

Bibliometric analysis of the scientific dissemination of the Colombian research journal from the formalism of complex networks

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Abstract— *In this study, a bibliometric analysis of scientific production (150 articles and seven journals) was carried out in two areas of knowledge in the 2019-2020 period: social, interdisciplinary, and other social sciences and Engineering and Technology. The study yielded the thematic trends in the different scientific publications. Relevant topics in social, interdisciplinary, such as social sciences are Development, Business, Data, Environmental, Resources, Social, Strategy, and Labour. The most frequent topics in the Engineering and Technology area are Research, Analysis, Strategy, Evidence, and Training. The methodology used for the study was descriptive. The findings showed that a shortcoming persists in incorporating study topics in the scientific field concerning government agendas. On the other hand, the results reflect the incorporation of incident themes in the development of the territories and the political agendas, marking a rapprochement. Finally, there is evidence of growth in scientific publication in the frequent topics linked to political, social, and scientific relevance topics.*

Keywords— *Complex networks, Bibliometric analysis, Big Data, Scientific production.*

I. INTRODUCTION

Scientific production results from the interaction between multiple social actors, academic and business communities to solve needs from the territory. The tool to study this production is through bibliometric analysis [1]. Colombia and several Latin American countries have ventured into improving their arbitration, editorial, and monitoring processes for quality scientific production to guarantee significant contributions from science to social realities and vice versa [2]. This article makes a bibliometric analysis under the complex network approach. For the analysis, scientific journals from Colombia were taken that publish articles in social, interdisciplinary, and other social sciences and Engineering and Technology. The study revealed frequent and recurrent themes and marked trends of study and incidence in the development of scientific production and political and social agendas. The study highlighted related and relevant issues in the social development of the country.

The article contains three sections; the first is the materials and methods used in the data analysis. The second is the findings and analysis of the same results obtained after running programs, statistics, and correlations. Moreover, the last section's discussion and conclusions reveal progress and even gaps in Colombian scientific production. Although gaps persist between scientific production and political and social agendas, the study highlighted related and relevant issues in the country's social development. The article has three sections; the first is materials and methods used in the data analysis. The second is the findings and analysis of the same results obtained after running programs, statistics, and correlations. Moreover, the last section's discussion and conclusions reveal progress and even gaps in Colombian scientific production.

II. MATERIALS AND METHODS

3.1 Materials

For the development of this research, the construction of a web scraping was carried out to generate a textual database to generate later a textual corpus. It was possible to identify the most important patterns of scientific dissemination in Colombia. As for the sample selection criterion, it developed under the principle of a non-probabilistic sample; but statistically significant with the system of scientific publications of the Ministry of Science and Technology of Colombia, because the National Network of Research Journals of Colombia has approximately 20 research journals in the following areas of the OECD:

- Engineering and Technology.
- Social, interdisciplinary, and other social sciences.

Once selected the journal in the previously mentioned categories [4-62], the next step is to select the articles from which the bibliometric analysis will be carried out from their metadata. The bibliometric analysis is a tool that allows the monitoring of scientific publications but also has the purpose of analyzing the functioning, impact, and scientific contribution to the development of nations in their different areas [3-5].

3.2 Methods

The central object of this research is to carry out a bibliometric analysis of Colombian scientific dissemination but from a systemic perspective. This tool is required to, in addition to representing the most critical aspects of it, capture its patterns, similarities, divergences, among other patterns and elements that emerge from their interactions through which it is possible to direct an approximation of the scientific dynamics in Colombia. In this sense, complex networks are an adequate tool for this study because modelling based on graph theory generates archetypes or skeletons of complex systems, which can be described and analyzed systemically from local and global topological measures of the network. To guarantee the construction of a robust model, through which analyzes and inferences about the system, it is necessary to previously carry out a series of processing to reduce the homogenization of the information and reduce the degree of uncertainty of the corpus with the selected articles. Therefore, the processing will be carried out through Natural Language Processing (NLP) techniques and algorithms, according to the following processes:

- **Tokenization:** through this process, the textual corpus is divided into characters to select the characters as the basic unit for constructing the nodes, vertices, or entities of the complex network representing the system with its interactions.
- **Cleaning:** the cleaning process is developed to reduce uncertainty like any other noise collected may have. This process requires a high computational demand. It is necessary to divide into two threads:
 - **Corpus selection:** Information that only constitutes a valid linguistic entity for the system is verified, that is, only select words from the text and eliminate everything that does not comply with the restriction (example: numbers, special characters, escape sequence, between others)
 - **Elimination of Stopwords:** Words that function as connectors in the textual corpus (The, and, a, and others) are eliminated.
 - **Lemantization** is a process transformation from the words in their base format, and any conjugation it eliminated; the dimensionality in the data set is reduced.

Once the refined textual corpus has been obtained, the next step is to build the complex networks from the definition of [45] (quotes from textual networks) from the definition of the set of nodes $V = \{v_1, v_2, \dots, v_n\}$, that is, the state is determined by the number of words that exist in the corpus. The edges $E = \{e_1, e_2, \dots, e_n\}$ is defined as the adjacency or sequentiality of the words v_1 y v_2 , therefore, $e_1 = (v_1, v_2)$.

The topological metrics of complex networks, which will be used in this research, focus on centrality and similarities in each area of knowledge. Centrality measures reflect the importance of a node in a network due to its high degree of connectivity (degree centrality), strategic position (proximity centrality), strategic step in navigating the flow of information (intermediation centrality), and the importance of the node for its neighbours, and its neighbours for it (centrality by eigenvalues). The similarity measures are based on a matrix from the Jaccard index to evaluate if those words with a high level of centrality have relationships with each other. It is a measure from the degree of scientific concentration production, reflecting its participation in the consolidation of science as a strategy primary need of the country.

III. RESULTS AND DISCUSSION OF RESULTS

The results are present in two subsections, the first Engineering and Technology, and the second Social Sciences, interdisciplinary and other social sciences.

3.1 Social, interdisciplinary and other social sciences.

First, the presentation of the global results in this area, a number from 694 topics have keys, valued through the number of nodes (n) of the network.

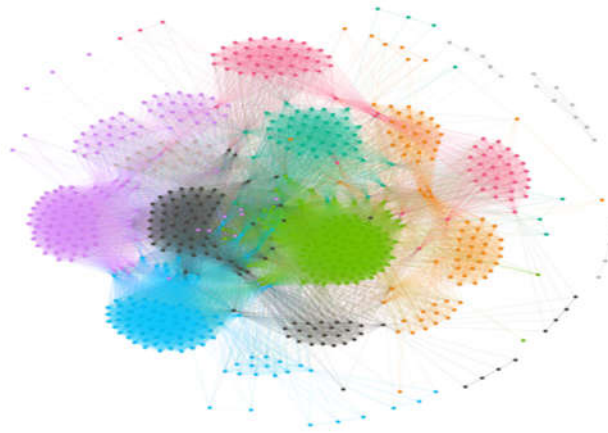


Figure 1. Complex network of key topics disclosed in research journals Social, interdisciplinary, and other social sciences in Colombia

Despite the number of nodes, the relationship of these themes is minimal, as evidenced in the density ($\Delta = 0.12$) where $0 \leq \Delta \leq 1$. The topics are scattered and few related, but the measures are based on the connectivity of the nodes or nodal degree (k). Therefore, a group of nodes with a small proportion of nodes have the most significant number of connections in the network. It is a determinant factor for applying centrality measures in the network to detect patterns in the information that determine the thematic trends disclosed in the research journals of Engineering and Technology in Colombia. The last global result that validates the emergence of central elements is the network's low degree-degree correlation (known as assortativity $\xi = 0.007$ where $-1 \leq \xi \leq 1$) because the most connected nodes are closely connected. Thus, there are a reduced number of highly egocentric subgraphs. Thus, the results obtained for the centrality measures are presented below:

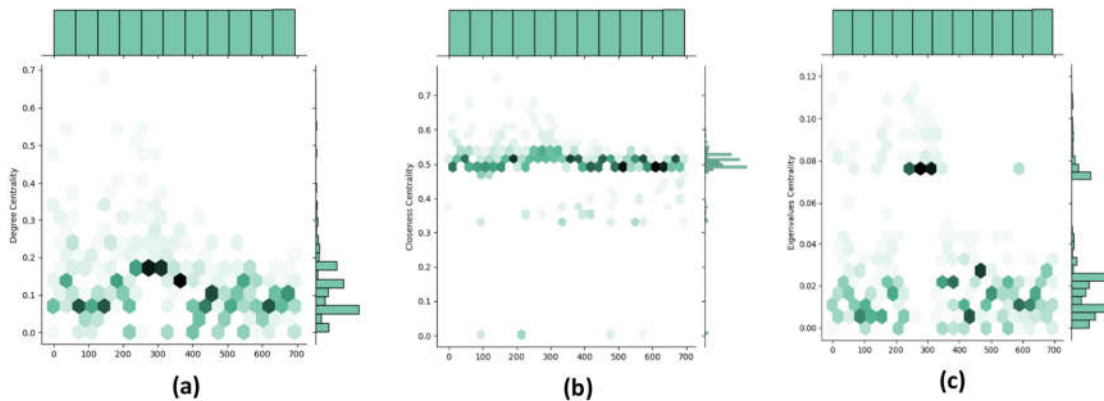


Figure 2. Measures of degree centrality (a), closeness centrality (b) and centrality by eigenvalues (c)

The degree centrality presents a sparse distribution in the region where the most significant values of this measure are concentrated (greater than 0.5, because it normalized between $\in [0,1]$), and, therefore, they are nodes that do not contribute to the generation of patterns from these key aspects that allow evidence of a trend in this area of knowledge. In this sense, the nodes Development (148), Company (6), Data (6), Environmental (416), Resources (505), Social (370), Strategy (208), and Labour (6) according to grade are the Relevant elements of scientific production in the area of Engineering and Technology from the connectivity found in the articles published in these journals. Regarding the closeness centrality, most of the nodes are in the vicinity of 0.5; that is, the geodesic distance between them is very similar, a phenomenon that frequently occurs when there are a small proportion of nodes that contain the greater number of connections in the network that become a mandatory step to interconnect any pair of nodes. In the result of this metric, the same nodes are highlighted as degree centrality. Even centrality by eigenvalues has the same results. Therefore, it confirms that these issues are the fundamental pillars and the most crucial trend in the area of knowledge are subscribed to in those concepts and that they are also utterly disjointed as presented in the similarity matrix presented in the Jaccard index.

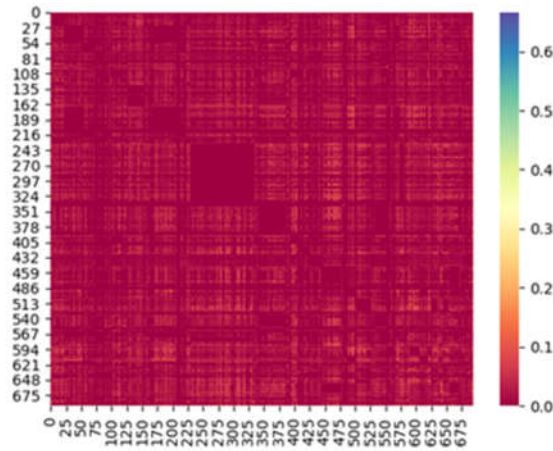


Figure 3. Similarity matrix between the nodes of the complex network of research journals Social Sciences, interdisciplinary and other social sciences

3.2 Engineering and Technology

Unlike the previous area, it is a smaller system because it has $n = 660$ terms, but with less interaction, as presented in the value of $\Delta = 0.076$, with which the differences at the level of the nodal degree are more accentuated, such as It is presented in the following figure:



Figure 4. Complex network of key topics disclosed in Engineering and Technology research journals

The dispersive compartment of this network is similar to the previous one but is more intense by the value of n , and therefore, the distribution of the connections or nodal degree continues to be dominant to determine the central axes of the themes that are present in the dissemination of results in this area of knowledge. A small number of nodes have the greatest number of interactions on the topic and are so decisive that it subordinates the remaining number of topics, a finding that confirms the presence of centralizing nodes. Regarding the existence of possible connectivity correlations between these nodes or degree-degree correlation, we have $\xi = -0.081$, with which it is shown that it is more disruptive than the previous one, with fewer subgraphs (or communities); but with a higher proportion of nodes. Under these principles, we proceed to calculate the centrality results in the following figure.

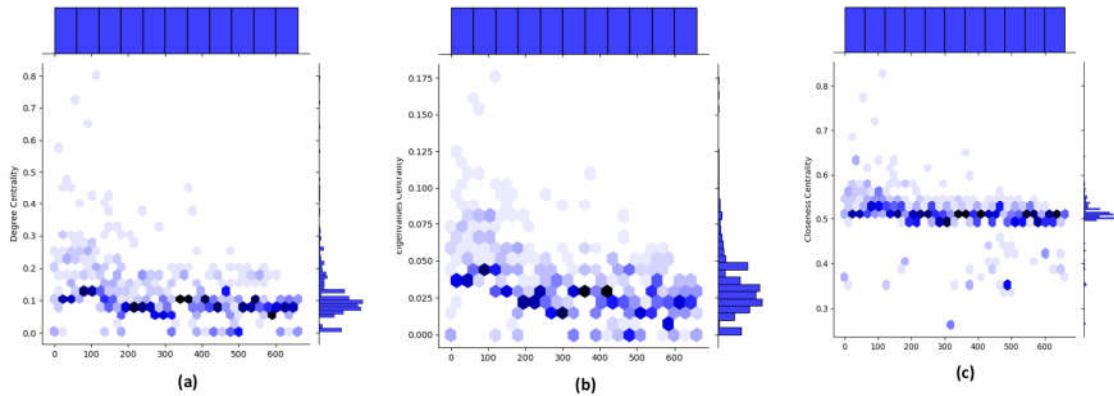


Figure 5. Measures of degree centrality (a), closeness centrality and centrality by eigenvalues (c) of the network of research journals in Engineering and Technology

The degree centrality measure has different limits than the Engineering and Technology journals, but with a greater presence of central nodes (greater than 0.5), among which Research (108), Analysis (19), Strategy (367) stands out. Evidence (147), Training (138). These nodes also contain centrality levels by proximity and by eigenvalues, which reflects a co-occurrence of the behaviour of the most central nodes in the network. Finding that validates the existence of a reduced preference for some topics that widely dominate the popularization of science in social, interdisciplinary, and other social sciences and the area of Engineering and Technologies. This pattern co-occurrence is reflected in the similarity matrix, in which there are few factors in common between the themes in this area, including the most central.

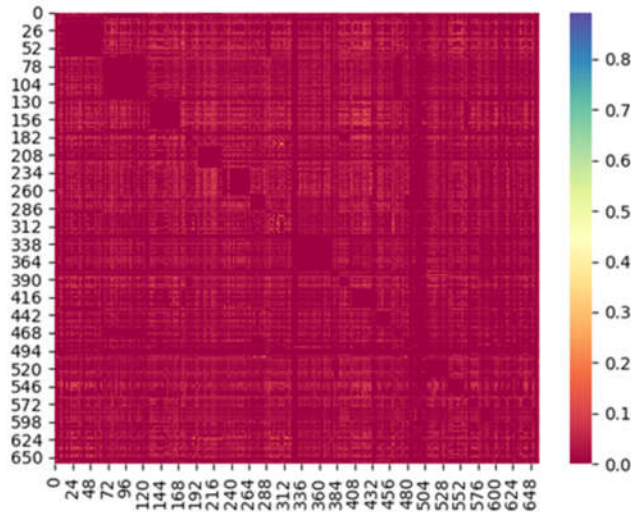


Figure 6. Similarity matrix between the nodes of the complex network of research journals in Engineering and Technology

V. CONCLUSIONS

The results show that trends in the dissemination of science in the country have preferential patterns in some specific aspects in each area of knowledge. For example, in the area of social sciences, interdisciplinary and other social sciences, "Company", "Data", and "Development", are the primary references in development plans and the social and economic councils of the country as stated [45]. Moreover, therefore, most of the country's scientific production must prioritize these elements. However, the volume of articles generated by research groups, science, and technology centers in the country published in high-impact journals do not contain analyses, studies, and / or methodological proposals that allow directing science to the regions with the greatest needs quantity of deprivation in the country. This situation is mentioned in Ostos et al. (2021), as the internationalization of the

country research is required to position research groups. However, it is far from the strategic agendas of the Colombian regions and, therefore, the effectiveness of budget investment is reduced. In particular, the treatment and processing of "Data" has become a determining element for the generation of value in organizations, especially "Companies", which explains the presence of these elements in the centralities detected. Finally, components such as "Environmental", "Resources", "Social", "Strategy" and "Labor", are presenting an essential contribution in the area of social sciences focusing on everything related to the Sustainable Development Goals, clean production, and the use of technology in different aspects of production and servuction. In the same way, the "Labor" element is highlighted, which, although timid in its contribution to measurement, does involve new reflections on labor relations, new ways of linking work in the organizational area, and the contribution to decent and dignified work [54].

Regarding the Engineering and Technology area, the results obtained, although important, are even more fragmented than social science production because the results do not include all of the variables and most essential dimensions of intervention programs and public policies in the country. Even the panorama becomes much more complex when the number of scientific journals that the country has in this area is analyzed, and it is minimal compared to other areas. On the other hand, the challenges and determining factors of the country's social situation are not addressed. Despite this lack, the results obtained with the analysis of centralities highlight "Research", "Analysis", "Strategy", "Evidence" and "Training" present interesting elements. This research is used to generate evidence that leads to the generation of improvements to the decision-making process. In relation to the terms "Analysis", Strateg>Aboutce "there is a frequent relationship in the study, and it has as a neighbor terms such as innovation, processes, methodology, statistics, finding. A close neighbor in the study appears when it accompanies the effective term, the term that has the most frequency. The other relevant issue is training. Although there is no direct relationship with the engineering and technology area at first glance, it is important to remember that it is a dynamic element for transferring knowledge and value management processes in organizations. In this context, it is important to highlight that terms or issues emerge that have been on the political agendas of Colombia for several periods, but, with a low scientific reference as in the case of the social sciences area "Data", "Strategy", " Labour "and for the engineering and technology area " Training "and " Strategy ".

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