, if there is corresponding author information in a publication and this corresponding author belongs to a different name than the first author, research leadership is attributed to that corresponding author. In this case, the leadership contribution is calculated for the institution and country to which the corresponding author belongs. This approach aimed to more accurately reflect the actual leadership roles and the institutional/national contributions associated with them.

In light of this information, this analysis aims to illustrate the research leadership across disciplines within the OTS member countries, providing valuable insights into each nation's scientific orientations. The visual representation highlights the relative research intensity of these countries across five core disciplines: Formal Sciences, Applied Sciences, Social Sciences, Natural Sciences, and Humanities.

Figure 6

Research Leadership of TDDT Member Countries by Discipline



Upon examining the visual, it becomes apparent that the scientific research priorities of OTS member countries exhibit distinct differences. While some nations demonstrate prominence in specific disciplines, others display a more balanced distribution. These variations can be linked to the respective countries' national development strategies, economic structures, and historical backgrounds.

Analyzing the research leadership across disciplines within the OTS member countries reveals distinct scientific priorities for each nation. Türkiye demonstrates strong leadership, particularly in Applied Sciences and Social Sciences, with significant activity also observed in Formal Sciences and Humanities; this reflects the country's dual emphasis on technological advancement and societal issues. Azerbaijan, in contrast, concentrates its research leadership predominantly in Formal Sciences and Applied Sciences, a focus that aligns with its objectives to bolster its energy sector and technological infrastructure. Similarly, Kazakhstan exhibits pronounced leadership in Formal Sciences, alongside robust positions in Applied Sciences and Social Sciences, indicating its engagement with both fundamental sciences and practical applications. Kyrgyzstan's profile, meanwhile, suggests a relatively more balanced distribution across Formal Sciences and Social Sciences, implying an effort to develop scientific capacity across a broader spectrum. Lastly, Uzbekistan showcases significant leadership in Formal Sciences and Applied Sciences, an emphasis that resonates with the nation's goals for industrialization and economic diversification. This comparison reveals that the OTS countries' diverse scientific priorities are closely linked to their national objectives, economic interests, and areas of science diplomacy. Our chapter analysis reveals significant opportunities for these nations to exchange expertise and strengthen their collaborations through science diplomacy, thereby facilitating shared progress and innovation.

Results also present significant opportunities for scientific collaborations among the OTS member countries. Nations can assist in developing the capacities of other states by sharing their knowledge and expertise in areas where they demonstrate strength. Türkiye’s accumulated knowledge in Social Sciences could serve as a valuable resource for other OTS countries. The leadership of Azerbaijan and Kazakhstan in Formal and Applied Sciences could lay the groundwork for joint research projects and technology transfer in these fields. Countries like Kyrgyzstan, exhibiting a more balanced distribution, could leverage the specialized expertise of other OTS nations to strengthen their scientific infrastructure. In this context, this figure clearly illustrates the diversity and potential of the scientific research ecosystems within the OTS member countries. It is of paramount importance that this data be discussed on diplomatic platforms to facilitate the identification of common research agendas and to advance regional scientific integration. Such analyses will play a critical role in enabling the OTS to achieve its objectives of deepening cooperation in science and technology.

Discussion

The results of this study offer important opportunities for scientific cooperation within OTS. The study points to a dataset suitable for discussion on diplomatic platforms, aiming to establish common research agendas among countries and advance regional scientific

integration. In particular, Türkiye's accumulated knowledge in the field of Social Sciences can be used as a valuable resource for other OTS countries. The leadership of Azerbaijan and Kazakhstan in the fields of Formal and Applied Sciences can lay the groundwork for joint research projects and technology transfer in these fields. Countries with a more balanced distribution, such as Kyrgyzstan, can strengthen their scientific infrastructure by taking advantage of the expertise of other OTS countries. The study results provide a framework for cooperation that can help each OTS member develop the capacities of other countries by identifying their strengths. This will be possible not only through the sharing of knowledge and expertise, but also through the provision of joint research projects and technology transfer. In the literature, it is seen that more successful results are obtained if similar types of scientific cooperation initiatives are carried out in coordination with international diplomacy (Gazni et al., 2012; Luukkonen et al., 1992; Sonnenwald, 2007; Wang et al., 2013).

Creating diplomatic and scientific spaces to share and discuss the findings of this study is crucial for building stronger and more meaningful ties between the science academies of OTS countries. These platforms can help explore how scientific research connects with regional integration and economic growth, and highlight the important role the OTS plays on the world stage.

It is also vital that these spaces ensure scientific data is shared securely and used ethically. The insights from this study can become a valuable tool to boost scientific cooperation among OTS countries, driving both academic progress and technological innovation in the region. The study's primary objective is to catalyze collaboration among OTS countries, facilitating the pursuit of common objectives for/in science diplomacy.

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