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A Bibliometric Analysis of Free Open-Source Software Adoption (2001-2023)

Domingos G. Silva*[a], Carlos Countinho[a], Carlos J. Costa[b]

[a]*Instituto Universitário de Lisboa (ISCTE-IUL), ISTAR, Lisbon, 1649-026, Portugal*
[b]*Advance/ISEG (Lisbon School of Economics & Management) Universidade de Lisboa, Lisbon, 1200-109, Portugal*

Abstract

Free and open-source software (FOSS) has gained increasing relevance worldwide due to its potential to catalyze innovation, reduce costs, and promote technological independence, among other benefits. Although widely adopted in developed countries, developing nations are beginning to realize its transformative potential in socioeconomic development and digital inclusion. Therefore, understanding the evolution of FOSS adoption and its impact is crucial. This research performed a bibliometric analysis of FOSS adoption from 2001 to 2023, using citation and reference data from scientific articles published in high-impact journals. The analysis was conducted using the VOSviewer software, and the data were collected from the Scopus platform. The research revealed a significant growth in scientific production on FOSS, with the United States, the United Kingdom, and India being the countries that produced the most research on the subject. The most common research topics were "foss," "health," "cost," and "information systems". Additionally, there was a lack of approach to the theme of interoperability in countries that collaborate less. The study provides a comprehensive view of the current state of research on FOSS adoption and its impact on different areas. It highlights the importance of understanding the evolving nature of FOSS adoption and its impact in various countries, which could aid researchers, managers, and decision-makers in developing effective strategies. Finally, it emphasizes the potential of FOSS adoption in developing and low-income countries as a viable economic alternative for adopting information and communication technologies.

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Keywords: foss; digitalization; low-income countries; bibliometric analysis; emerging technologies.

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1. Introduction

FOSS has been consolidated in the last two decades as an essential pillar in technological innovation, being widely recognized for its ability to reduce costs, ensure technological independence and promotes innovation [1], [2]. Based on principles of collaboration and transparency, FOSS has fostered an ecosystem conducive to the development and dissemination of innovations [3], [4], [5]. In addition, its benefits, such as security, ease of customization and interoperability, reinforce its relevance as a strategic choice in an economic environment where speed of innovation is crucial to maintain competitiveness [6].

In emerging economies, where, for example, resources are often limited, FOSS plays an even more vital role, offering a unique opportunity to democratize access to technology, boost socio-economic development, and promote digital inclusion [7], [8], [9]. Given the growing relevance of this topic, systematically analyzing FOSS research becomes imperative to understand the state of the art and provide references for future research. The literature on FOSS has gained prominence in recent years, especially in developing countries, due to its potential benefits, such as cost reduction, greater accessibility, and customization options. Studies show that FOSS has been successfully applied in areas such as environmental monitoring, education, and healthcare. For example, Cuppens et al. [10] presented a FOSS-based autonomous vehicle project to monitor pollution in stabilization ponds, demonstrating that, in addition to cost reduction, FOSS promotes more affordable solutions. Another study proposed an integrated software architecture for education systems, highlighting the efficiency and customization that FOSS provides. Wadali et al. [14] , explored the use of FOSS in Indian telemedicine, emphasizing its potential, although it still needs improvements in functionality and integration.

Despite these benefits, challenges such as lack of technical expertise, support, and security and reliability concerns are often cited as barriers to widespread adoption [12], [13], [14]. In Chinese libraries, Jabeen et al. [15]. encountered similar problems, highlighting the need for increased technical support and training. Institutions such as the Open Source Initiative (OSI) [16] and the Free Software Foundation (FSF) [17] have been crucial in promoting FOSS globally, supporting the development and adoption of this software. In addition, companies such as Caixa Mágica Software (CMS) [18] in Portugal have contributed significantly to the spread of FOSS, especially in African countries.

In this context, the present study qualitatively and qualitatively examines FOSS literature in the period from 2001 to 2023, with the main objective of describing scientific mapping of FOSS literature to show current trends and future expectations, thus motivating future development in this field.

The methodology adopted includes a rigorous bibliometric analysis [19], using the Scopus platform for data collection and the VOSviewer software for the visualization of collaboration networks and co-occurrence of research topics. The results indicate a significant growth in scientific production on FOSS, with the United States, the United Kingdom, and India standing out as the main contributors. The research focuses on crucial areas such as "health", "cost" and "information systems", reflecting the interest in understanding the benefits and challenges of adopting FOSS in these sectors. However, it has been observed that less collaborative countries address the topic of interoperability less frequently, which may limit the potential for effective implementation of FOSS in these regions.

This research aims to provide a comprehensive understanding of FOSS adoption, offering valuable insights for developing strategies that can maximize the impact of this technology, especially in developing countries. By identifying the trends and gaps in current research, we hope to contribute to a more coordinated and effective advancement of FOSS on the global stage.

The remaining sections of the article are organized as follows: Section 2 outlines the Materials and Methods, identifying the articles refined through the search strategy and presenting the analytical strategy and VOSviewer software programs. Section 3 presents the results based on the research objectives. Section 4. provides a discussion of the results, followed by conclusions in Section 5.

2. Materials and Methods

2.1. Data Sources and Strategies

The literature review was carried out systematically, analyzing relevant sources [20], [21], [22], using bibliometric analysis techniques, such as co-citation, co-occurrence of keywords and co-authorship by country, to identify trends

in the FOSS domain. The search was conducted in the Scopus database, using the keyword query: ("Open source" OR "Free Software") AND ("Developing countries" OR "low-income countries"). Initially, 9,645 articles published between January 1st, 2001 and March 20, 2023 were found. After applying specific filters to include only final articles, in English and published in journals, the number of relevant articles was reduced to 5,580.

2.2. Data Analysis

The selected articles were extracted in CSV format and imported into VOSviewer, a bibliometric analysis tool [23]. Descriptive analysis helped identify key terms and their connections. Analyses of co-citation, co-occurrence of keywords and co-authorship by country were performed to understand the relationships between the studies. Co-citation revealed how often two articles are cited together, indicating a connection. Keyword co-occurrence showed the most used words and their associations, helping to identify related themes. The analysis of co-authorship by country revealed the frequency of international collaborations between authors, contributing to the understanding of the interrelationships in the studies.

3. Results

3.1. Annual Analysis of Publications

The annual review of publications involves a quantitative and qualitative evaluation of scientific articles in a specific field over a given period. In the case of FOSS, bibliometric analysis reveals patterns and trends in scientific production. The distribution of the research, presented in Fig. 1, shows an increase in the production of articles from 2001 to 2023, with peaks in 2021 and 2022, when 982 articles were published in 2022. This growth trend indicates a growing interest in FOSS, especially compared to previous years such as 2001 and 2011, when fewer than 100 papers were published. This increase may reflect a greater awareness and interest in FOSS in information technology and society.

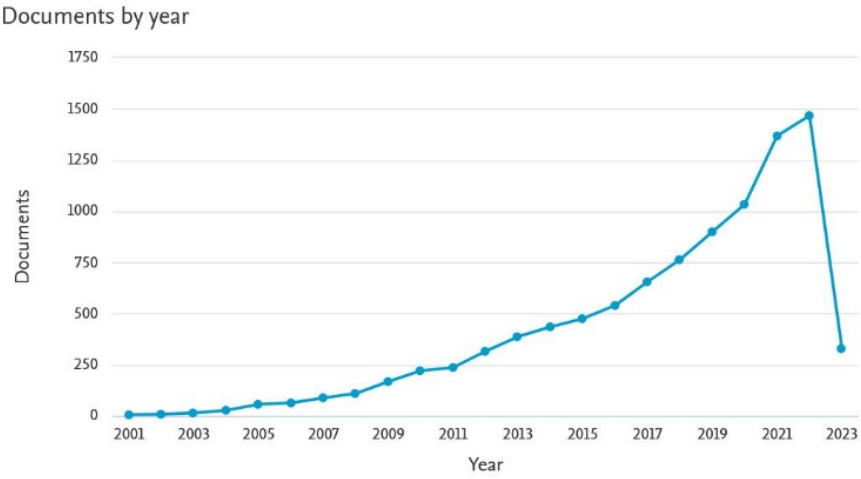


Fig. 1. documents by year (2001 to 2023).

3.2. Publications by Countries

A total of 5,580 articles were obtained from the FOSS domain. According to Fig. 2, the United States and the United Kingdom lead the production of research on free software, with 1,339 and 722 publications, respectively, reflecting their strong interest in the subject. India and China also contributed significantly, with 460 and 457 publications, indicating a focus on accessible and sustainable software solutions, especially in education and governance. Brazil and South Africa had lower production, with 243 and 234 publications, but still contribute to the global understanding of the benefits and challenges of FOSS adoption. Factors such as limited research resources and IT infrastructure can influence scientific production in these countries.

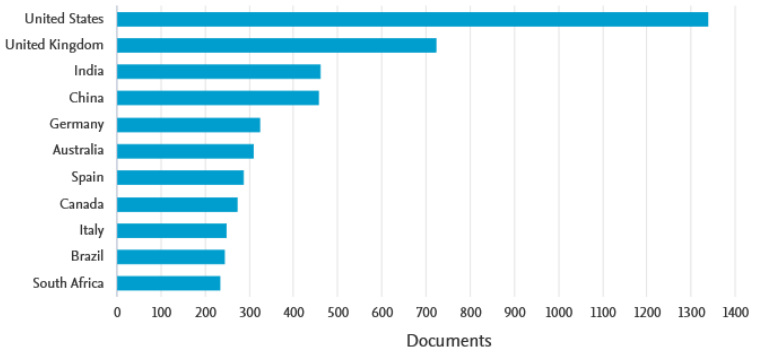


Fig. 2. documents by country.

3.3. Co-Authorship Network of Countries

The cross-country co-authorship analysis, presented in Fig. 3, reveals significant collaboration in research on FOSS adoption. Three large groups, representing the United States, the United Kingdom, and India, stand out, positioned close to the center of the figure, indicating a high frequency of publications in which authors from these countries collaborate. This suggests a strong network of scientific collaboration among these researchers, which can contribute significantly to the advancement of knowledge in areas related to the adoption of FOSS.

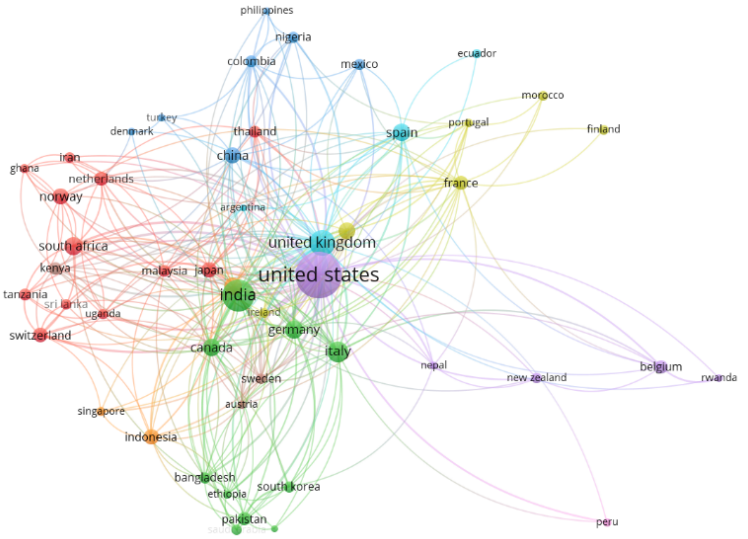
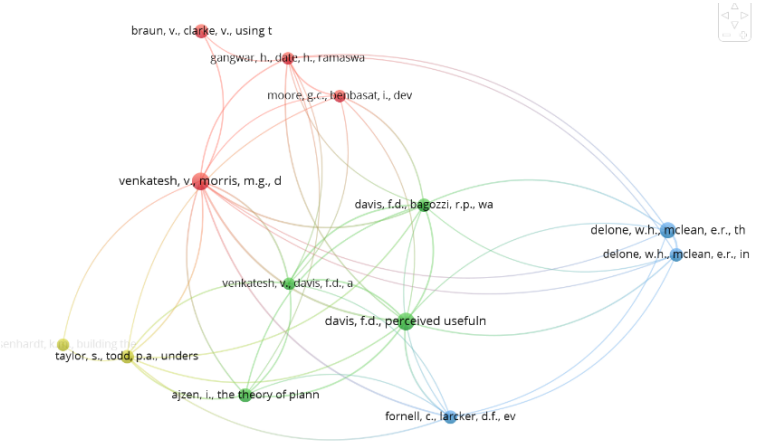


Fig. 3. country co-authorship analysis.

3.4. Co-Citation Network

The most common research topics in FOSS among the countries with the highest scientific production are illustrated in Fig. 4, which highlights the theoretical bases of these countries. The analysis reveals a co-citation network composed of four clusters, indicating the most influential references in the analyzed literature [24], [25]. Other references include [26], which uses case studies for theoretical construction, and [27], on evaluating structural equation models. The reference [28] presents an integrated TAM-TOE model for cloud computing adoption. The co-citation network allowed us to identify the connections between the references and an overview of the main topics and lines of research in the field.

Fig. 4. co-citation network



3.5. Co-occurrence of keywords

The analysis of keyword co-occurrence allowed the identification of the main topics and lines of research among the countries with the highest scientific production. The map of keyword clusters (Fig. 5) shows the connections and frequency of terms in scientific articles. Words such as "FOSS", "health", "cost" and "information system" are recurrent, suggesting that these countries seek FOSS-based solutions to improve health information systems, reduce costs of proprietary technologies and improve the quality of health services.

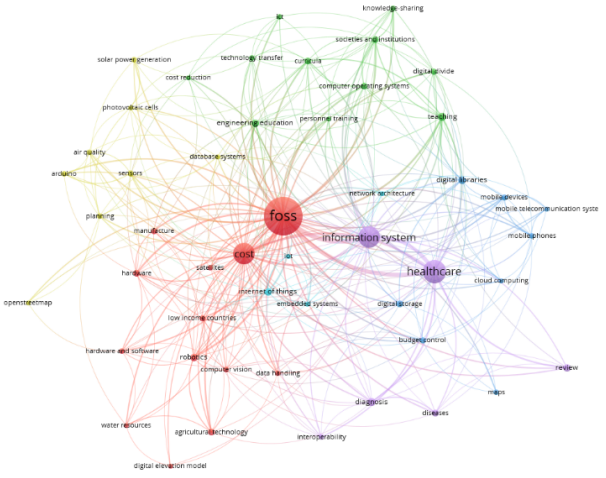


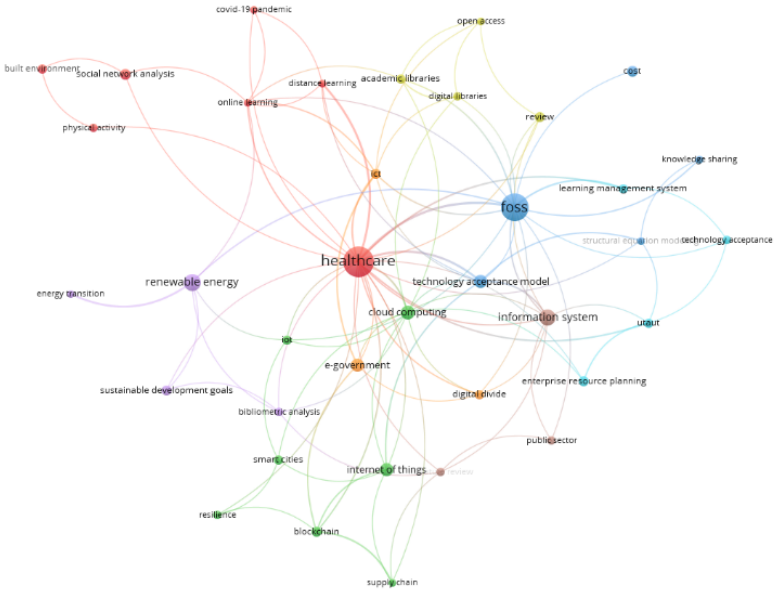
Fig. 5. keyword co-occurrence network _ countries with highest collaboration

The semantic space analysis showed that "FOSS" (394 occurrences, 891 total binding force), "cost" (126 occurrences, 330 total binding force) and "information systems" (124 occurrences, 324 total binding strength) are

closer to each other compared to "health" (142 occurrences, 311 total binding strength). This suggests that the use of free software can reduce the costs of implementing and maintaining information systems, while the adoption of FOSS in healthcare is still under development.

The analysis of Fig. 6 reveals significant differences in research topics between countries with greater and lesser collaboration on the adoption of FOSS. Countries with strong collaboration focus more on FOSS and health, with keywords such as cost and information systems standing out, suggesting a practical interest in FOSS adoption in healthcare. Countries with less collaboration, on the other hand, have a more diversified focus, addressing topics such as renewable energy, cloud computing, blockchain, e-government, and technology acceptance models.

Fig. 6. keyword co-occurrence network _ countries with less collaboration



4. Discussions and Results

Based on the results presented previously, it can be concluded that there has been significant growth in scientific production on FOSS over the investigated period. This steady increase in the number of publications in recent years shows a growing interest in the topic and indicates that it is relevant to the scientific community.

The United States, the United Kingdom, and India were the countries that produced the most research on FOSS, maintaining constant leadership over the others. This suggests that these countries have a more conducive environment for FOSS research, whether due to cultural, political, or economic issues. The most common areas of interest in FOSS research include "foss," "health," "cost," and "information systems." These themes are relevant to various fields of knowledge and indicate that the adoption of FOSS is seen as a solution to specific problems in these areas. Additionally, the relationship of these studies with "interoperability" suggests that there is a concern to ensure that FOSS solutions can work together with other technologies and systems.

However, countries that collaborate less present a more diversified approach, indicating that there are several unexplored areas of interest in FOSS research. Additionally, these countries lack an approach around the theme of interoperability, which may limit the practical application of FOSS solutions in these countries.

However, it is important to note that our cluster analyses are based on a limited sample of studies, and therefore, these differences may not be generalizable to all contexts. Our findings suggest that the relationship between interoperability and telemedicine may be complex and vary depending on the context in which it is studied. This fact highlights the need for further studies to explore these issues in different contexts and identify best practices to support the effective implementation of technologies.

In summary, the results indicate that FOSS research is a growing area of great interest to the scientific community. There is a consensus around some relevant themes, but there are also several unexplored areas and challenges to be faced, such as interoperability.

5. Conclusions

Based on the findings presented in this study, it can be concluded that there has been significant growth in scientific production on FOSS over the period investigated. The constant increase in the number of publications in recent years shows a growing interest in the topic and indicates that it is relevant to the scientific community.

The United States, the United Kingdom, and India were the countries that produced the most research on FOSS, maintaining a constant leadership position in relation to others. This suggests that these countries have a more conducive environment for FOSS research, whether due to cultural, political, or economic reasons. The most common areas of interest in FOSS research include "foss," "health," "cost," and "information systems." These topics are relevant to various fields of knowledge and indicate that the adoption of FOSS is seen as a solution to specific problems in these areas. In addition, the relationship of these studies with "interoperability" suggests that there is a concern to ensure that FOSS solutions can work together with other technologies and systems. However, countries that collaborate the least present a more diversified approach, indicating that there are several unexplored areas of interest in FOSS research. Additionally, these countries lack an approach around the topic of interoperability, which may limit the practical application of FOSS solutions in these countries.

In summary, the results indicate that FOSS research is a growing area of great interest to the scientific community. There is a consensus around some relevant topics, but there are also several unexplored areas and challenges to be faced, such as interoperability. It is important to note that our cluster analyses are based on a limited sample of studies, and therefore, these differences may not be generalizable to all contexts. Our findings suggest that the relationship between interoperability and telemedicine may be complex and vary depending on the context in which it is studied. This fact highlights the need for more studies to explore these issues in different contexts and identify best practices to support the effective implementation of technologies.

Overall, this study contributes to understanding the state of research on FOSS and highlights the need for further investigation into the potential benefits and challenges of its adoption in various fields. The growing interest in FOSS research suggests that this topic will continue to be relevant and important for years to come.

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