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A Mathematical Perspective on the Research Trends in Positive Operators on Banach Lattices (2000-2024)

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ABSTRACT: This study presents a comprehensive bibliometric analysis of research on positive operators in Banach lattices, based on 633 publications indexed in Scopus database between 2000 and 2024. Using Bibliometrix (R) and Vosviewer, we examined annual publication trends, most productive authors, prominent journals, leading institutions, contributing countries, and the most frequent keywords and co-authorship network analyses were used. We found that the number of studies has increased within the last years, with significant contributions from Moroccan institutions and researchers. This work provides a structured overview of current research dynamics and highlights emerging themes and collaborative patterns in the field.

Key Words: Banach lattices, positive operators, bibliometric analysis.

Contents

1. Introduction

The theory of positive operators emerged in the early 20th century, has become one of the most inherently fascinating branches of mathematical analysis in recent years, driven by the increasing development across various fields, particularly in spectral theory, economic mathematics, theoretical physics and engineering. Riesz's early work, combined with that of Kantorovich, Freudenthal, and Birkhoff, established the axiomatic and structural foundations of ordered vector spaces and Banach lattices. Since then, the field has been augmented by such milestones as Schaefer's Banach Lattices and Positive Operators (1974), Aliprantis and Burkinshaw's Positive Operators (1985; reprinted 2006), Zaanen's Riesz Spaces II (1983), Luxemburg and Zaanen's Riesz Spaces I (1971), and Meyer-Nieberg's Banach Lattices (1991). They remain the standard texts, shaping the research of compact, Dunford–Pettis, narrow, and

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dominated operators.
While the conceptual grounding is solid, the literature is not supported by a formal bibliometric overview of scholarly work in this area. Discovery of trends in publications, geography, institutional productivity, and novel themes is essential to determine the state of the art and recommend future research. A bibliometric perspective can reveal collaboration patterns, identify top authors and journals, and trace changing research themes over time.
Consequently, this research answers the following research questions:

1. What is the annual publication trend in this field from 2000 to 2024?
2. Which journals publish the most research on Banach lattices and positive operators?
3. Which countries and institutions are leading contributors?
4. Who are the most productive authors?
5. What are the prominent keywords and thematic trends?
6. What collaborative networks exist among authors?

2. Methodology

2.1. Research Design

In this study, a bibliometric analysis approach is adopted as the main research methodology. Bibliometric methodology is a quantitative approach that combines statistical and mathematical methods to analyze the connections between research in a particular discipline (Broadus, 1987; Pritchard and Y Wittig, 1981). Bibliometric analysis have been increasingly applied to map scientific fields (Zupic and Čater, 2015; Donthu et al., 2021) [12,15]. Recent reviews in education and technology (Abuhassna et al., 2022; 2024) [8,9] demonstrate how bibliometrics reveals research structure, hotspots, and emerging trends. However, bibliometric studies in mathematics remain limited, often focusing on general productivity rather than specialized subfields. This study contributes novelty by applying bibliometric analysis to Banach lattice operator theory, a domain with growing but fragmented literature.
This bibliometric study followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) framework(Moher et al., 2010) [5]. The study has established comprehensive research, including the analysis of major countries, educational institutions, primary publications, and authors. By exploring keywords in this field, the research not only reflects the content of bibliometric reviews but also indicates the potential future trends.

2.2. Data collection

On July 22, 2025, his study chose the Scopus database for this review, due to its extensive coverage and excellent reputation in the field of scientific article analysis. Through a carefully designed search strategy, this study used the following search terms: TITLE-ABS-KEY (("Banach lattice" AND "operator") OR ("Banach lattices" AND "positive operators")), combined with publication year (PUBYEAR¿1999 AND PUBYEAR¡2025). The targeted subject areas was Mathematics. The search was strictly limited to articles, and English-language publications were implemented. Furthermore, only journal sources were searched.

According to the PRISMA framework, the literature screening is divided into three stages: identification, screening, and inclusion. The primary keywords "Banach lattice" AND "operator" were used in the identification stage, which produced 925 items. By using the inclusion and exclusion criteria (publication year, subject areas, English language, and articles journal), there were 633 articles left. The process of screening brought about the exclusion of 292 papers that failed to satisfy the predetermined criteria.

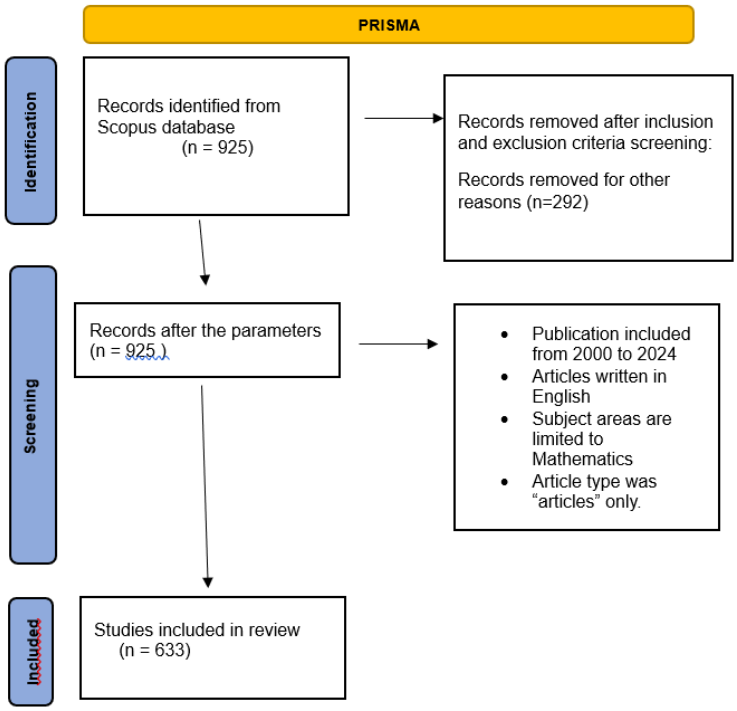

Figure 1: PRISMA Framework.

2.3. Data Analysis

In this study, R Studio (Bibliometrix) and VOSviewer software were used to explore and visually present the scientific collaboration between studies, potential research foci, and trends in the field. After the documents were analyzed, the final bibliometric files were imported into VOSviewer and Bibliometric software. The data files were organized as RIS files for VOSviewer and BibTex files for Bibliometrix. The information obtained from the analysis was visualized, and various scientific maps and network maps were created to present a comprehensible picture of the studies on integrated education research.

3. Results

3.1. Distribution by Years

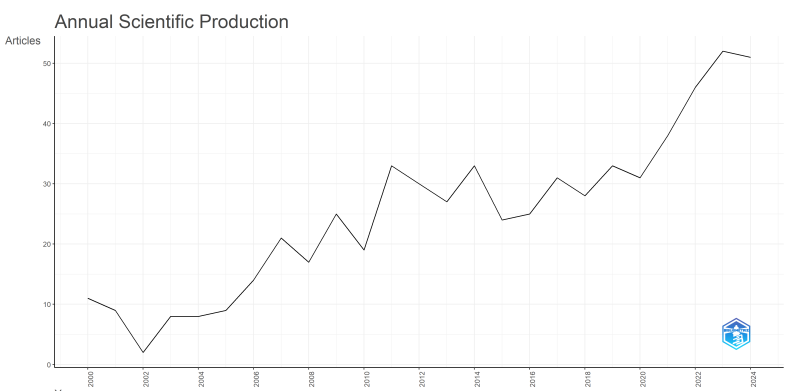

Figure 2: Annual Scientific Production.

The data are displayed in Figure 2. The number of publications related to positive operators on Banach lattices studied from 2000 to 2024 shows an overall upward trend accompanied by short-term fluctuations, reflecting a growing focus on this area. From 2000 to 2005, the number of documents was relatively low and fluctuated, ranging roughly between 3 and 12 per year. The lowest point was in 2002. From 2006 to 2010, A moderate upward trend began. There were occasional dips (like in 2009), but overall the output increased, peaking at around 25 documents in 2009. From 2011 to 2015, A noticeable rise occurred 2011, with document count jumping to over 30. The numbers then fluctuated but remained relatively high. From 2016 to 2020: Output remained somewhat stable with minor ups and downs, generally staying in the 25–35 range. From 2021 to 2023, A significant increase in publications is evident, peaking in 2023 at just over 50 documents. Finally, 2024: Slight dip from 2023 but still above 50, indicating sustained high activity.

3.2. The Most Relevant Journals

Regarding the second research inquiry, which journals publish the most research on positive operators in Banach lattices? A wide array of publications that provide substantial contributions to this topic are evident in Figure 3, according to the data supplied for the years 2000 through 2024. Therefore, this section will answer this question clearly and precisely.

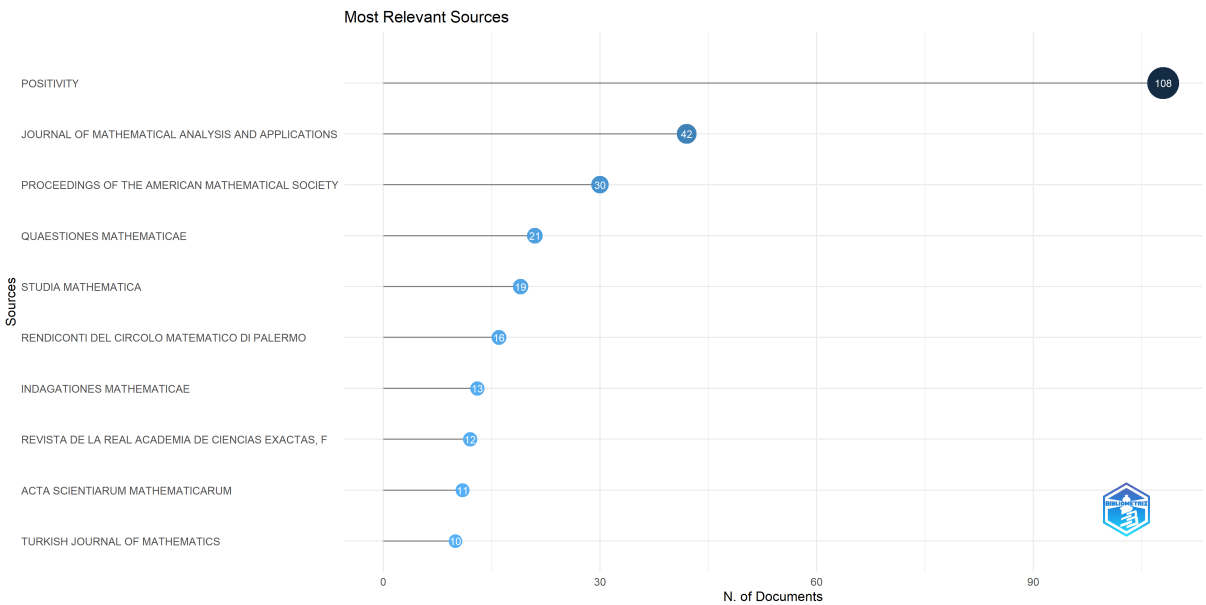

Figure 3: The Most Relevant Sources

At the top of the list is the journal Positivity, which significantly outpaces all other sources with a total of 108 documents. This indicates its dominant role and high relevance in the field under analysis. Following Positivity, the Journal of Mathematical Analysis and Applications holds the second position with 42 documents, suggesting it is also a major contributor to the literature in this area.
Other notable sources include the Proceedings of the American Mathematical Society with 30 documents, and Quaestiones Mathematicae with 21 documents, both of which are well-established journals in the mathematical sciences. The remaining sources show a more gradual decline in publication counts, with journals like Studia Mathematica, Indagationes Mathematicae, and Turkish Journal of Mathematics contributing between 10 and 19 documents each.
Overall, the figure shows the prominence and frequency of contributions by key mathematical journals, highlighting where the most impactful or relevant research in this domain has been published.

3.3. Country contributions

As shown in Table 1. Distribution of publications by countries .

Country	Articles	Articles %	SCP	MCP	MCP %
Morocco	80	12.8	77	3	3.8
Spain	50	8.0	34	16	32.0
China	37	5.9	23	14	37.8
USA	34	5.4	21	13	38.2
Iran	28	4.5	22	6	21.4
Turkey	23	3.7	20	3	13.0
Poland	21	3.4	18	3	14.3
Germany	17	2.7	13	4	23.5
United Kingdom	17	2.7	12	5	29.4
Slovenia	15	2.4	12	3	20.0

Table 1: Top contributing countries by number of articles and level of international collaboration.
SCP: Single-Country Publications **MCP**: Multi-Country Publications

The table presents a comparative overview of the top contributing countries in terms of research articles, highlighting their levels of international collaboration. Morocco leads with the highest number of articles (80), representing 12.8% of the total. Interestingly, the vast majority of Morocco's publications (77) are single-country publications (SCP), indicating low international collaboration, as only 3 articles are multi-country publications (MCP), accounting for 3.8%.
Spain follows with 50 articles (8%), showing a much higher proportion of international collaboration, with 16 MCPs, which represent 32% of its output. China, with 37 articles, also demonstrates strong collaboration (37.8% MCP), similar to the USA (34 articles), which has the highest proportion of MCPs at 38.2%, despite slightly fewer total publications. Other countries such as Iran (21.4% MCP), Germany (23.5%), and the United Kingdom (29.4%) show moderate to high collaboration levels. In contrast, Turkey, Poland, and Slovenia have relatively lower MCP percentages, with 13%, 14.3%, and 20%, respectively.
That table highlights a trend where countries with fewer total publications often engage more in international collaboration, while the leading contributor, Morocco, shows a strong preference for domestic research production. These insights can be useful for identifying potential for collaborative partnerships and understanding the global distribution of scientific output.

3.4. Leading institutions

The data shown in Figure 4 underscores the most important academic institutions in this domain.

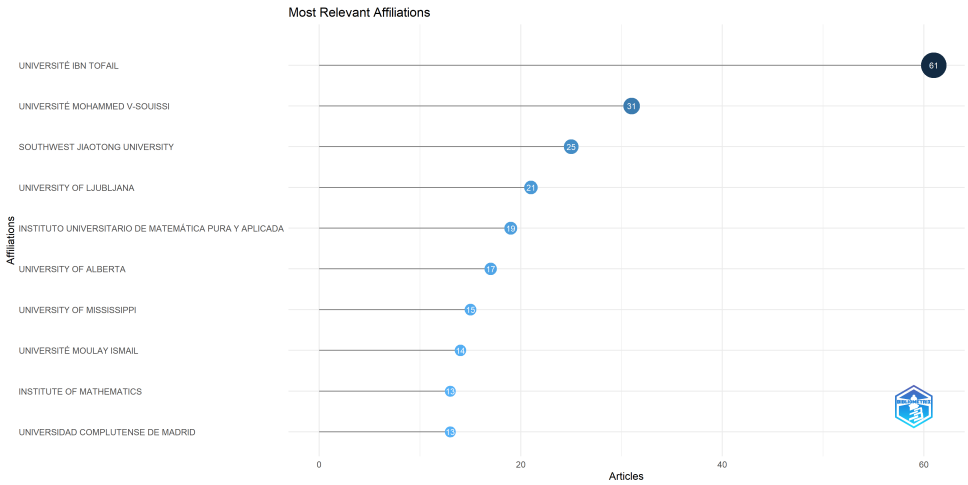

Figure 4: The Most Relevant Affiliations.

University Ibn Tofail has generated the greatest number of publications overall, with 61, which indicates the institution's commitment to Banach lattices research. University Mohammed V-Souissi published 31 articles in this field. These two entities together account for a substantial portion of the total Moroccan output, reinforcing the country's dominant position in the dataset. Other notable Moroccan institutions include the University Moulay Ismail published 14 articles, indicating a strong national research ecosystem. Outside Morocco, institutions like Southwest Jiaotong University (China) published 25 papers, the University of Ljubljana (Slovenia) published 21 papers, and the Instituto Universitario de Matemática Pura y Aplicada (Spain) published 19 papers, also contributing meaningfully. The concentration of output within three Moroccan universities suggests effective institutional strategies and possibly coordinated research agendas, while the involvement of diverse global universities points to growing international collaboration in the field.

3.5. Top Authors

To examine the fourth study question, Who are the most productive authors? The data is shown in Figure 5 and Figure 6.

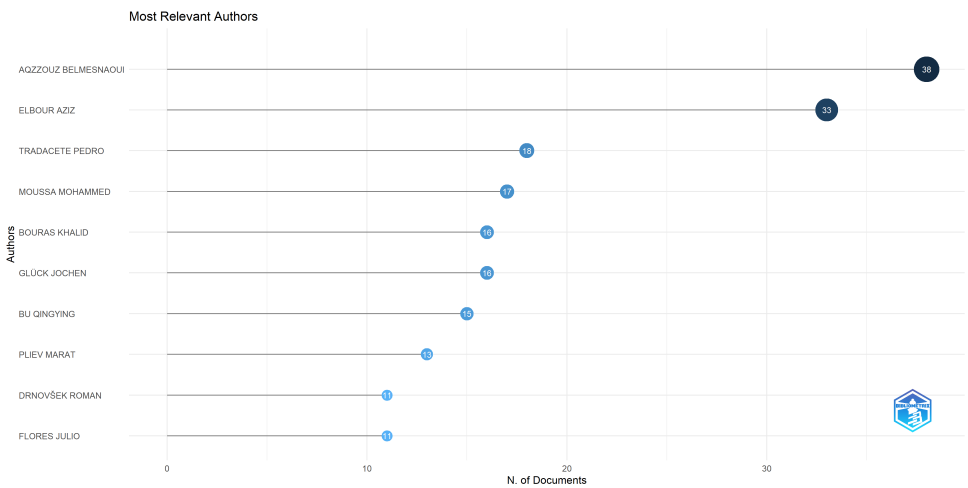

Figure 5: The Most Relevant Authors.

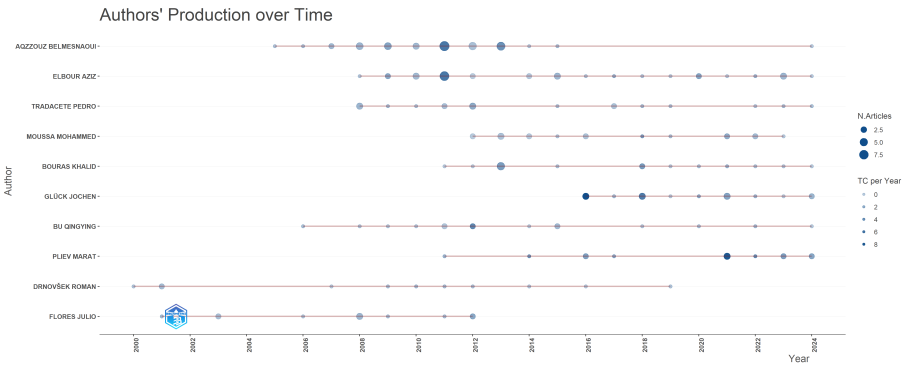

Figure 6: The Authors' Production Over Time.

The figures 5 and 6 reveal that AQZZOUZ BELMESNAOUI is the most prolific author in the field, with 38 publications between 2006 and 2024, followed closely by ELBOUR AZIZ with 33 articles. These two authors demonstrate sustained and consistent scientific output over nearly two decades, with peaks of activity and citation impact around 2011–2012. Other notable contributors include TRADACETE PEDRO (18 articles), MOUSSA MOHAMMED (17), BOURAS KHALID (16), and GLÜCK JOCHEN (16), who also show strong engagement in the field, particularly in the 2010s. Their contributions are regularly cited, reflecting the relevance of their work.
The second tier of active researchers includes BU QINGYING (15 articles), PLIEV MARAT (13), DRNOVŠEK ROMAN (11), and FLORES JULIO (11). While DRNOVŠEK and FLORES were among the earliest to publish in the field (starting before 2005), BU and PLIEV have shown more recent increases in productivity and citation impact. Overall, the results highlight both long-standing contributors and emerging voices, indicating the dynamic and evolving nature of research in Banach lattice theory and operator-related topics.

3.6. Keywords Analysis

To address the fifth question. The figure demonstrates the primary research terms and tendencies, as shown by the information presented in the picture.

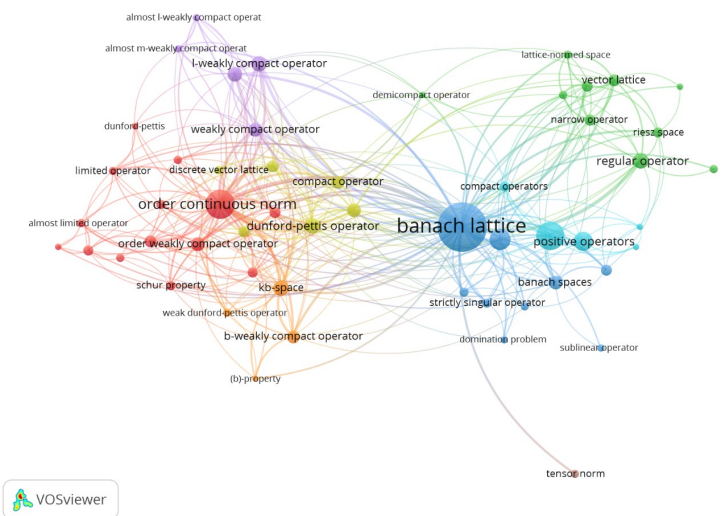

Figure 7: The Most Relevant Words.

Within this section, we draw attention to the study of the occurrences of keywords to define the research emphasis relating to positive operators and Banach lattices. Of the 1693 author keywords reported from 633 articles, 117 keywords meet the threshold of 4 minimum number of keyword occurrences. This number was reduced to 54 keywords in total after relabeling keywords with slight differences using the thesaurus. In Figure 6, the bibliometric map of the keywords is shown using VOSviewer overlay visualization mode to illustrate the effect.

The keyword co-occurrence map generated reveals the intellectual structure and thematic organization of research in the field of Banach lattices and related operator theory. At the center of the network lies the term "Banach lattice", indicating its pivotal role as the core topic around which most of the other concepts revolve. The dense web of connections highlights the rich interrelation between this central concept and various classes of linear and nonlinear operators, lattice structures, and norm properties.

One of the most prominent research clusters focuses on different types of compactness-related operators, such as weakly compact operators, compact operators, order weakly compact operators, and b-weakly compact operators. These operators are frequently studied in the context of Banach lattices due to their significance in understanding weak and norm convergences, as well as their applications in operator theory and functional analysis. Notably, newer variants such as l-weakly compact operators, almost l-weakly compact, and m-weakly compact operators have emerged more recently, as shown by their yellow coloring, indicating publications from around 2020–2022.

Another closely linked thematic area involves Dunford-Pettis-type operators, including Dunford-Pettis operators, weak Dunford-Pettis operators, and almost limited operators. These concepts are typically investigated in connection with the order continuous norm, limited operators, and Schur property, pointing to a significant line of research that blends properties of compactness, weak convergence, and order structure in Banach lattices.

The map also reveals a robust cluster around positive operators, regular operators, and narrow operators, which are crucial in applications involving lattice structures and domination theory. Closely related are the terms Riesz space, vector lattice, and lattice-normed space, which provide the abstract framework underpinning much of the operator theory in ordered vector spaces.

In terms of temporal evolution, the map shows a gradual shift in focus from classical concepts such as the Schur property and KB-space (primarily published around 2012–2015, in darker blue), to more recent interests including tensor norms, domination problem, and narrow operators, highlighted in green and yellow. This temporal gradient suggests emerging research directions and potential areas for future investigation, especially in extending classical results to generalized operator classes or exploring domination phenomena in new contexts.

In summary, the co-occurrence network underscores the central role of Banach lattices in operator theory, while also mapping out the diverse and evolving landscape of research topics. The visualization effectively captures both foundational themes and emerging trends, offering valuable insights for researchers aiming to position their work within current scholarly discourse or to identify promising directions for further exploration.

3.7. Collaboration Networks

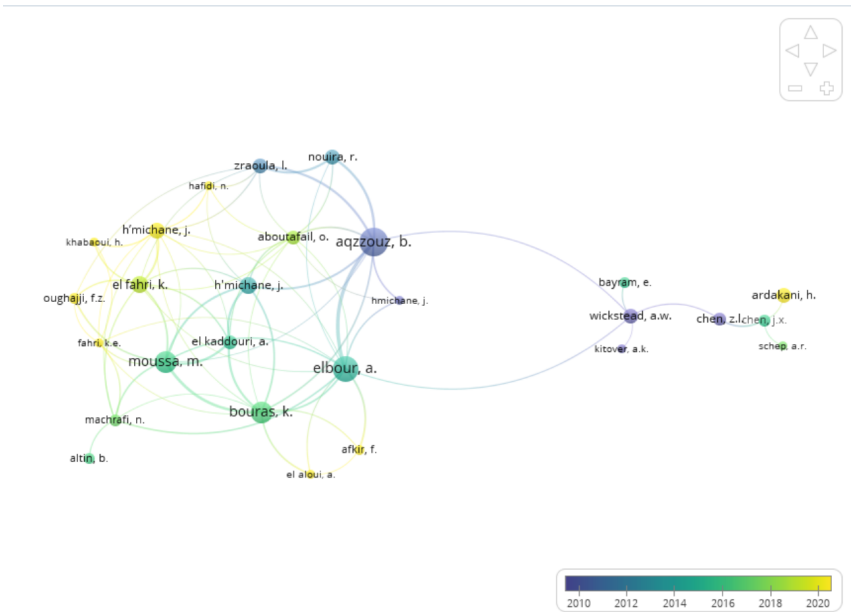

Figure 8: The Collaboration Network.

The co-authorship network displays a well-organized and dynamic collaboration landscape, with Moroccan researchers forming a dense and highly interconnected core. At the center of this network is Aqzzouz, B., who acts as a strategic link between Moroccan scholars and leading international researchers. His collaborations with Nouira, R., Zraoula, L., H'michane, J., Aboutafail, O., and El Bouras, K. highlight his vital role in connecting local expertise to the broader global community. A second influential cluster features Elbour, A., Bouras, K., Moussa, M., El Fahri, K., and El Kaddouri, A., creating a productive and cohesive Moroccan research group. The size of the nodes and the density of links within this subnetwork indicate ongoing collaboration and robust scientific output.

The network also emphasizes several bridging figures who help connect local and international research groups. Aqzzouz, B. serves a central integrative role, linking Moroccan researchers to international collaborators such as Wickstead, A.W., Bayram, E., and Kitover, A.K. This dual positioning suggests his increasing role in promoting cross-border scientific exchange. Meanwhile, the international cluster—comprising authors like Wickstead, A.W., Chen, Z.L., Ardakani, H., and Schep, A.R.—is more loosely connected but maintains important theoretical ties with the Moroccan core through these bridging scholars. The overall structure shows a progressively globalized collaboration landscape.

The temporal color gradient, from dark blue (earlier average publication year) to yellow (more recent), provides insight into the development of co-authorship over time. Earlier collaborations involved scholars such as Wickstead, A.W., Kitover, A.K., and Aqzzouz, B., reflecting the initial phases of international engagement in the early 2010s. More recent authors like Ardakani, H., Hafidi, N.

Overall, the co-authorship map reveals a well-organized structure of collaboration, with a strong local (Moroccan) network that is actively publishing and developing, alongside international collaborations that, while more limited in number, demonstrate important academic ties. Strengthening these global connections may present a valuable opportunity for expanding research impact and visibility.

3.8. Trend Topic

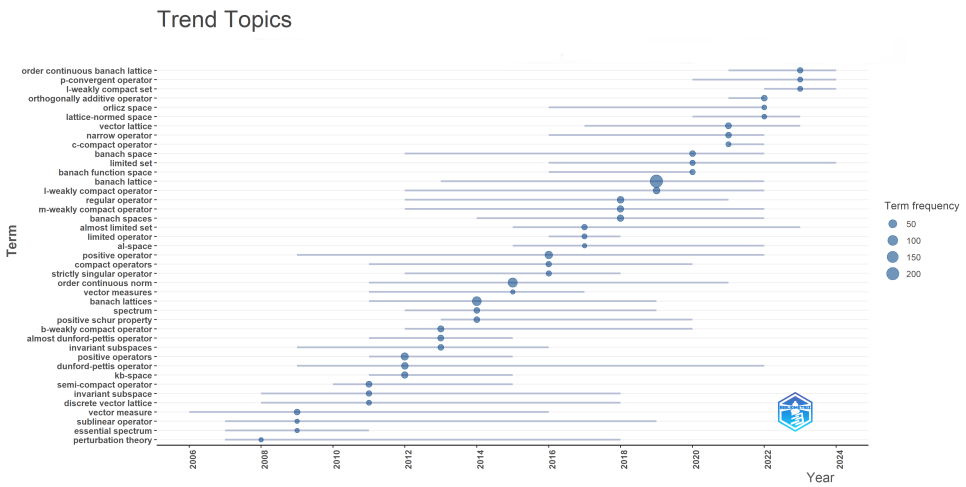

Figure 9: The Trend Topics.

The analysis of topic trends based on author keywords from 2000 to 2024 confirms how the areas of research within the field of positive operators on Banach lattices have evolved over time. A timeline visualization of the occurrences of the keywords provides evidence of several different timelines of topic developments.

In the early 2000s, studies concentrated primarily on general topics such as "positive operator," "Banach lattice," "Riesz space," and "compact operator." These topics note the initial focus of the field of study on the structural properties of ordered vector spaces and classical aspects of operator theory.

From 2010 to 2015, the topics of research began moving towards more narrow topics such as "Dunford-Pettis operators," "almost limited operators," "order weakly compact operators," and "KB-space." In this period, a further understanding and development of weak topologies and concepts of compactness related to Banach lattices was initiated.

Since 2020, the introduction of new keywords shows a change in topic character. Newly developed topics, such as "p-convergent operator," "uaw-convergence," "L-weakly compact set," "tensor norm," "domination problem," and "narrow operator," suggest an interest in more precise convergence properties, generalizations of classical operators as well as structural properties of domination in partially ordered spaces.

4. Discusion

The bibliometric analysis of research on positive operators in Banach lattices published between 2000 and 2024 illustrates a well-established and continuously expanding academic discipline. The increasing trend of publications, especially the spectacular increase after 2011, is indicative of uninterrupted interest and an emerging base for research. The maximum year of publication in 2023 is especially telling, illustrating the present health of the discipline.

The journal analysis confirms the specialized nature of the field because Positivity is found to be the major channel for the circulation of research. The dominance of the journal suggests its significance in setting the discourse and circulating root and pioneer research. The existence of other recognized mathematical journals supports the scientific density of the field.

Morocco is geographically the most productive, a remarkable accomplishment given the typical dominance of countries like the USA or China in mathematics research. However, the proportionally lower international collaboration in Morocco suggests potential for enhancing international partnerships. Conversely, countries like the USA and Spain have higher international collaborations, resulting in the more

integrated global research system.
Institutionally, University Ibn Tofail and University Mohammed V-Souissi have dominated as the primary contributors, underscoring Morocco's domestic research capacity. This concentration in few institutions could be the result of strategic funding, leadership, or research agendas.
At the author level, authors like Aqzzouz Belmesnaoui and Elbour Aziz are also the leaders at both productivity and co-authorship levels. High co-authorship rates between them could reflect an active internal research culture in Morocco, whereas collaboration with international researchers like A. W. Wickstead indicates growing global integration.
Keyword and co-occurrence analysis indicate that even though simple notions such as "Banach lattice" and "positive operator" still constitute the bulk, the field is shifting towards more contemporary notions such as "p-convergent operators", "L-weakly compact sets", and "domination problems." The very fact that they have appeared, especially in recent years, indicates that researchers are pushing the orthodox theory to its limits and investigating more refined or generalized configurations.
Overall, the co-authorship network and trend topic maps indicate an active but still somewhat disjunctive research community. Increased global collaboration and exploration of interdisciplinary applications could continue to enhance the field's visibility and impact.

5. Conclusion

This bibliometric study gives valuable insight into the development of positive operator theory in Banach lattices over the past 24 years. The consistent growth trend of publications, particularly the sharp rise after 2011 and the record-breaking 2023 peak, bears witness to the increasing solidity of the field. Journals such as Positivity have turned into central publication channels, while Moroccan institutions and authors are among the world's top producers.
The findings have both discipline and method contributions. Methodologically, this project applies state-of-the-art bibliometric techniques to operator theory and provides a replicable model for using the same analysis on other areas of mathematics. Disciplinarily, it maps the intellectual landscape of Banach lattice operator theory and shows how core areas have evolved into narrower and more sophisticated subjects.
Practical applications also hold value. To academics, the study points to powerful authors, institutions, and journals that they should be reading or interacting with. To institutions, the analysis proposes greater international cooperation to gain greater visibility and impact. To journals, the results highlight the influence they have on the conversation and on guiding nascent themes.
Future directions are proposed in the study. Expanding the dataset to include Web of Science and MathSciNet would potentially cover more terrain. A move towards more international collaboration, particularly for researchers from Morocco, would increase knowledge exchange and global visibility. Finally, exploring interdisciplinary uses of Banach lattice theory in quantum computing, data science, and economics would potentially open up new research streams and increase the relevance of the field.

6. Strengths, Limitations, and Recommendations

This bibliometric analysis has several strengths. First, it illustrates a complete landscape of the research development on positive operators on Banach lattices during 24 years (2000–2024) both on long-term developments as well as latest developments. Drawing on the Scopus database, the analysis assures high-quality and coherent data, as Scopus is one of the most reliable and widely used academic databases. Additionally, the study integrates multiple levels of bibliometric metrics—e.g., authorship patterns, institutional publication, country-level productivity, co-authorship networks, and keyword co-occurrences—offering a multi-faceted perspective of the field. Using visualization tools like VOSviewer makes it easier to read complex relationships by mapping them as network maps.
Further, the study appropriately identifies potential research topics, such as p-convergent operators and l-weakly compact sets, that can be pivotal research directives. Along with these strengths, the study does have some limitations. The most notable of these limitations is the exclusive use of the Scopus database, which though broad, may not be wide enough to cover all the relevant literature published elsewhere on Web of Science, MathSciNet, or preprint servers such as arXiv. The second limitation lies in the language filter applied, where only English-language publications were considered. This may result in missing seminal work authored in languages other than English. Additionally, the focused attention on positive

operators on Banach lattices, although useful for readability, may overlook concurrent work in more general subfields of functional analysis or operator theory. Lastly, author disambiguation problems—e.g., variations in name spelling or inconsistent use of initials—can put author-level measures and collaboration visualization into question.

Based on these findings, certain recommendations can be made for future bibliometric research in this area. Future research needs to combine multiple databases, including Web of Science, MathSciNet, and Google Scholar, to enhance inclusiveness by searching more indexed literature. More international collaboration is also suggested, especially for countries like Morocco with high research productivity but relatively low global collaborations. Developing further collaborative networks will drive the visibility and impact of research. It is also recommended that researchers explore interdisciplinary applications of Banach lattice theory, for instance, quantum mechanics, economics, or computational sciences, to expand the frontiers of the field. In addition, more usage of author identification tools like ORCID will improve the accuracy of bibliometric analysis. Finally, periodic review of bibliometric studies is suggested in order to track evolving topics and aid academic researchers as well as policymakers to make informed decisions regarding prioritizing future research.

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