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Reshaping research in crisis: bibliometric analysis of Ecuadorian public universities during COVID-19 (2019–2021)

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Introduction: Ecuadorian public universities have significantly expanded their scientific output in recent years; however, few studies have conducted a multivariate bibliometric analysis to assess how these institutions adapted their research agendas during the COVID-19 pandemic.

Methods: This study examines publication patterns from 2019 to 2021 using data from the Web of Science, focusing on four primary research areas: Education, Social Sciences, Engineering, and Multidisciplinary Sciences. Institutional performance was evaluated across seven variables: article count, citation impact, and open-access prevalence. By applying a dynamic HJ-Biplot approach in R (dynBiplotGUI), we visualized the relationships among the 24 public universities and tracked their temporal evolution.

Results: The results indicated that Education and Social Sciences were the most productive areas, with the Technical University of Machala leading in both publication volume and number of citations. Open-access publishing exhibited substantial growth—reaching up to 300% in some institutions—and was positively linked to higher citation impact. The dynamic trajectories revealed a noticeable shift among mid-tier institutions toward engineering research and open dissemination models.

Discussion: These findings underscore the adaptability of Ecuadorian universities during global disruptions, emphasizing the importance of multivariate bibliometric approaches for strategic research planning, policymaking, and the promotion of open science in emerging contexts.

KEYWORDS

scientific production, Ecuadorian universities, HJ-Biplot analysis, research trends, higher education, Web of Science

1 Introduction

The scientific and academic development of Ecuador has accelerated remarkably in recent years, as demonstrated by a growing body of literature that spans diverse themes, ranging from higher education to seed sovereignty in university contexts (Guerrero-Quíñonez et al., 2023; Lyon et al., 2021). Within the global academic space, Ecuadorian institutions have expanded their focus to include issues of educational quality and the intersection of policy and teaching (Bonilla Carchi et al., 2022; Guerrero-Quíñonez et al., 2023), reflecting a commitment to

continuous improvement and academic excellence. Efforts to increase scientific productivity have targeted both the quantity and quality of research, evidenced by Ecuador's growing inclusion in international indexed databases and benchmark comparisons with other South American countries (Araujo-Bilmonite et al., 2020; Jaramillo et al., 2023). Studies on human capital and performance in educational institutions highlight the intersection between research and national development policies (González Cisneros et al., 2021), while investigations in fields such as agriculture underscore the pivotal role of specialized research centers like the National Institute of Agricultural Research (Viera-Arroyo et al., 2020).

Collaboration and knowledge exchange within academic networks are essential for advancing science in Ecuador (Luque González et al., 2022). Analyses of trends and collaborative publication patterns confirm a country's deeper integration into global scientific dialog (Bindu et al., 2019; Sekhar et al., 2022). Despite these positive developments, persistent challenges remain, including the need for broader international collaboration and the more direct relevance of research outputs to labor markets and national development (Carrión and Figueroa, 2023; Toapanta Toapanta et al., 2023). A detailed bibliometric analysis can identify these gaps, inform policy decisions, and project future research trajectories (Quincho-Lopez and Pacheco-Mendoza, 2021; Tang et al., 2022).

The present study addresses these challenges by applying a multivariate statistical tool, the HJ-Biplot, to Ecuadorian research output. Traditional bibliometric methods often isolate indicators rather than examining them concurrently; in contrast, the HJ-Biplot permits a simultaneous view of multiple variables, revealing nuanced relationships and clustering patterns that might otherwise remain obscured. Citation counts, open-access publications, and subscription-based publications are especially relevant to Ecuadorian universities because citations illustrate the visibility and impact of research. Open access facilitates broad dissemination in resource-constrained contexts, and subscription-based publishing, despite increasing shifts toward open-access models, still confers substantial academic recognition.

The HJ-Biplot, introduced by Galindo-Villardón (1986) as a generalization of Gabriel's classical biplot, projects observations and variables onto the same Euclidean plane, while jointly maximizing their representation quality. This dual-scaling property preserves interinstitution distances and variable contributions in a single diagram, providing a concise picture of multivariate relationships. Applications in university ranking analysis and network studies show that the HJ-Biplot reveals clusters and dominant indicators more intuitively than principal-component biplots, multidimensional scaling, or hierarchical clustering (Frutos Bernal et al., 2020). These strengths make it well-suited for mapping research performance across institutions with many correlated bibliometric metrics. Although there have been analyses of Ecuador's scientific production, no study has yet applied this type of multivariate examination to the selected timeframe. The present research aims to fill this gap by exploring how Ecuadorian public universities have adapted their research strategies from 2019 to 2021, focusing on the Web of Science database and examining publication output, citation impact, and publishing models. By providing a pioneering example of multivariate bibliometric analysis in an emerging research context, this study offers insights that can guide policymaking, bolster strategic planning, and optimize resource allocation across Ecuador's public universities.

2 Materials and methods

2.1 Data sources and search strategy

This study examined the scientific output of Ecuadorian public universities between 2019 and 2021, a period marked by significant disruptions due to the COVID-19 pandemic. Data were retrieved from the Web of Science (WoS) on August 17, 2023, and included all major collections: SCIE, SSCI, AHCI, ESCI, CPCI, and BKCI. Although Scopus also offers comprehensive coverage, WoS was selected to ensure methodological consistency across a unified indexing framework and because it is often perceived as more competitive owing to its selective inclusion criteria and long-standing reputation for curation rigor. Documents published between 2019 and 2021 were retrieved using the query CU = (ECUADOR) AND PY = (2019–2021) AND DT = (Article), yielding 9,085 articles as of August 17, 2023. Restricting the analysis to 2019–2021 provides a clear before-during-after snapshot: 2019 reflects research conditions immediately prior to the World Health Organization's pandemic declaration (March 11, 2020); 2020 captures the period of nationwide lockdowns and emergency institutional responses; 2021 marks the earliest phase of adaptation when universities resumed mixed instructional modalities and re-oriented research funding, while citation accrual for later years remains incomplete.

2.2 Variables and operationalization

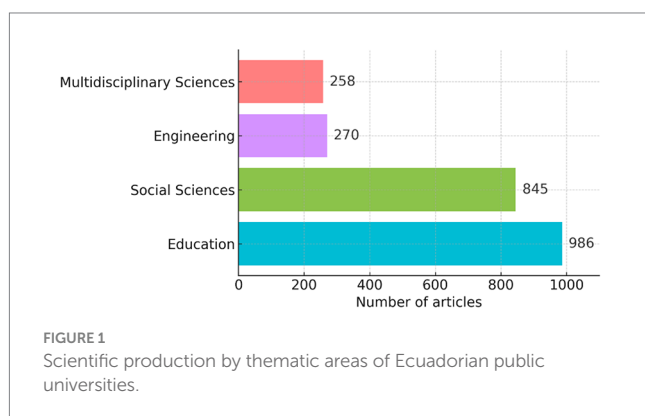
The analysis emphasized research areas with the highest volume of articles affiliated with Ecuadorian universities. The chosen areas—Education, Social Sciences, Engineering, and Multidisciplinary Sciences—accounted for a substantial portion of the country's publications. Three additional variables were selected to evaluate publishing models and scholarly impact: (1) total citations, which measures the visibility of research outputs; (2) articles in subscription-based journals, which continue to be a common publishing route despite trends toward open science; and (3) articles in open-access outlets, which can broaden the dissemination and accessibility of scientific findings. Focusing on these variables offers insights into how Ecuadorian institutions navigate changing research landscapes under constrained budgets, how they align their outputs with global dissemination practices, and how citation patterns might differ across publishing models.

2.3 Statistical methods and visualization

Data were analyzed using the dynBiplotGUI package in R developed by Egido Miguélez (2015). A biplot was chosen to provide simultaneous visualization of observations (in this case, universities) and variables (research areas, publication models, and citation counts) in a two-dimensional plane. The HJ-Biplot variant was selected for its capacity to optimize the representation of both rows and columns, thereby facilitating a more comprehensive exploration of intervariable relationships (Gómez-Marcos et al., 2022). This technique surpasses simpler methods by revealing correlations and clustering patterns that might otherwise remain hidden if indicators are assessed independently.

To evaluate research trajectories from 2019 to 2021, the analysis incorporated a dynamic biplot, an extension that allows the

examination of three-dimensional datasets across different time points (Egido Miguélez, 2015). This approach captures year-to-year shifts in both the research focus and publishing models, providing a richer view of the evolution of Ecuadorian universities. No previous studies have employed dynamic biplots to explore the correlations between research areas, citations, subscription-based publishing, and open-access output in this context, reinforcing the novelty and potential impact of the methodology used.



3 Results

3.1 Overview of publication output

Figure 1 illustrates the distribution of 9,085 scientific articles published by Ecuadorian public universities between 2019 and 2021. Of these, 2,359 were grouped under four main research domains: education (986), Social Sciences (845), engineering (270), and Multidisciplinary Sciences (258). The remaining 6,726 articles were categorized as belonging to other fields.

3.2 University-specific performance and trends

Table 1 lists 24 public universities, providing each institution's Spanish and English names, geographic region, and abbreviation. These abbreviations are used consistently throughout subsequent figures and tables, allowing for clearer comparison of institutional performance across different regions: Coastal, Andean, Amazonian, and Southern.

Table 2 provides the annual publication counts, citation data, subscription-based articles, and open-access outputs for each university between 2019 and 2021. The table also includes annual averages and

TABLE 1 Ecuadorian public universities.

| Abbreviation | University name (Spanish) | University name (English) | Geographic region |
|----------------|---|---|-------------------|
| ESPAM | Escuela Superior Politécnica Agropecuaria de Manabí | Higher Polytechnic School of Manabí | Coastal Region |
| EPN | Escuela Politécnica Nacional | National Polytechnic School | Andean Region |
| ESPOL | Escuela Superior Politécnica del Litoral | Higher Polytechnic School of the Coast | Coastal Region |
| ESPE | Escuela Politécnica del Ejército | Higher Polytechnic School of the Army | Andean Region |
| UAE | Universidad Agraria del Ecuador | Agrarian University of Ecuador | Coastal Region |
| ESPOCH | Escuela Superior Politécnica de Chimborazo | Higher Polytechnic School of Chimborazo | Andean Region |
| UG | Universidad de Guayaquil | University of Guayaquil | Coastal Region |
| U-CUENCA | Universidad de Cuenca | State University of Cuenca | Southern Region |
| ULEAM | Universidad Laica Eloy Alfaro de Manabí | Lay University Eloy Alfaro of Manabí | Coastal Region |
| UAE (Amazonía) | Universidad Estatal Amazónica | State Amazonian University | Amazon Region |
| UNEMI | Universidad Estatal de Milagro | State University of Milagro | Coastal Region |
| UEB | Universidad Estatal de Bolívar | State University of Bolívar | Andean Region |
| UNESUM | Universidad Estatal del Sur de Manabí | State University of South Manabí | Coastal Region |
| UNACH | Universidad Nacional de Chimborazo | National University of Chimborazo | Andean Region |
| UPSE | Universidad Estatal Península de Santa Elena | Polytechnic University of Santa Elena | Coastal Region |
| UNAE | Universidad Nacional de Educación | National University of Education | Andean Region |
| UTB | Universidad Técnica de Babahoyo | Technical University of Babahoyo | Coastal Region |
| UNL | Universidad Nacional de Loja | National University of Loja | Southern Region |
| UTEQ | Universidad Técnica Estatal de Quevedo | Technical University of Quevedo | Coastal Region |
| UTC | Universidad Técnica de Cotopaxi | Technical University of Cotopaxi | Andean Region |
| UTMACH | Universidad Técnica de Machala | Technical University of Machala | Coastal Region |
| UTN | Universidad Técnica del Norte | Technical University of the North | Andean Region |
| UTM | Universidad Técnica de Manabí | Technical University of Manabí | Coastal Region |
| YACHAY | Universidad Yachay Tech | Yachay Technological University | Andean Region |

percentage changes over this period. The Technical University of Machala (UTMACH) has an averages of 17.00 articles per year in Education and 28.67 in Social Sciences, along 1077.33 citations. The State University of Cuenca (U-CUENCA) reports an average of 3.67 articles per year in Engineering and a 300% increase in open-access publications, while the National Polytechnic School (EPN) records an average of 6.00 articles in Multidisciplinary Sciences. The Higher Polytechnic School of the Coast (ESPOL) had a 732% increase in citations. The Polytechnic School of the Army (ESPE) displayed a 200% increase in subscription-based articles, whereas the Technical University of Manabí (UTM) showed a 300% increase in open-access publications by 2021.

3.3 HJ-Biplot analysis

Table 3 indicates that the first three axes of the HJ-Biplot accounted for 88.66% of total variance, summarizing the relationships among research areas, citation counts, and publishing models. Axis 1 (50.8%) is a size dimension associated with overall article volume and citation strength; Axis 2 (21.7%) contrasts universities that publish predominantly in open-access venues with those favoring subscription outlets; and Axis 3 (16.2%) separates institutions focused on Education and Social Sciences from those emphasizing Engineering and Multidisciplinary fields.

Table 4 details each variable's contribution to these axes. Social Sciences and Subscription are more closely associated with Axis 2, whereas Citations and Open Access align more with Axis 1.

Figure 2 displays the 2021 HJ-Biplot on the Axis 1–2 plane. Axis 1, the size dimension, runs horizontally, while Axis 2 contrasts subscription-based publishing and Social Sciences (positive values) with open-access engineering output (negative values). Social Sciences points sharply toward the subscription vector, and the Engineering, Education, and Multidisciplinary vectors tilt toward open access. UTMACH and UG plot in the first quadrant, where high Social Sciences production, extensive subscription publishing, and elevated citation counts converge. U-CUENCA and UTM lie on the lower-right sector, reflecting stronger engineering output and a marked preference for open-access venues. ESPE, UNACH, and EPN cluster nearer the Multidisciplinary vector, whereas institutions on the negative side of both axes register lower scores across the bibliometric indicators.

Figure 3 presents the same data on the axes 1–3 plane to emphasize disciplinary contrasts. Axis 3 separates Education and Social Sciences (positive) from the Engineering and Multidisciplinary fields (negative). UPSE appears high on Axis 3, aligning with education and reflecting a 125% increase in that area. U-CUENCA occupies the positive side of both Axes 1 and 3, indicating a large output with a balanced emphasis on education and Open Access. EPN, in contrast, falls on the negative side of Axis 3, underscoring its stronger multidisciplinary profile. The concentration of many universities around the origin in both figures confirms that most institutions share broadly similar bibliometric patterns, while those positioned farther away represent notable deviations in their research focus or publishing strategy.

3.4 Dynamic analysis of research trends

Figure 4 traces institutional movement from 2019 to 2021 on the size-and-publishing plane, where Axis 1 explains 52.09% of total variance and

Axis 2 captures an additional 22.04%. In an HJ-Biplot, the origin marks the system average, the distance between two points represents how dissimilar their bibliometric profiles are, and the direction of an arrow shows the gradient of increase for that indicator; projecting a university onto an arrow reveals its relative score, and the angle between two arrows reflects their correlation (small angles signal positive association, right angles independence, wide obtuse angles negative association). The cloud of nearly superimposed dots around the origin may look visually crowded, but this overlap is expected: it simply means that many institutions have very similar indicator values and changed little from year to year. Eighteen of the 24 public universities—roughly three-quarters of the system—remain within ± 1 unit of the origin throughout the period, confirming that most experienced only modest shifts. In contrast, UG and UTMACH start at the outer edge of the Social-Sciences/Subscription quadrant with above-average publication volume and citation counts in 2019 but drift inward by 2021, indicating a measurable contraction in those advantages. UTM moves decisively outward along the Engineering and Open-Access vectors, lifting its open-access output by about 300% between 2019 and 2021. U-CUENCA keeps a stable Engineering focus yet shifts rightward as its share of open-access articles rises, while UNACH and EPN push toward the Multidisciplinary-Sciences vector and ESPE follows the same direction with smaller amplitude. Supplementary estimates on Axis 3 (not shown) reveal that UPSE records a 125% increase in Education publications, explaining why it departs vertically rather than within the two-dimensional space depicted here.

4 Discussion

This study examined trends in research output among Ecuadorian public universities between 2019 and 2021, focusing on the most productive areas, publishing models, and citation performance. The four most prominent research areas during this period were education, social sciences, engineering, and multidisciplinary science. The dominance of education, with 986 published articles, aligns with the recognition that education is a critical driver of social and economic development in emerging economies (Zoido, 2008).

Social Science research in Ecuador is particularly relevant, contributing to an understanding of societal transformations and supporting development-oriented policies (Thuy, 2022). Engineering reflects national priorities related to infrastructure, technology, and human capital development, particularly in resource-constrained environments (Murad et al., 2017; Zarog, 2022). The integration of open-source technologies and e-learning has further facilitated growth in this field (Onime and Uhomobhi, 2012; Forcael et al., 2022). Multidisciplinary research has also emerged as a significant focus, offering evidence of growing institutional commitment to knowledge production that transcends disciplinary silos (Chavarro et al., 2014).

In this analysis, we relied primarily on the HJ-Biplot technique because it offers two decisive advantages over more familiar multivariate tools, such as principal component biplots, multidimensional scaling, and hierarchical clustering. First, HJ scaling jointly maximizes the quality of representation for both rows (universities) and columns (bibliometric indicators); thus, inter-university distances and variable contributions remain in a single low-dimensional map (Galindo-Villardón, 1986). Second, its metric properties allow the simultaneous visual interpretation of clusters and

TABLE 2 Annual scientific output, citation metrics, and publishing model (subscription vs. open access) across Ecuadorian public universities in four leading research areas (2019–2021).

| | Year | Education | Engineering | Multidisciplinary sciences | Social sciences | Citations | Subscription | Open access |
|-----------|------|-----------|-------------|----------------------------|-----------------|-----------|--------------|-------------|
| ESPAM | 2019 | 0 | 1 | 1 | 1 | 58 | 2 | 1 |
| | 2020 | 0 | 0 | 0 | 1 | 55 | 1 | 0 |
| | 2021 | 0 | 1 | 0 | 1 | 66 | 1 | 1 |
| Average | | 0,00 | 0,67 | 0,33 | 1,00 | 59,67 | 1,33 | 0,67 |
| Variation | | – | 0,00 | –100,00 | 0,00 | 13,79 | –50,00 | 0,00 |
| ESPOL | 2019 | 0 | 0 | 3 | 0 | 50 | 0 | 3 |
| | 2020 | 1 | 0 | 1 | 0 | 97 | 1 | 1 |
| | 2021 | 2 | 0 | 3 | 0 | 416 | 1 | 4 |
| Average | | 1,00 | 0,00 | 2,33 | 0,00 | 187,67 | 0,67 | 2,67 |
| Variation | | – | – | 0,00 | – | 732,00 | – | 33,33 |
| UAE | 2019 | 0 | 1 | 1 | 0 | 39 | 0 | 2 |
| | 2020 | 0 | 1 | 0 | 0 | 14 | 0 | 1 |
| | 2021 | 0 | 0 | 1 | 0 | 42 | 0 | 1 |
| Average | | 0,00 | 0,67 | 0,67 | 0,00 | 31,67 | 0,00 | 1,33 |
| Variation | | – | –100,00 | 0,00 | – | 7,69 | – | –50,00 |
| UG | 2019 | 12 | 1 | 6 | 27 | 881 | 39 | 7 |
| | 2020 | 12 | 0 | 0 | 24 | 706 | 28 | 8 |
| | 2021 | 6 | 1 | 1 | 19 | 478 | 25 | 2 |
| Average | | 10,00 | 0,67 | 2,33 | 23,33 | 688,33 | 30,67 | 5,67 |
| Variation | | –50,00 | 0,00 | –83,33 | –29,63 | –45,74 | –35,90 | –71,43 |
| ULEAM | 2019 | 7 | 1 | 1 | 8 | 444 | 15 | 2 |
| | 2020 | 10 | 0 | 2 | 10 | 500 | 16 | 6 |
| | 2021 | 7 | 0 | 0 | 3 | 244 | 8 | 2 |
| Average | | 8,00 | 0,33 | 1,00 | 7,00 | 396,00 | 13,00 | 3,33 |
| Variation | | 0,00 | –100,00 | –100,00 | –62,50 | –45,05 | –46,67 | 0,00 |
| UNEMI | 2019 | 2 | 1 | 0 | 8 | 204 | 9 | 2 |
| | 2020 | 4 | 1 | 0 | 6 | 200 | 9 | 2 |
| | 2021 | 2 | 0 | 0 | 1 | 60 | 2 | 1 |
| Average | | 2,67 | 0,67 | 0,00 | 5,00 | 154,67 | 6,67 | 1,67 |

(Continued)

TABLE 2 (Continued)

| | Year | Education | Engineering | Multidisciplinary sciences | Social sciences | Citations | Subscription | Open access |
|-----------|------|-----------|-------------|----------------------------|-----------------|-----------|--------------|-------------|
| Variation | | 0,00 | −100,00 | − | −87,50 | −70,59 | −77,78 | −50,00 |
| UNESUM | 2019 | 0 | 0 | 2 | 3 | 85 | 5 | 0 |
| | 2020 | 1 | 0 | 7 | 0 | 269 | 7 | 1 |
| | 2021 | 1 | 0 | 3 | 1 | 192 | 3 | 2 |
| Average | | 0,67 | 0,00 | 4,00 | 1,33 | 182,00 | 5,00 | 1,00 |
| Variation | | − | − | 50,00 | −66,67 | 125,88 | −40,00 | − |
| UPSE | 2019 | 8 | 0 | 1 | 3 | 303 | 3 | 9 |
| | 2020 | 7 | 0 | 2 | 1 | 282 | 3 | 7 |
| | 2021 | 18 | 0 | 0 | 2 | 373 | 2 | 18 |
| Average | | 11,00 | 0,00 | 1,00 | 2,00 | 319,33 | 2,67 | 11,33 |
| Variation | | 125,00 | − | −100,00 | −33,33 | 23,10 | −33,33 | 100,00 |
| UTB | 2019 | 13 | 0 | 0 | 0 | 142 | 13 | 0 |
| | 2020 | 5 | 0 | 0 | 1 | 92 | 6 | 0 |
| | 2021 | 5 | 0 | 0 | 6 | 209 | 10 | 1 |
| Average | | 7,67 | 0,00 | 0,00 | 2,33 | 147,67 | 9,67 | 0,33 |
| Variation | | −61,54 | − | − | − | 47,18 | −23,08 | − |
| UTEQ | 2019 | 8 | 0 | 1 | 38 | 609 | 46 | 1 |
| | 2020 | 8 | 1 | 3 | 9 | 430 | 18 | 3 |
| | 2021 | 4 | 0 | 1 | 11 | 249 | 15 | 1 |
| Average | | 6,67 | 0,33 | 1,67 | 19,33 | 429,33 | 26,33 | 1,67 |
| Variation | | −50,00 | − | 0,00 | −71,05 | −59,11 | −67,39 | 0,00 |
| UTM | 2019 | 5 | 3 | 0 | 9 | 343 | 14 | 3 |
| | 2020 | 3 | 2 | 3 | 7 | 374 | 10 | 5 |
| | 2021 | 10 | 4 | 6 | 4 | 854 | 12 | 12 |
| Average | | 6,00 | 3,00 | 3,00 | 6,67 | 523,67 | 12,00 | 6,67 |
| Variation | | 100,00 | 33,33 | − | −55,56 | 148,98 | −14,29 | 300,00 |
| UTMACH | 2019 | 19 | 0 | 2 | 30 | 1,209 | 47 | 4 |
| | 2020 | 26 | 0 | 0 | 31 | 1,141 | 53 | 4 |
| | 2021 | 6 | 2 | 1 | 25 | 882 | 26 | 8 |
| Average | | 17,00 | 0,67 | 1,00 | 28,67 | 1,077,33 | 42,00 | 5,33 |

(Continued)

TABLE 2 (Continued)

| | Year | Education | Engineering | Multidisciplinary sciences | Social sciences | Citations | Subscription | Open access |
|-----------|------|-----------|-------------|----------------------------|-----------------|-----------|--------------|-------------|
| Variation | | −68,42 | – | −50,00 | −16,67 | −27,05 | −44,68 | 100,00 |
| EPN | 2019 | 0 | 12 | 8 | 0 | 693 | 3 | 17 |
| | 2020 | 0 | 5 | 4 | 1 | 0 | 3 | 7 |
| | 2021 | 0 | 5 | 6 | 1 | 547 | 4 | 8 |
| Average | | 0,00 | 7,33 | 6,00 | 0,67 | 413,33 | 3,33 | 10,67 |
| Variation | | – | 0,00 | −25,00 | – | −21,07 | 33,33 | −52,94 |
| ESPE | 2019 | 1 | 4 | 3 | 1 | 265 | 1 | 8 |
| | 2020 | 3 | 2 | 2 | 6 | 270 | 7 | 6 |
| | 2021 | 1 | 3 | 4 | 1 | 328 | 3 | 6 |
| Average | | 1,67 | 3,00 | 3,00 | 2,67 | 287,67 | 3,67 | 6,67 |
| Variation | | 0,00 | 0,00 | 33,33 | 0,00 | 23,77 | 200,00 | −25,00 |
| ESPOCH | 2019 | 20 | 13 | 0 | 0 | 749 | 26 | 7 |
| | 2020 | 2 | 5 | 0 | 1 | 124 | 4 | 4 |
| | 2021 | 3 | 2 | 1 | 1 | 269 | 3 | 4 |
| Average | | 8,33 | 6,67 | 0,33 | 0,67 | 380,67 | 11,00 | 5,00 |
| Variation | | −85,00 | 0,00 | – | – | −64,09 | −88,46 | −42,86 |
| U-CUENCA | 2019 | 4 | 4 | 1 | 3 | 478 | 4 | 8 |
| | 2020 | 7 | 2 | 6 | 4 | 603 | 1 | 18 |
| | 2021 | 8 | 5 | 2 | 3 | 803 | 4 | 14 |
| Average | | 6,33 | 3,67 | 3,00 | 3,33 | 628,00 | 3,00 | 13,33 |
| Variation | | 100,00 | 0,00 | 100,00 | 0,00 | 67,99 | 0,00 | 75,00 |
| UEA | 2019 | 1 | 0 | 1 | 1 | 170 | 1 | 2 |
| | 2020 | 0 | 0 | 4 | 0 | 254 | 0 | 4 |
| | 2021 | 1 | 3 | 0 | 2 | 298 | 1 | 5 |
| Average | | 0,67 | 1,00 | 1,67 | 1,00 | 240,67 | 0,67 | 3,67 |
| Variation | | 0,00 | 0,00 | −100,00 | 100,00 | 75,29 | 0,00 | 150,00 |
| UEB | 2019 | 1 | 0 | 0 | 1 | 40 | 2 | 0 |
| | 2020 | 1 | 0 | 0 | 1 | 25 | 2 | 0 |
| | 2021 | 2 | 1 | 0 | 2 | 175 | 2 | 3 |
| Average | | 1,33 | 0,33 | 0,00 | 1,33 | 80,00 | 2,00 | 1,00 |

(Continued)

TABLE 2 (Continued)

| | Year | Education | Engineering | Multidisciplinary sciences | Social sciences | Citations | Subscription | Open access |
|-----------|------|-----------|-------------|----------------------------|-----------------|-----------|--------------|-------------|
| Variation | | 100,00 | 0,00 | – | 100,00 | 337,50 | 0,00 | – |
| UNACH | 2019 | 28 | 0 | 1 | 1 | 718 | 26 | 4 |
| | 2020 | 0 | 1 | 1 | 2 | 124 | 2 | 2 |
| | 2021 | 6 | 1 | 4 | 0 | 405 | 3 | 8 |
| Average | | 11,33 | 0,67 | 2,00 | 1,00 | 415,67 | 10,33 | 4,67 |
| Variation | | –78,57 | 0,00 | 300,00 | –100,00 | –43,59 | –88,46 | 100,00 |
| UNAE | 2019 | 2 | 0 | 0 | 0 | 70 | 1 | 1 |
| | 2020 | 3 | 0 | 0 | 0 | 118 | 0 | 3 |
| | 2021 | 3 | 0 | 0 | 0 | 1 | 0 | 3 |
| Average | | 2,67 | 0,00 | 0,00 | 0,00 | 63,00 | 0,33 | 2,33 |
| Variation | | 50,00 | 0,00 | – | – | –98,57 | –100,00 | 200,00 |
| UNL | 2019 | 3 | 1 | 1 | 4 | 186 | 4 | 5 |
| | 2020 | 3 | 1 | 2 | 2 | 261 | 3 | 5 |
| | 2021 | 3 | 0 | 0 | 0 | 111 | 1 | 2 |
| Average | | 3,00 | 0,67 | 1,00 | 2,00 | 186,00 | 2,67 | 4,00 |
| Variation | | 0,00 | 0,00 | –100,00 | –100,00 | –40,32 | –75,00 | –60,00 |
| UTC | 2019 | 1 | 2 | 1 | 2 | 192 | 3 | 3 |
| | 2020 | 1 | 2 | 0 | 2 | 147 | 4 | 1 |
| | 2021 | 0 | 1 | 0 | 2 | 59 | 3 | 0 |
| Average | | 0,67 | 1,67 | 0,33 | 2,00 | 132,67 | 3,33 | 1,33 |
| Variation | | –100,00 | 0,00 | –100,00 | 0,00 | –69,27 | 0,00 | –100,00 |
| UTN | 2019 | 4 | 2 | 2 | 1 | 275 | 4 | 5 |
| | 2020 | 1 | 0 | 3 | 0 | 228 | 0 | 4 |
| | 2021 | 1 | 2 | 0 | 0 | 73 | 1 | 2 |
| Average | | 2,00 | 1,33 | 1,67 | 0,33 | 192,00 | 1,67 | 3,67 |
| Variation | | –75,00 | 0,00 | –100,00 | –100,00 | –73,45 | –75,00 | –60,00 |
| YACHAY | 2019 | 0 | 1 | 5 | 1 | 317 | 1 | 6 |
| | 2020 | 0 | 0 | 6 | 2 | 476 | 0 | 8 |
| | 2021 | 0 | 0 | 3 | 0 | 79 | 0 | 3 |
| Average | | 0,00 | 0,33 | 4,67 | 1,00 | 290,67 | 0,33 | 5,67 |
| Variation | | – | 0,00 | –40,00 | –100,00 | –75,08 | –100,00 | –50,00 |

TABLE 3 Eigenvalue, explained variance, and accumulated.

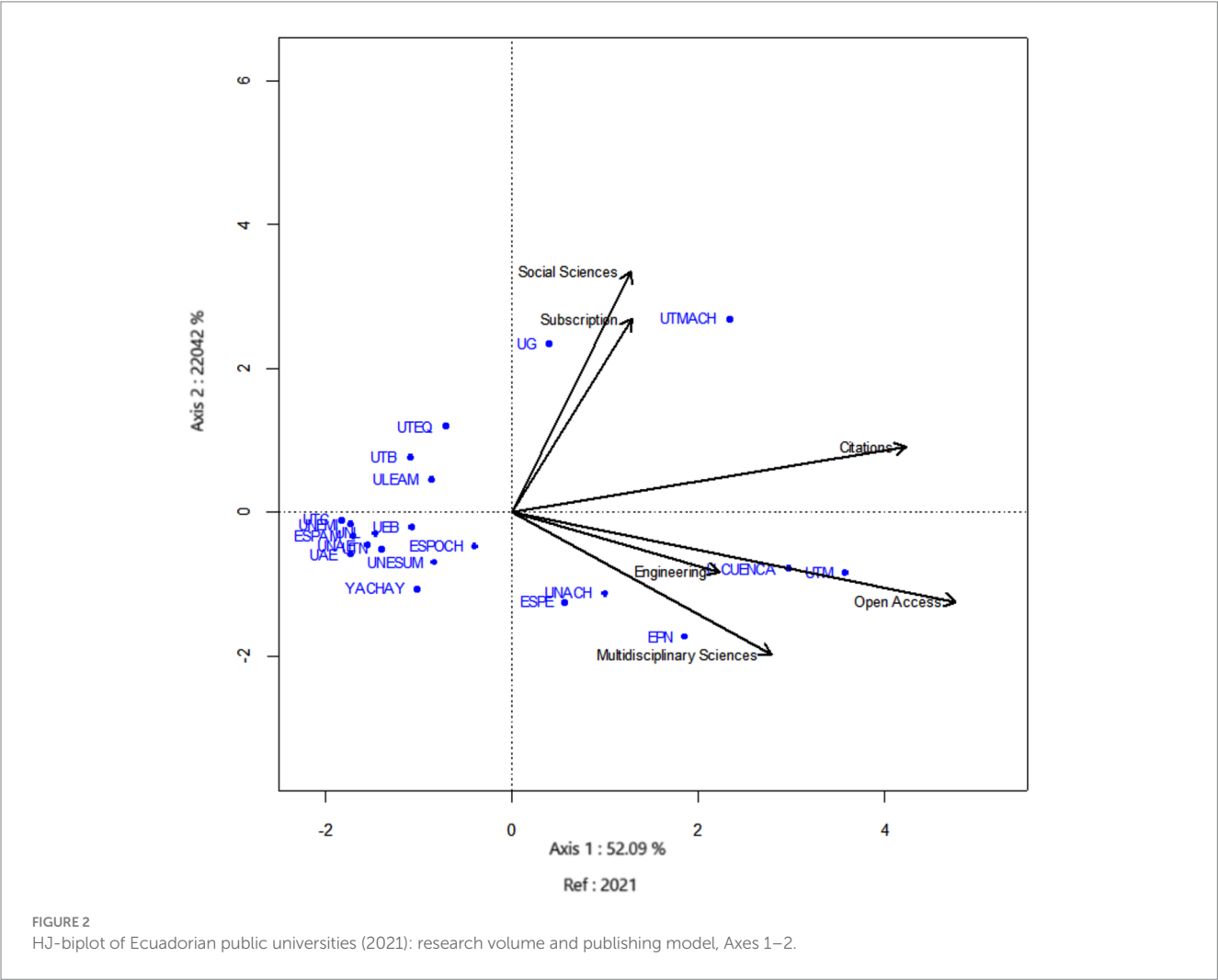
| Axis | Eigen value | Explained variance | Accumulated variance |
|------|-------------|--------------------|----------------------|
| 1 | 7,84 | 50,77 | 50,77 |
| 2 | 5,13 | 21,69 | 72,46 |
| 3 | 4,43 | 16,20 | 88,66 |

TABLE 4 Contribution of each factorial axis to the variability of variables.

| Variable | Axis 1 | Axis 2 | Axis 3 |
|----------------------------|--------|--------|--------|
| Education | 413 | 60 | 378 |
| Engineering | 451 | 64 | 111 |
| Multidisciplinary Sciences | 362 | 187 | 348 |
| Social Sciences | 118 | 820 | 34 |
| Citation | 880 | 41 | 27 |
| Subscription | 164 | 725 | 75 |
| Open Access | 767 | 54 | 166 |

indicator vectors without separate graphs or post-hoc rotations, which simplifies communication in institutional assessments (Frutos Bernal et al., 2020). These features are especially valuable for small systems with many correlated indicators, such as the 24 Ecuadorian public universities analyzed here, because they condense complex covariance patterns into one intuitive display. Among the 24 institutions analyzed, only one-third exhibited notable strengths in terms of specific indicators. The University of Guayaquil and the Technical University of Machala were prominent in Social Sciences, subscription publishing, and citation counts. The State University of Cuenca and Technical University of Manabí performed strongly in engineering and open-access publishing. Others, including the Higher Polytechnic School of the Army, the National University of Chimborazo, and the National Polytechnic School, stood out in Multidisciplinary Sciences and Engineering. Polytechnic University of Santa Elena was the leader in education-focused output.

The data also revealed a substantial shift toward open-access publishing. Institutions such as the Technical University of Manabí, the State University of Cuenca, and the Amazonian University of Ecuador saw significant increases in open-access output, some exceeding 200%. This reflects a broader movement toward open science, which appears to be associated with increased citation visibility (Khan et al., 2023).



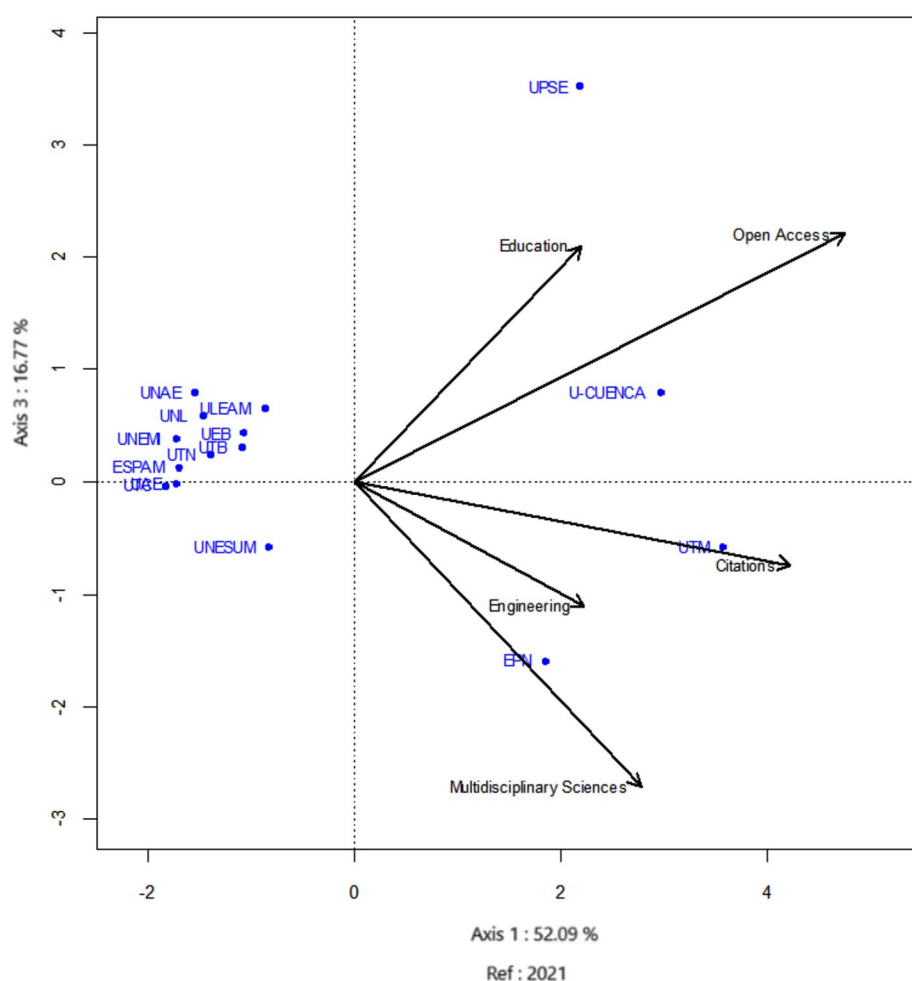


FIGURE 3

HJ-biplot of Ecuadorian public universities (2021): research volume and disciplinary focus, Axes 1–3.

Conversely, subscription-based publishing declined in nearly all universities with the exception of ESPE and EPN.

Recent work reinforces these patterns. A bibliometric study of BRICS universities reported a parallel pandemic-era surge in online learning research and a marked tilt toward open dissemination models (Masalimova et al., 2024), while empirical reviews of open educational practices and online-learning effectiveness underscored that open access and digital participation were critical for maintaining instructional continuity during COVID-19 (Brandenburger, 2022; Meng et al., 2024). Our findings also support earlier studies on Ecuador's rising scientific productivity (Bashir et al., 2021; Sweileh, 2022) and underscore its integration into international research communities, particularly through studies in the health and environmental sciences (Fei et al., 2021; Quincho-Lopez and Pacheco-Mendoza, 2021). Ecuador's growing research visibility has been acknowledged in recent global analyses (Lancho-Barrantes and Cantu-Ortiz, 2021; Wani et al., 2023), although significant challenges remain, especially in enhancing international collaboration and aligning research agendas with national priorities (Guerrero-Quiñonez et al., 2023; Bonilla Carchi et al., 2022).

Our results are consistent with broader regional comparisons of scientific production in Latin America (Jaramillo et al., 2023;

Araujo-Bilmonite et al., 2020), which have identified education, agriculture, and social development as priority areas (González Cisneros et al., 2021; Viera-Arroyo et al., 2020). The role of academic collaboration, both domestic and international, remains the cornerstone of Ecuador's emerging research capacity (Luque González et al., 2022; Bindu et al., 2019; Sekhar et al., 2022). Latin American benchmarks sharpen the perspective on Ecuador's gains. Brazil, the region's principal knowledge producer, recorded 2,703 Web of Science indexed COVID-19 articles in 2020, with the University of São Paulo and Fiocruz accounting for a substantial share (Mateus and Berrío-Zapata, 2021). A complementary survey of SciELO identified 261 COVID-19 papers up to May 2020, two-thirds of which were published in Brazilian journals, underscoring Brazil's hub role and the uneven distribution of output elsewhere in Latin America (Gallegos et al., 2020). Against this backdrop, Ecuadorian public universities produced 3,047 articles across all fields in 2020, a volume proportionate to national research capacity yet notable for its rapid shift toward open access.

Global bibliometric analyses have revealed a surge peak-plateau pattern in pandemic publishing. Hossain (2020) mapped a 26 percent rise in COVID-19 studies worldwide between 2020 and 2021, followed by a deceleration in early 2022, as research attention diversified. A scientometric review of 342,000 records confirmed this crest in late

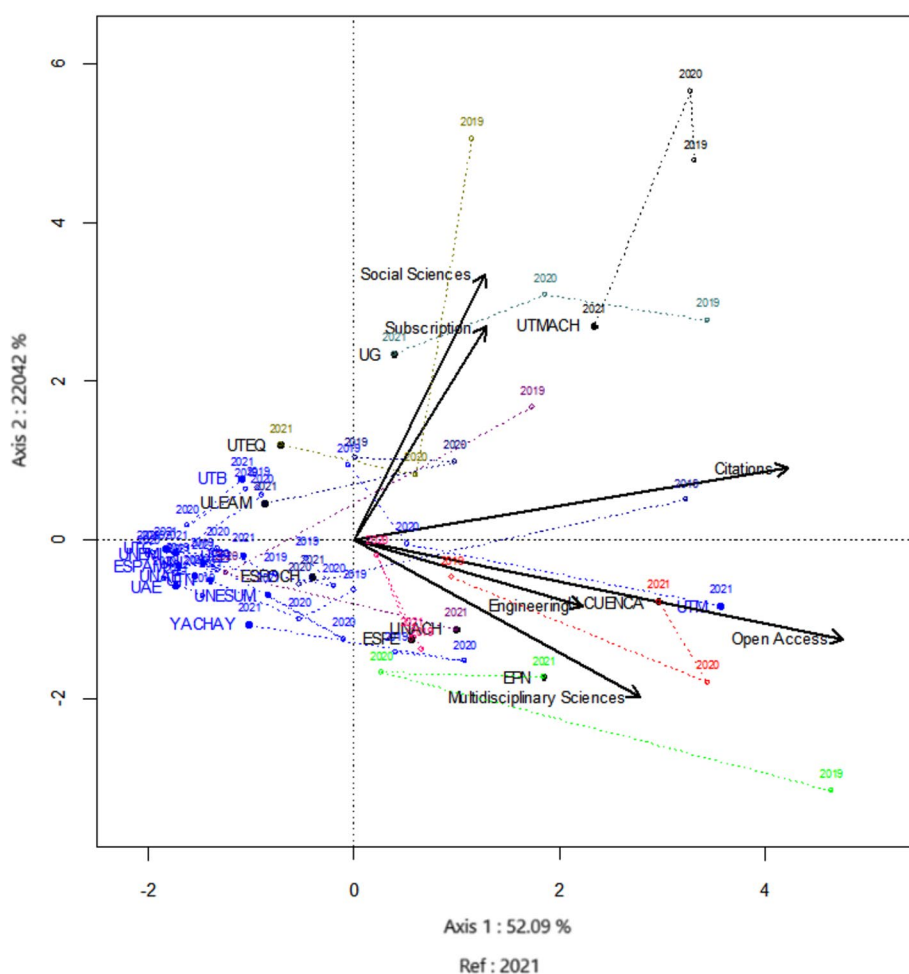


FIGURE 4
Dynamic HJ-biplot of Ecuadorian public universities, 2019–2021 (Axes 1–2).

2021 and its subsequent slowdown (Funada et al., 2023; Wang and Tian, 2021; Haghani and Bliemer, 2020). Ecuador mirrored the international upswing-public-university output that grew by 9.4 percent from 2020 to 2021, yet it did not exhibit the immediate downturn reported elsewhere, suggesting that the performance-based incentives introduced by the Higher Education Council in mid-2020 helped sustain momentum despite resource constraints.

5 Limitations and further research

This analysis relied on the Web of Science Core Collection, whose coverage of regional journals, conference proceedings, and non-English outlets is incomplete; therefore, the publication counts reported here should be considered conservative estimates. The study also focused solely on Ecuadorian public universities, excluding private institutions and specialized research centers that may follow different trajectories. Because the observation window spans only 2019–2021, it captures the immediate pandemic shock and early recovery but cannot reveal long-term shifts in research priorities. Moreover, the bibliometric indicators employed assess productivity and visibility, not research quality or societal impacts. Notwithstanding

these constraints, the multivariate HJ-Biplot framework provides a replicable model for examining research dynamics in emerging systems where traditional evaluation metrics may be limited. Future work should extend the database coverage to Scopus or SciELO, incorporate altmetric and qualitative evidence, and compare public and private universities over a longer time horizon to assess the post-pandemic convergence or divergence.

6 Conclusion

The multivariate analysis presented in this study revealed that Ecuadorian public universities demonstrated resilience and adaptability in the face of COVID-19–related disruptions. Between 2019 and 2021, institutions not only maintained but, in many cases, increased their research output, particularly in the areas of Education, Social Sciences, Engineering, and Multidisciplinary Sciences. This trend reflects the critical role of higher education institutions as both learning centers and agents of national development.

The prominence of educational and social science research reflects a strategic orientation toward addressing national development

priorities. The significant expansion of open-access publishing across multiple institutions highlights a deliberate effort to promote wider dissemination of academic knowledge, particularly in times of crisis where access to information is crucial.

Universities such as the Technical University of Machala and the State University of Cuenca have emerged as leaders, reflecting focused institutional strategies in response to global disruptions. Their example underscores the importance of sustained investment in research even during periods of uncertainty.

It is essential to continue supporting research capacity at Ecuadorian public universities, particularly in areas with high societal relevance. Efforts to broaden open-access publishing, promote interdisciplinary collaboration, and align research agendas with local and global development needs are critical to ensuring the continued growth and impact of Ecuadorian science.

These findings are especially relevant because they illustrate how national systems of higher education, particularly in developing contexts, can adapt research priorities and publishing strategies to meaningfully contribute to both global knowledge production and local development goals.

Data availability statement

Publicly available datasets were analyzed in this study. The data used in this study were retrieved from the Web of Science database (<https://www.webofscience.com/>).

Author contributions

BS-O: Data curation, Formal analysis, Software, Writing – original draft, Writing – review & editing. JS-P: Conceptualization, Data curation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing. OR: Formal analysis, Investigation, Methodology, Writing – original draft. LB-G: Conceptualization, Data

curation, Formal analysis, Writing – original draft. PA-M: Writing – review & editing, Methodology. MF-H: Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. The author(s) verify and take full responsibility for the use of generative AI in the preparation of this manuscript. Generative AI was used to improve the formatting of tables and to enhance sentence structure and flow in the Discussion section. All content was reviewed and verified by the authors to ensure accuracy and originality.

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References

- Araujo-Bilmonde, E., Huertas-Tulcanaza, L., and Párraga-Stead, K. (2020). Análisis de la producción científica del Ecuador a través de la plataforma Web of Science. *Cátedra* 3:2. doi: 10.29166/catedra.v3i2.2160
- Bashir, M. F., Ma, B., Bilal, Komal, B., and Bashir, M. A. (2021). Analysis of environmental taxes publications: a bibliometric and systematic literature review. *Environ. Sci. Pollut. Res.* 28, 20700–20716. doi: 10.1007/s11356-020-12123-x
- Bindu, N., Sankar, C. P., and Kumar, K. S. (2019). Research collaboration and knowledge sharing in e-governance: temporal analysis of co-author network. *Transfor. Gov People Proc Policy* 13, 2–33. doi: 10.1108/TG-03-2018-0022
- Bonilla Carchi, S. M., Ramírez Yagual, J. P. I., Barbecho Quizhpe, N. J., and Coronel Rosero, C. X. (2022). Análisis bibliométrico de la producción científica sobre calidad educativa en el Ecuador | Revista de Ciencias Sociales. Available online at: <https://produccioncientificaluz.org/index.php/rcs/article/view/38148> (Accessed December 27 2024).
- Brandenburger, B. (2022). A multidimensional and analytical perspective on open educational practices in the 21st century. *Front. Educ.* 7:990675. doi: 10.3389/feduc.2022.990675
- Carrión, D. J. S., and Figueroa, F. E. (2023). La producción científica sobre el turismo en el Ecuador. *Universidad-Verdad* 1, 62–79. doi: 10.33324/uv.v1i82.641
- Chavarró, D., Tang, P., and Rafols, I. (2014). Interdisciplinarity and research on local issues: evidence from a developing country. *Res. Evaluat.* 23, 195–209. doi: 10.1093/reseval/rvu012
- Egido Miguélez, J. F. (2015). Biplot dinámico. Salamanca: Universidad de Salamanca.
- Fei, X., Wang, S., Zheng, X., Liu, K., and Liang, X. (2021). Global research on cognitive behavioural therapy for schizophrenia from 2000 to 2019: a bibliometric analysis via CiteSpace. *Gen. Psychiatry* 34:e100327. doi: 10.1136/gpsych-2020-100327
- Forcael, E., Avila, A., and Tenreiro, C. (2022). Lessons learned from an engineering doctoral program created in the developing countries context. Proceedings – 8th International Symposium on Accreditation of Engineering and Computing Education, ICACIT 2022.
- Frutos Bernal, E., Martín del Rey, A., and Galindo Villardón, P. (2020). Analysis of Madrid metro network: from structural to HJ-Biplot perspective. *Appl. Sci.* 10:5689. doi: 10.3390/app10165689
- Funada, S., Yoshioka, T., Luo, Y., Iwama, T., Mori, C., Yamada, N., et al. (2023). Global trends in highly cited studies in COVID-19 research. *JAMA Netw. Open* 6:e2332802. doi: 10.1001/jamanetworkopen.2023.32802
- Galindo-Villardón, P. (1986). Una alternativa de representación simultánea: HJ-Biplot. *Qüestió* 10, 13–23.
- Gallegos, M., Cervigni, M., Consoli, A. J., Caycho-Rodríguez, T., Polanco, F. A., and Martino, P. (2020). COVID-19 in Latin America: a bibliometric analysis of scientific publications in health. *Electron. J. Gen. Med.* 17:em261. doi: 10.29333/ejgm/8460
- Gómez-Marcos, M. T., Vicente-Galindo, M. P., and Rodero, H. M. (2022). Is the Shanghai ranking a guarantee of high academic performance? *Revista Espanola Documentacion Cientifica* 45:e318. doi: 10.3989/redc.2022.1.1805

- González Cisneros, A. L., Pedraza Melo, N. A., González Cisneros, A. L., and Pedraza Melo, N. A. (2021). Factores del capital humano y desempeño en instituciones de educación media superior. *Perfiles Educativos* 43, 93–113. doi: 10.22201/iisue.24486167e.2021.174.59393
- Guerrero-Quinonez, A. J., Guagua, O. Q., and Barrera-Proano, R. G. (2023). A look at university education in Ecuador: politics, quality and teaching. *Ibero-American J. Educ. Soc. Res.* 3, 244–248. doi: 10.56183/iberoeds.v3i1.623
- Haghani, M., and Bliemer, M. C. (2020). Covid-19 pandemic and the unprecedented mobilisation of scholarly efforts prompted by a health crisis: Scientometric comparisons across SARS, MERS and 2019-nCoV literature. *Scientometrics* 125, 2695–2726.
- Hossain, M. M. (2020). Current status of global research on novel coronavirus disease (COVID-19): A bibliometric analysis and knowledge mapping. *F1000Research* 9:374. doi: 10.12688/f1000research.23690.1
- Jaramillo, R. A. A., Soledispa, D. L. P., Santana, M. A. Z., Macías, V. G. M., Coyago, O. F. C., and Bravo, A. V. S. (2023). La investigación productiva en el área de la educación: Una comparación del Ecuador con otros países de América del Sur. *Ciencia Latina Revista Científica Multidisciplinar* 7, 4319–4339. doi: 10.37811/cl_rcm.v7i2.5646
- Khan, D., Ashar, M., and Yuvaraj, M. (2023). Do open access journals have a greater citation impact? A study of journals in library and information science. *Collection Curation* 42, 13–24. doi: 10.1108/CC-03-2022-0010
- Lancho-Barrantes, B. S., and Cantu-Ortiz, F. J. (2021). Quantifying the publication preferences of leading research universities. *Scientometrics* 126, 2269–2310. doi: 10.1007/s11192-020-03790-1
- Luque González, A., Coronado Martín, J. A., Fernández García, C., Luque González, A., Coronado Martín, J. A., and Fernández García, C. (2022). “Academic migration from scientist networks in the global environment: a case study” in advances in educational technologies and instructional design (academic-migration-from-scientist-networks-in-the-global-environment). (USA: IGI Global), 267–291.
- Lyon, A., Friedmann, H., and Wittman, H. (2021). Can public universities play a role in fostering seed sovereignty? *Elementa Sci Anthropocene* 9:00089. doi: 10.1525/elementa.2021.00089
- Masalimova, A. R., Orekhovskaya, N. A., Pivovarov, V. A., Borovikova, Y. V., and Zhirkova, G. P. (2024). Analyzing trends in online learning in higher education in the BRICS countries through bibliometric data. *Front. Educ.* 9:1409013. doi: 10.3389/feduc.2024.1409013
- Mateus, I. M. A., and Berrío-Zapata, C. (2021). “Brazilian scientific production on COVID-19: a bibliometric and altmetric analysis” in Proceedings of the 18th international conference on Scientometrics and Informetrics. eds. W. Glänzel, S. Heeffer, P.-S. Chi and R. Rousseau (Australia: International Society for Scientometrics and Informetrics), 783–790.
- Meng, W., Yu, L., Liu, C., Pan, N., and Pang, X. (2024). A systematic review of the effectiveness of online learning in higher education during the COVID-19 pandemic period. *Front. Educ.* 8:1334153. doi: 10.3389/feduc.2023.1334153
- Murad, M. A. A., Vanfretti, L., Rokonzuzaman, M., and Tuhin, R. A. (2017). Enhancing engineering studies in developing countries using OpenModelica. In 2017 4th International Conference on Advances in Electrical Engineering (ICAEE) Dhaka, Bangladesh: IEEE. 153–158.
- Onime, C. E., and Uhomobhi, J. O. (2012). Engineering education in a developing country: experiences from Africa. 2012 15th International Conference on Interactive Collaborative Learning, ICL 2012.
- Quincho-Lopez, A., and Pacheco-Mendoza, J. (2021). Research trends and collaboration patterns on Polymyxin resistance: a bibliometric analysis (2010–2019). *Front. Pharmacol.* 12:702937. doi: 10.3389/fphar.2021.702937
- Sekhar, R., Shah, P., and Iswanto, I. (2022). Robotics in industry 4.0: a bibliometric analysis (2011–2022). *J. Robot. Control* 3, 583–613. doi: 10.18196/jrc.v3i5.15453
- Sweileh, W. M. (2022). Analysis and mapping of global research publications on shift work (2012–2021). *J. Occupat. Med. Toxicol.* 17:22. doi: 10.1186/s12995-022-00364-0
- Tang, R., Zhang, S., Ding, C., Zhu, M., and Gao, Y. (2022). Artificial intelligence in intensive care medicine: bibliometric analysis. *J. Med. Internet Res.* 24:e42185. doi: 10.2196/42185
- Thuy, P. T. T. (2022). The role of social science research: some requirements for Vietnam. *Int. J. Health Sci.* 6, 1166–1175. doi: 10.53730/ijhs.v6nS4.6012
- Toapanta Toapanta, S. M., Zambrano, M., Paredes Parada, W., Rivera Gutierrez, M. J., Mafla Gallegos, L. E., Baño Hifong, M. M., et al. (2023). “An approach to scientific research for the continuous improvement of scientific production in Ecuador” in Lecture notes in networks and systems, 619 LNNS, ed. J. Kacprzyk, Springer. 247–261.
- Viera-Arroyo, W., Sánchez-Arizo, V., Merino-Toro, J., and Domínguez-Andrade, J. (2020). Scientific production of Ecuador in the agricultural field: case of the National Institute of agricultural research, period 2014–2019. *Rev. Espanola Document. Cientifica* 43, e280–e218. doi: 10.3989/redc.2020.4.1722
- Wang, P., and Tian, D. (2021). Bibliometric analysis of global scientific research on COVID-19. *J. Biosafety Biosecur.* 3, 4–9. doi: 10.1016/j.jobb.2020.12.002
- Wani, J. A., Ganaie, S. A., and Rehman, I. U. (2023). Mapping research output on library and information science research domain in South Africa: a bibliometric visualisation. *Informat. Discov. Delivery* 51, 194–212. doi: 10.1108/IDD-10-2021-0115
- Zarog, M. (2022). Engineering research impact in developing countries. 2022 International Conference on Science and Technology, ICOSTECH 2022.
- Zoido, P. (2008). Public spending on education in Latin America: Does it pay? Paris: OECD Publishing, 80.