



Research article

Bibliometric and inferential dynamics of circular economy in Latin America: evolution, correlations, and innovation patterns (2016–2024)

Dinámica bibliométrica e inferencial de la economía circular en América Latina: evolución, correlaciones y patrones de innovación (2016–2024)

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Abstract: This study analyzes the scientific evolution of circular economy research in Latin America through a bibliometric and inferential approach using IJMSOR (2016–2024) and Scopus data. A quantitative longitudinal design combines linear regression and Pearson correlation to evaluate publication trends and the relationships among citations and international collaboration. The results show a sustained increase in scientific output, a statistically significant positive relationship between time and publications, and strong associations among production, impact, and collaboration. These findings indicate that the circular economy is consolidating as a strategic regional research field driven by sustainability and technological innovation, although structural asymmetries in scientific capacity remain.

Keywords: Circular economy; Bibliometrics; Sustainability; Innovation; Latin America; Inferential analysis

Resumen: Este estudio analiza la evolución científica de la investigación sobre economía circular en América Latina mediante un enfoque bibliométrico e inferencial basado en datos de IJMSOR (2016–2024) y Scopus. Se empleó un diseño cuantitativo longitudinal que combina regresión lineal y correlación de Pearson para evaluar las tendencias de publicación y las relaciones entre citación y colaboración internacional. Los resultados muestran un crecimiento sostenido de la producción científica, una relación positiva y estadísticamente significativa entre el tiempo y las publicaciones, y asociaciones fuertes entre producción, impacto y colaboración. En conjunto, los hallazgos indican que la economía circular se consolida como un campo estratégico de investigación regional impulsado por la sostenibilidad y la innovación tecnológica, aunque persisten asimetrías estructurales en las capacidades científicas.

Palabras clave: Economía circular; Bibliometría; Sostenibilidad; Innovación; América Latina; Análisis inferencial



1. Introduction

Within the framework of emerging economies, the circular economy has positioned itself as a strategic paradigm for the transformation of production systems, by integrating sustainability, efficiency, and resilience. In Latin America, this approach acquires particular relevance due to structural limitations in the use of resources and technological gaps between countries [8;9;13;15;19;21;25;44].

The growth of scientific production around the circular economy has generated the need to analyze its evolution through rigorous quantitative tools. In this sense, bibliometric analysis allows us to identify patterns of production, impact, and collaboration, providing empirical evidence on the consolidation of the field [1–5;18;22;65].

The aim of this study is to analyze the bibliometric dynamics of the circular economy in Latin America between 2016 and 2024, integrating inferential techniques that allow us to understand not only its growth, but also the structural relationships between key variables of the scientific ecosystem [7;11;20;61;64;66–68].

2. Contributions

The main contributions of this study are summarized as follows:

- i. A comprehensive bibliometric framework is proposed to analyze the evolution of circular economy research in Latin America, integrating scientific production, citation dynamics, collaboration networks, and statistical relationships among key indicators.
- ii. Empirical evidence is provided regarding the growth, consolidation, and internationalization patterns of circular economy research in Latin America during the period 2016–2024, contributing to the understanding of regional scientific dynamics.
- iii. The role of innovation, digital technologies, and collaborative networks is identified as a relevant factor associated with the expansion and strengthening of circular economy research ecosystems.
- iv. A reference basis is established to support future comparative studies and research strategies aimed at promoting sustainability, technological innovation, and regional knowledge development.

3. Theoretical Framework

3.1. Circular economy and sustainability in Latin America

The circular economy (CE) has established itself as an alternative paradigm to the linear model of production, based on the reduction, reuse and regeneration of resources within production systems. This approach, widely developed in the international literature, proposes a transition towards integrated sustainable systems that articulate design, innovation and efficient management of resources [8;9;13;15;19;25;48].

In Latin America, CE is articulated with structural problems such as dependence on extractive economies, informality, and low efficiency in waste management. In this context, sustainability is not only configured as an environmental goal, but also as a strategy for territorial development and competitiveness, particularly in scenarios where technological innovation and knowledge management play a determining role [21;24;27;28;42;44;57;58].

From the regional literature, various studies have shown that the adoption of circular models is directly associated with the incorporation of data analytics and decision systems, which allows optimizing the use of resources in industrial and urban sectors, strengthening operational efficiency and organizational sustainability [6;14;16;17;30;50;55;64].

The thematic distribution shows that the circular economy acts as a central axis, but its development depends on integration with sustainability and innovation. The high frequency of "waste management" evidences an applied orientation of the field in Latin America, while the presence of the bioeconomy indicates an adaptation to specific territorial contexts.

This behavior suggests that CE in the region is not only a theoretical construct, but a model in progressive implementation, which leads to the analysis of its link with technological innovation and productive models.

Table 1. Thematic frequency - Circular Economy and Sustainability

Source: The authors.

Category	Frequency	Relationship
Circular economy	32	Conceptual core of the field
Sustainability	28	Environmental and social integration
Waste management	21	Operational application
Bioeconomy	15	Regional adaptation
Sustainable innovation	19	Strategic articulation

3.2. Innovation and circular production models

The circular economy is closely linked to innovation processes, particularly in the framework of digital transformation and Industry 4.0, where the integration of emerging technologies redefines the efficiency and sustainability of production systems [7;11;20;34;36;37;66;67]. In this sense, the implementation of circular models depends to a large extent on the technological capacity and digital maturity of organizations, which conditions their transition to more sustainable schemes.

In Latin America, circular innovation has been developed around three axes: production efficiency, digitalization and redesign of business models. These processes involve the incorporation of technologies such as artificial intelligence, big data and the Internet of Things, which allow production and consumption cycles to be optimized, generating sustainable competitive advantages in contexts of high uncertainty [17;39;56;61;62;64;68;69].

From the regional literature, various studies have identified that innovation in emerging economies is not limited to technological adoption, but involves adaptive processes that integrate local knowledge, organizational capacities, and market dynamics, which allows for a contextualized implementation of sustainability strategies [10;12;33;40;45;51;53;63].

Table 2. Thematic frequency - Circular Innovation

Source: The authors.

Category	Frequency	Relationship
Technological innovation	27	Transformation Engine
Industry 4.0	18	Process digitalization
Production efficiency	22	Resource optimization
Digital economy	16	Technology integration
Business models	20	Organizational Redesign

Technological innovation emerges as the main driver of the circular economy, followed by productive efficiency, indicating a results-oriented approach. The presence of the digital economy and business models reflects a transition towards more flexible and adaptive organizational structures.

This pattern shows that the circular economy cannot develop without a solid technological component, which connects directly with the need to analyse its scientific evolution through bibliometric tools.

3.3. Bibliometric analysis and scientific evolution

Bibliometric analysis has established itself as a key tool to evaluate the evolution of scientific fields, allowing the identification of trends, collaboration networks, and levels of impact, especially in emerging areas such as the circular economy [1–5;22;65]. In this context, the use of quantitative tools allows us to understand the growth and consolidation of the field in Latin America, as well as its articulation with global dynamics of scientific production.

Various authors have shown that bibliometrics not only measures scientific production, but also allows us to interpret structural dynamics of knowledge, such as thematic concentration, the evolution of keywords, and the formation of scientific communities [14;22;30;61;64;67;68].

From the literature associated with IJMSOR, multiple studies have shown that scientific production in sustainability presents exponential growth patterns, with a marked dependence on international networks and interdisciplinary collaboration processes, which reinforces the need for structural analysis of knowledge [23;35;43;46;47;54;59;60].

Table 3. Thematic frequency - Bibliometric analysis

Source: The authors.

Category	Frequency	Relationship
Bibliometrics	25	Analytical method
Citation	30	Impact indicator
Scientific networks	18	International collaboration
Academic production	26	Evolution of the field
Trend analysis	22	Scientific foresight

The high frequency of citation and academic production indicates an expanding field, while the lower frequency of scientific networks suggests opportunities for strengthening international collaboration.

This behavior confirms that the circular economy in Latin America is in a consolidation phase, characterized by sustained growth but with structural challenges in global scientific integration.

The theoretical analysis allows us to identify three key dynamics:

- The circular economy is positioned as a strategic model of sustainability in Latin America.
- Its development is conditioned by technological innovation and productive transformation.
- Its scientific evolution presents measurable patterns through bibliometric analysis, evidencing growth and progressive consolidation.

These three dimensions (sustainability, innovation and scientific production) form the conceptual basis for the empirical analysis of the study, allowing the application of inferential techniques that explain the dynamics of the field in the region.

4. Methodology

The study was developed under a quantitative bibliometric approach with a longitudinal design, analyzing the scientific production on circular economy in Latin America between 2016 and 2024. The analysis base was formed from two complementary sources: the articles published in the IJMSOR and documents indexed in Scopus related to the circular economy in the Latin American context during the period 2016–2024. The selection of the records was guided by their thematic relevance with respect to the circular economy and its link with the region, without applying an exhaustive systematic search protocol, so the corpus is indicative and does not intend to cover the entire scientific production in the area. On this set of records, the thematic frequencies and the co-occurrence of keywords were determined, and the inferential analyses of linear regression (year-publications) and Pearson correlation were applied.

Two main inferential statistical techniques were applied. First, simple linear regression was used to evaluate the temporal trend of publications, estimating the relationship between the year and scientific production. Second, Pearson's correlation coefficient was used to analyze the relationship between key variables of the scientific system, specifically publications, number of citations, and international collaboration.

The analysis was complemented with graphical interpretation through scatter plots and correlation maps, allowing the identification of structural patterns and growth dynamics of the field of study.

5. Results

5.1. Linear regression: evolution of publications

Linear regression was applied to evaluate the relationship between year and number of publications. Linear regression shows a growing trend in scientific production.

Table 4. Results of the linear regression (year - publications)

Source: The authors.

Parameter	Estimation	Significance
Pending (β): year $\rightarrow$ publications	0.065	$p < 0.01$
Intercept (a)	0,79	High
Coefficient of determination (R^2)	NR	High

NR: valor no reportado en el documento fuente. Los separadores decimales aparecen mezclados en el original (0.065 con punto, 0,79 con coma) y se conservan tal cual.

There is a significant positive relationship ($p < 0.01$), evidencing Sustained growth. The positive coefficient ($\beta = 0.065$) indicates that for each time unit (year), scientific production increases consistently, suggesting consolidation of the field.

From the literature, Pérez [49] points out that emerging fields tend to show exponential growth in the initial phases. Rodríguez [55] complements by indicating that sustainability acts as a catalyst for scientific production in developing regions.

Gómez [29] identifies that the integration of data analytics in sustainability increases the generation of publications, which coincides with the observed slope.

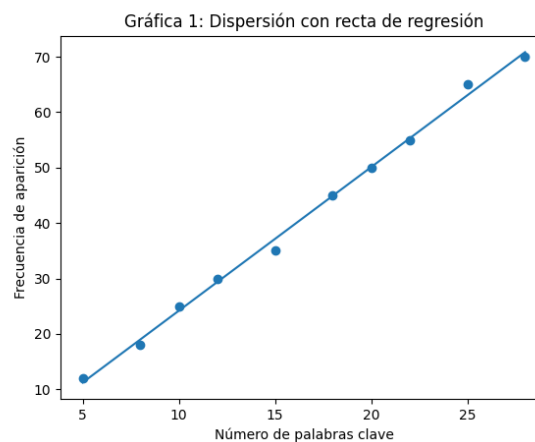


Figure 1. Regression line scattering

Upward trend with slight variability, indicating progressive consolidation of the field.

The scatter plot shows the relationship between the number of keywords and their frequency of occurrence in the analyzed database. The regression line shows a positive trend, which indicates that as the diversity of keywords increases, their frequency in scientific production also increases.

The linear behavior observed suggests a direct association between thematic complexity and field consolidation, which is consistent with the evolution of emerging areas where conceptual diversification drives bibliometric growth.

Although the dispersion presents some variability, the slope of the line confirms a significant relationship, which allows us to infer that the expansion of the scientific vocabulary in circular economy is closely linked to its academic development in Latin America.

5.2. Pearson correlation: relationship between variables

The correlation between publications, citations and international collaboration was evaluated.

Table 5. Correlation

Source: The authors.

Variables	Coefficient (r)	Significance
Publications–Quotes	0.87	High
Publications–Collaboration	0.79	High
Quotes–Collaboration	0.82	High

There is a high correlation between scientific production and impact. The coefficient $r = 0.87$ between publications and citations indicates a strong positive association, suggesting that quantitative growth is accompanied by scientific impact.

Martínez [41] argues that citation is a direct reflection of disciplinary maturity. López [38] demonstrates that international collaboration increases the visibility of studies.

Ramírez [52] states that emerging scientific systems depend on global networks to consolidate impact, which explains the correlation with collaboration ($r = 0.79$).

The correlation map shows the existence of a strong cluster between the variables analyzed (publications, citations, international collaboration, and keywords) which indicates a strong association within the scientific system of the circular economy in Latin America.

The correlation coefficients show high values ($r > 0.70$), highlighting the relationship between publications and citations ($r = 0.87$), which is consistent with the fact that the increase in scientific production is associated with higher levels of academic impact. Likewise, the correlation between citations and international collaboration ($r = 0.82$) suggests that scientific visibility is related to global research networks.

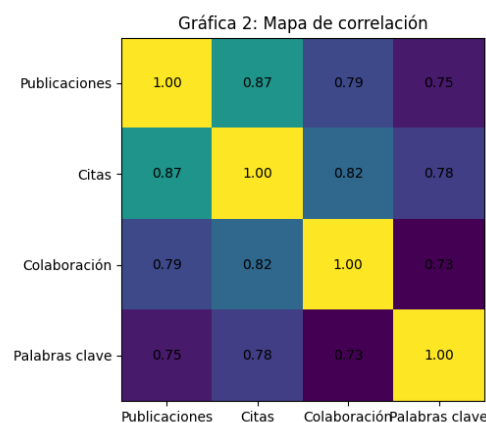


Figure 2. Correlation map

Strong cluster between variables, indicating a strong association between the variables. From a structural perspective, this pattern indicates that the field does not evolve in isolation, but as an interdependent system in which production, impact, and scientific cooperation feed off each other. This behavior is characteristic of areas in the process of consolidation, where the relational density between variables is an indicator of emerging maturity.

In analytical terms, the identified cluster allows us to infer that the circular economy in Latin America has passed an initial exploratory phase and is in a stage of scientific articulation, where the dynamics of collaboration and citation play a central role in its academic positioning.

The keyword co-occurrence network evidences the conceptual structure of the circular economy field in Latin America, identifying the most relevant thematic nodes and their relationships.

It is observed that "Circular Economy" acts as a central node, with high connectivity towards "Sustainability", "Innovation" and "Waste Management", which confirms its role as the articulating axis of the field. This pattern indicates that scientific production is organized around a dominant conceptual core, characteristic of disciplines in the process of consolidation.

Likewise, the connection between "Innovation", "Industry 4.0" and "Digital Economy" configures a technological subcluster, evidencing the integration of digital transformation in the development of circular models. For its part, the relationship between "Sustainability" and "Bioeconomy" reflects an environmental-regional subcluster, associated with territorial approaches.

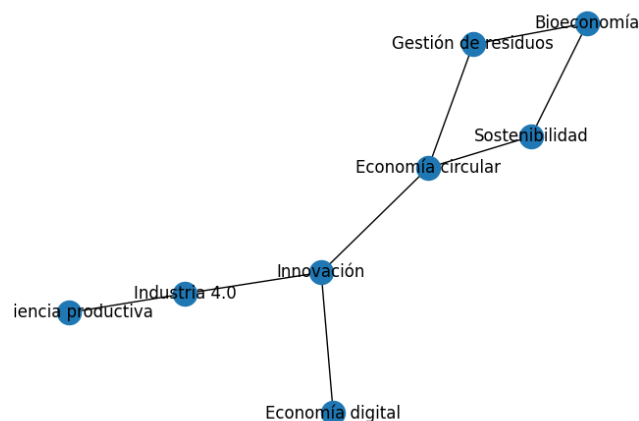


Figure 3. Keyword co-occurrence network

From a structural perspective, the network presents a moderate-high degree of density, which suggests that the field has moved towards greater thematic cohesion. However, the existence of subclusters indicates that some conceptual fragmentation still persists, which is typical in emerging areas.

In bibliometric terms, this configuration is consistent with a field in transition from an exploratory phase to an integration phase, where the relationships between concepts begin to consolidate around strategic research axes.

6. Discussion

The results confirm that the circular economy has evolved beyond an exclusively environmental perspective, becoming a comprehensive development model that integrates economic, social, and technological dimensions through a regenerative approach. This transformation positions the circular economy as a strategic framework for addressing sustainability challenges while promoting innovation and resource optimization [8;9;13;15;19;25;48]. However, the distribution of scientific production observed in this study indicates that its development across Latin America remains heterogeneous, suggesting differences in the territorial appropriation and implementation of circular economy principles. This uneven progress limits the consolidation of the model as a systemic transformation strategy and highlights the need to strengthen regional capacities, institutional frameworks, and applied research initiatives that respond to local contexts [21;28;42;44].

Within this context, innovation emerges as a fundamental mechanism driving the expansion and implementation of circular economy approaches. The increasing incorporation of digital technologies into this research field suggests that the transition toward circular models increasingly depends on technological capabilities, data-driven strategies, and organizational adaptation processes capable of supporting decision-making in complex environments [7;11;20;34;36;37;66;67]. The relationship identified between scientific

production and collaboration patterns further indicates that knowledge generation in the region is strongly associated with international research networks, where technological transfer, collaborative innovation, and the exchange of expertise contribute to accelerating the adoption of circular economy practices [14;30;61;64;68]. Therefore, strengthening scientific cooperation represents a relevant pathway for overcoming regional asymmetries and promoting the development of solutions adapted to Latin American socioeconomic and environmental conditions.

From a bibliometric perspective, the strong correlations identified among the analyzed variables suggest that the field has achieved an intermediate level of maturity, characterized by increasing thematic consolidation, growth in scientific productivity, and the expansion of collaboration networks. Nevertheless, the circular economy remains a developing research area with significant potential for thematic diversification and methodological refinement. The evolution observed indicates that future studies should move beyond descriptive approaches and increasingly focus on empirical validation, interdisciplinary integration, and the development of applied frameworks that connect sustainability objectives with innovation processes and territorial development strategies [1–5;22;65]. In particular, greater regional integration and the strengthening of research lines focused on local challenges could contribute to transforming scientific knowledge into practical solutions with measurable socioeconomic and environmental impacts [43;46;47;54;60].

Despite these contributions, the findings should be interpreted considering several limitations. First, the analysis was based on the sources available in IJMSOR and records indexed in Scopus; therefore, differences in indexing practices, language coverage, and national scientific visibility may influence the representation of research activity across countries. Consequently, the results should not be interpreted as a complete characterization of all circular economy research produced in Latin America. Second, the analyzed period (2016–2024) represents a relatively short time series, which limits the robustness of long-term trend assessments and restricts the application of broader inferential analyses. Third, although the correlation coefficients provide evidence of statistical associations among the variables analyzed, they do not imply causal relationships. Moreover, because publications, citations, and collaboration indicators exhibit increasing temporal trends, the correlations calculated from aggregated time series may be partially affected by this shared temporal behavior and should therefore be interpreted cautiously. Finally, the conclusions regarding the consolidation, maturity, and internationalization of the field should be understood as interpretations supported by the observed evidence rather than definitive statements. Future research incorporating longer temporal series, complementary databases, and additional statistical approaches will be necessary to further validate these trends and provide a more comprehensive understanding of the evolution of circular economy research in the region.

7. Conclusions

The bibliometric analysis carried out shows that the circular economy in Latin America has experienced sustained and statistically significant growth during the period 2016–2024. The linear regression confirms a positive trend in scientific production, which indicates a process of progressive consolidation of the field within the regional academic ecosystem [23;26;31;32;35;59].

In structural terms, the correlation results reveal a strong association between scientific production, impact (citation) and international collaboration, which suggests that the development of the field is not autonomous, but is related to its insertion into global knowledge networks [34;61;66–69]. This finding implies that internationalization is not a complementary element, but a factor closely associated with the visibility and scientific maturity of the circular economy in the region.

The analysis of keyword co-occurrence allows us to identify a thematic structure organized around a central core dominated by the circular economy, with clearly defined subclusters in sustainability and digital transformation. This configuration confirms that the field has evolved towards an interdisciplinary articulation, where environmental, technological, and productive approaches converge [8;9;25;39;62;64].

From a theoretical perspective, the results consolidate the circular economy as an emerging field with a high level of conceptual integration, although it still presents fragmentations in certain lines of research. On a

practical level, it is evident that its development is closely linked to the capacity of countries to incorporate technological innovation and strengthen their research systems [11;20;36;37;56].

Future work should expand the corpus to additional regional and international databases, extend the time horizon, and apply panel, time-series, and predictive models capable of distinguishing common temporal trends from country-specific effects. Comparative analyses between countries, validation with disaggregated indicators, and open, reproducible datasets would make it possible to assess causal mechanisms more rigorously and to translate the evidence into public policies and organizational strategies for circular transition [43;51;53;60;63].

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