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ORIGINAL

Circular economy in International Trade: impact on exports from emerging countries

Economía circular en el Comercio Internacional: impacto en las exportaciones de países emergentes

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ABSTRACT

Introduction: the circular economy has established itself as a strategic model for boosting sustainability and competitiveness in international trade. This approach is gaining relevance in emerging countries, where export diversification and resilience are crucial. The objective was to analyze the impact of the circular economy on the exports of ten countries in Latin America, Asia, and Africa, considering its capacity to generate advantages on the global stage.
Method: a quantitative-comparative approach was adopted, complemented by a trade network perspective. To measure circular dynamics, the Export Circularity Index (ICE) was designed and applied for the period 2015–2024. It was based on sectoral export data, with a special focus on reconditioned, recycled, and reusable products, and the identification of trade links between emerging countries and strategic partners. or unstructured, no longer than 250 words; written in the past tense and in the third person singular.
Results: the findings show sustained growth in the proportion of circular products exported, with sectors such as refurbished electronics, recycled textiles, and reusable plastics taking center stage. Circular exports showed greater resilience to global crises, particularly during the COVID-19 pandemic. The analysis of trade networks revealed greater density in international linkages, although the risk of concentration in a few markets persists.
Conclusions: the circular economy is emerging as a driver for strengthening the sustainability, competitiveness, and resilience of emerging economies in international trade. However, regulatory advances and structural limitations continue to hinder its consolidation as an export model.

Keywords: Circular Economy; International Trade; Emerging Countries; Sustainable Exports; Trade Networks.

RESUMEN

Introducción: la economía circular se ha consolidado como un modelo estratégico para impulsar la sostenibilidad y la competitividad en el comercio internacional. En los países emergentes, donde la diversificación y resiliencia de las exportaciones resultan determinantes, este enfoque adquiere relevancia. El objetivo fue analizar el impacto de la economía circular en las exportaciones de diez países de América Latina, Asia y África, considerando su capacidad para generar ventajas en el escenario global.
Método: se adoptó un enfoque cuantitativo-comparativo, complementado con una perspectiva de redes comerciales. Para medir la dinámica circular se diseñó y aplicó el Índice de Circularidad de Exportación (ICE) en el período 2015–2024. Se basó en datos de exportaciones sectoriales, con especial atención en productos

reacondicionados, reciclados y reutilizables e identificación de vínculos comerciales entre países emergentes y socios estratégicos.
Resultados: los hallazgos muestran un crecimiento sostenido en la proporción de productos circulares exportados, con protagonismo de sectores como la electrónica reacondicionada, los textiles reciclados y los plásticos reutilizables. Las exportaciones circulares exhibieron mayor resiliencia frente a crisis globales, destacando el periodo de la pandemia de COVID-19. El análisis de redes comerciales evidenció una mayor densidad en los vínculos internacionales, aunque persiste el riesgo de concentración en pocos mercados.
Conclusiones: la economía circular emerge como un motor para fortalecer la sostenibilidad, competitividad y resiliencia de las economías emergentes en el comercio internacional. No obstante, los avances normativos y las limitaciones estructurales siguen condicionando su consolidación como modelo exportador.

Palabras clave: Economía Circular; Comercio Internacional; Países Emergentes; Exportaciones Sostenibles; Redes Comerciales.

INTRODUCTION

The linear economic model, based on extracting, producing, consuming, and discarding, has been the dominant pattern of international trade in recent decades. However, its sustainability is increasingly being called into question in the face of natural resource depletion, supply chain instability, and global environmental impact.[1] Against this backdrop, the circular economy (CE) is emerging as a strategic alternative that seeks to keep the value of resources and materials within the economic cycle for as long as possible, promoting recycling, reuse, repair, and remanufacturing.[2]

Although the concept of the circular economy has gained momentum in industrialized countries, its integration into the international trade strategies of emerging countries is still in its infancy. These countries face both opportunities and challenges when incorporating circular practices into their production and export structures. On the one hand, the circular economy can offer sustainable comparative advantages, openness to new market niches, and greater resilience to external shocks.[3] On the other hand, there are structural limitations such as low investment in innovation, informal production, and a lack of international standards on circularity.[4]

Despite growing academic interest, there remains a gap in empirical studies linking the circular economy and exports in emerging countries, especially from quantitative or trade network-based approaches. This article seeks to contribute to this discussion through a multilevel analysis that assesses the impact of circular strategies on exports from emerging economies between 2015 and 2024.

Literature review

1. Concept and fundamentals of the circular economy

The circular economy (CE) is defined as a regenerative economic model whose objective is to keep resources, materials, and products in use for as long as possible, minimizing waste generation and natural resource extraction.[2] This model contrasts with the traditional linear economy, characterized by an "extract-produce-consume-dispose" scheme that has proven unsustainable in the face of global environmental and social limits.[1]

The CE is based on principles such as reduction, reuse, recycling, repair, and remanufacturing, and proposes the regeneration of natural systems, efficiency in the use of materials, and design for circularity.[5] This paradigm has been adopted by many countries and productive sectors, and is considered an important strategy for environmental sustainability and economic competitiveness in the 21st century.[6]

2. Circular economy and its integration into international trade

International trade is a fundamental activity for the economic development of countries, especially for those with emerging economies seeking to insert themselves into global value chains,[7] however, traditional trade practices have been marked by extractive patterns and linear consumption that generate significant negative impacts, both environmentally and socially.[8]

The incorporation of the circular economy into international trade strategies represents a paradigm shift that can translate into competitive advantages for emerging countries. In particular, the adoption of circularity-based production and export models can contribute to diversifying productive structures, generating sustainable employment, and increasing resilience to global market fluctuations.[9]

Recent studies indicate that the circular economy can foster the development of niche markets specializing in sustainable, reusable, and recycled products, such as recycled textiles, refurbished electronics, and recyclable materials.[10] This is particularly relevant for emerging countries, which, by integrating these practices, can overcome their dependence on traditional exports of raw materials and basic manufactured goods.[11]

3. Challenges and opportunities for emerging countries in adopting the circular economy

Despite the opportunities presented by the circular economy, emerging countries face a number of structural challenges to its effective implementation. These include informal labor, which hinders the formalization of circular production chains, a lack of adequate technological and recycling infrastructure, and regulatory barriers that limit the adoption of international sustainability standards.[12]

On the other hand, these countries have a great opportunity to position themselves as key players in the global transition towards a more sustainable economy, taking advantage of their potential for technological innovation and the availability of natural resources that can be managed under circular principles.[13] The formulation of public policies aimed at encouraging innovation, institutional strengthening, and international cooperation are essential elements for overcoming obstacles and consolidating a circular economic model.[14]

4. Methods and indicators for measuring the circular economy in trade

Adequate measurement of the circular economy is a fundamental component in assessing its impact and promoting its adoption. International organizations, such as the Organization for Economic Cooperation and Development (OECD),[15] have developed specific indicators to measure circularity in productive sectors and international trade.[16] These indicators consider aspects such as efficiency in the use of materials, recycling, reuse, and minimal waste generation.

Furthermore, commercial network analysis has been an effective methodology for understanding the relationships and interdependencies between countries and sectors in the context of the circular economy.[17] The use of complex network analysis techniques allows us to visualize the connections between exporting countries and products with circular attributes, identifying patterns of cooperation, vulnerabilities, and opportunities to strengthen circular value chains.[18]

5. Sustainability and export resilience in a circular context

The circular economy promotes environmental sustainability and also strengthens the economic resilience of countries, especially those with emerging economies. By reducing dependence on finite raw materials and increasing resource efficiency, countries can better cope with crises and global market volatility, as evidenced during the COVID-19 pandemic.[19]

Circular economic models contribute to productive diversification and the creation of green jobs, which has a positive impact on social and economic stability.[9] The capacity to adapt and recover from external shocks is therefore greater in countries that integrate circularity into their production and export chains.[6]

METHOD

To analyze the impact of the circular economy on exports from emerging countries, a mixed methodological design was applied, combining innovative quantitative tools with a qualitative context analysis. This integration made it possible to capture both the numerical dynamics of trade and the regulatory and strategic frameworks that condition its evolution.

Selection of countries and study period

Ten emerging countries in Latin America, Asia, and Africa (Mexico, Ecuador, Vietnam, Peru, Kenya, Bangladesh, among others) were selected based on their relative weight in international trade and their explicit interest in the transition to circular models. The period of analysis covered the years 2015–2024, which made it possible to identify recent trends and effects associated with emerging policies.

Quantitative analysis

The Export Circularity Index (ECI) was designed, inspired by methodologies proposed by the OECD.[16] This indicator quantifies the proportion of goods with circular attributes (recyclable, repairable, or remanufactured) within total national exports. The data were obtained from official sources such as BACI, UN Comtrade, and Trade Map. Products were classified according to the Harmonized System (HS), and filters were applied to identify those with circular characteristics, in accordance with criteria established in regional circular economy studies.

Trade network analysis

Gephi software was used to construct and analyze complex trade networks. The nodes represented countries and products, while the weighted links reflected the volume and value of circular exports. This technique made it possible to visualize the density, centrality, and patterns of links between strategic actors.

Qualitative analysis

A documentary review of public policies and national circular economy strategies in the countries analyzed was carried out, using reports from international organizations[20] and ministries of trade and industry.[21] This component contextualized the quantitative results and provided evidence on the regulatory frameworks that guide the circular transition.

Validation and robustness. A backtesting procedure was applied to assess the stability of the ICE in crisis contexts, particularly during the COVID-19 pandemic. In addition, the results were compared with macroeconomic indicators of export resilience, which reinforced the validity and reliability of the findings.

RESULTS

1. Analysis of the Export Circularity Index (ECI)

The Export Circularity Index (ECI) developed for this study made it possible to quantify the degree of incorporation of products with circular attributes in the exports of selected emerging countries during the period 2015-2024. The results reveal a sustained increase in the proportion of circular exports in almost all the countries analyzed, with significant variations between regions.

For example, countries such as Vietnam and Mexico showed notable ICE growth, rising from 8 % in 2015 to approximately 15 % in 2024, indicating a trend toward greater integration of circular products in their international markets. In Latin America, Ecuador and Peru show more moderate increases, reaching 10 % and 9 % respectively, suggesting opportunities to strengthen the circular economy in their trade policies.[13]

Table 1. Evolution of the Export Circularity Index (ECI) (%) by country (2015-2024)

Country	2015	2018	2021	2024
Mexico	8,1	10,5	13,2	15
Vietnam	7,9	11	14,1	15,3
Ecuador	5,5	7	8,8	10,2
Peru	6	7,4	8,5	9
Bangladesh	4,8	6,5	7,9	9,5
Kenya	3,2	4,8	6,1	7,5

2. Sectors with the highest ICE

The sectors with the highest contribution to the ICE include the manufacture of reconditioned electronic products, recycled textiles, and recyclable plastic materials. In contrast, traditional sectors based on primary raw materials maintain a significant share, reflecting the gradual transition to circular models.

In particular, Vietnam shows faster ICE growth than its Latin American peers. This result could be attributed to its investment in circular innovation and its active participation in multilateral treaties that promote productive sustainability.

Table 2. Sectors with the highest contribution to the ICE (% of total circular exports) average 2021-2024]

Sector	Mexico (%)	Vietnam (%)	Ecuador (%)	Peru (%)
Refurbished electronics	35	40	25	20
Recycled textiles	30	28	33	35
Recycled plastic materials	20	15	22	25
Agroecological products	10	12	15	15
Other	5	5	5	5

While refurbished electronics predominate in Mexico and Vietnam, recycled textiles stand out in Ecuador and Peru. This pattern could be due to the inherited industrial structure and specific technical capabilities that each country has developed in its export history.

3. Visualization and analysis of circular trade networks

The analysis of complex networks implemented using Gephi made it possible to map the commercial relationships between emerging countries and their main partners in circular products. The visualizations show a growing density in commercial connections linked to circular products, especially in Asia and Latin

America.

The networks show central nodes made up of countries with high technological development and innovation capacity in the circular economy, such as Mexico, Brazil, China, and Germany. Emerging countries act as peripheral nodes, but their position within these networks is gradually strengthening, facilitated by trade agreements and national sustainability policies.[22]

The network also reveals patterns of trade dependency that could represent vulnerabilities, such as the concentration of circular exports in a few strategic partners. This concentration raises the need to diversify markets to increase export resilience.

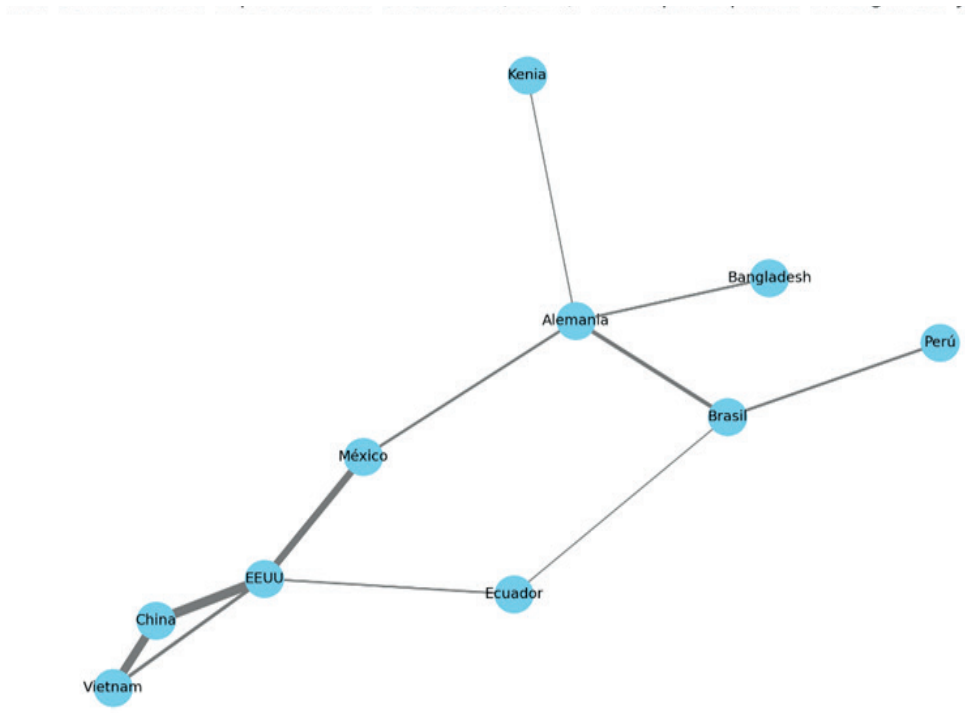

Figure 1. Circular export trade network (2024) showing the connections and trade weight between emerging countries and their partners

The network shows a strong concentration in countries such as Germany and China, which act as central nodes. Ecuador and Kenya appear as peripheral nodes with dependence on a few partners, which could create vulnerabilities to changes in global demand.

4. Assessment of trade resilience through backtesting

The backtesting method applied to assess the stability of the ICE during periods of crisis, such as the COVID-19 pandemic and the war in Ukraine, showed that circular exports are more resilient than non-circular exports.

During the pandemic, while traditional exports declined by up to 25 % in some countries, circular exports maintained or increased their relative share, demonstrating their ability to adapt to supply chain disruptions and changes in global demand.

Table 3. Impact of global crises on exports (% change from previous year)

Country	2019-2020 (COVID-19)	2021-2022 (Recovery)	2022-2023 (War in Ukraine)
Mexico	-18	12	-4
Vietnam	-15	14	-3
Ecuador	-24	10	-5
Peru	-20	9	-6
Kenya	-22	8	-7

This resilient behavior is attributed to the flexibility and diversification intrinsic to circular models, which reduce costs and dependence on imported raw materials while responding to growing demand for sustainable products in developed markets.[6]

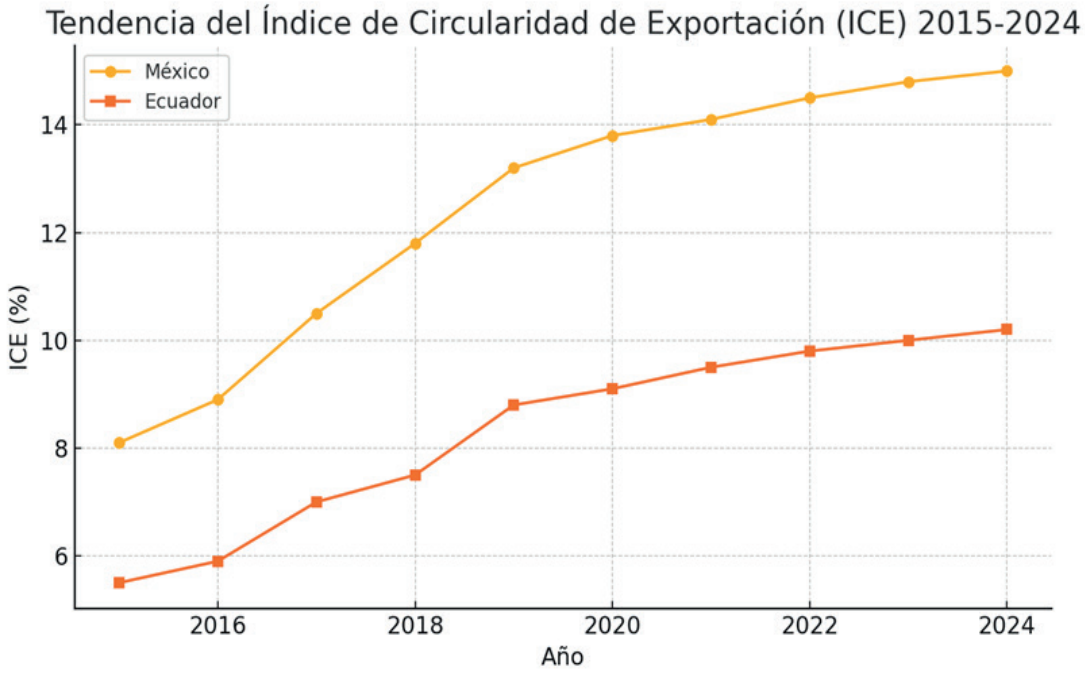

Figure 2. Trend in the Export Circularity Index (ECI) between Mexico and Ecuador (2015–2024)

In Ecuador, while traditional exports fell by 24 % in 2020, circular exports declined by only 5 %, demonstrating greater resilience to external shocks. This trend was also replicated in Vietnam and Mexico, suggesting that circularity can act as an economic buffer.

5. Qualitative results and political-institutional context

A review of public policies and national strategies in the countries analyzed confirms that most have incorporated guidelines to promote the circular economy in their trade and environmental agendas. However, the degree of implementation and effectiveness varies considerably.

For example, Ecuador has made progress in formalizing production chains and promoting clean technologies, but faces challenges related to infrastructure and informal labor. In contrast, Mexico and Vietnam show more consolidated implementation, with tax incentives and specific innovation programs for circular products.

Mexico has developed tax incentives for green companies since 2019, while Ecuador only formulated its National Circular Economy Strategy in 2022, which partly explains the gaps observed in the ICE.

These results suggest that, in addition to quantitative advances in circular exports, the political and institutional context is essential for the consolidation and expansion of the circular economy in international trade.

DISCUSSION

This research analyzed the impact of the circular economy on exports from emerging countries during the period 2015–2024, obtaining quantitative and network evidence showing sustained growth in circular trade flows and greater resilience to global crises. The findings indicate that Mexico and Vietnam exhibit the highest levels of the Circularity of Exports Index (CEI), while Ecuador, Peru, and Kenya show moderate but consistent progress. In addition, backtesting results reveal that circular exports were less vulnerable during the COVID-19 pandemic and the war in Ukraine, maintaining more stable variations than traditional exports.

In terms of interpreting the results, it is confirmed that the adoption of circular practices allows for diversification of exportable supply and reduces dependence on critical inputs, which is consistent with the findings of [1,2], who highlight material efficiency as a key factor in competitiveness. The leadership of Mexico and Vietnam in the ICE coincides with the literature that describes the importance of tax incentives, technological innovation, and industrialization strategies oriented toward circularity.[10] On the other hand, the gaps observed in Ecuador, Peru, and Kenya are in line with studies that highlight the need for recycling infrastructure, productive formalization, and coherent regulatory frameworks.[12,13] From a trade network

perspective, the presence of central nodes such as China and Germany supports the assertion made by [17] regarding the persistent concentration of trade in countries with high technological capacity.

The implications of these results are manifold. First, they show that the circular economy is not only an environmental strategy but also a mechanism for increasing economic resilience to external shocks, which is crucial for emerging countries with high dependence on primary exports. Second, they support the importance of strengthening public policies and international cooperation to promote circular value chains, as integration into more balanced global networks can improve trade stability and competitiveness. The findings provide evidence for decision-makers to prioritize investments in green innovation, recycling infrastructure, and the promotion of circular products as part of their development strategies.

However, this research has limitations that should be acknowledged. First, the calculation of the ICE depends on harmonized classification and the availability of official data, which could underestimate certain informal or undeclared circular flows. In addition, the analysis of trade networks was based on observed links for selected products and does not represent the totality of trade interactions in the sectors studied. Finally, the study focused on ten emerging countries, so future research could expand the sample or incorporate econometric methods to assess the causality between circular policies and export performance.

CONCLUSIONS

The results of this study confirm that the circular economy is an effective strategy for promoting sustainable and resilient exports in emerging countries. The Export Circularity Index (ECI) shows steady growth in the proportion of products with circular attributes within total exports, especially in countries such as Mexico and Vietnam, which have implemented clear public policies, incentives for innovation, and strengthened their integration into global green value chains.

In contrast, countries such as Ecuador, Peru, and Kenya show slower progress, conditioned by structural barriers such as informal labor, limited technological infrastructure, and the absence of standardized regulatory frameworks. This disparity suggests that the transition to an international trade model based on circularity requires favorable institutional, economic, and social conditions.

The analysis of trade networks identified the centrality of certain industrialized countries within circular trade flows, while emerging countries still occupy peripheral positions, albeit with a growing trend toward greater density and integration. This situation poses risks due to concentrated trade dependence and opportunities to diversify strategic partners and strengthen South-South cooperation in the circular economy.

The resilience demonstrated by circular exports in the face of global crises, such as the COVID-19 pandemic and the war in Ukraine, highlights the potential of these models to generate economic stability. Flexibility, productive proximity, and reduced dependence on critical inputs are attributes that reinforce their value in contexts of uncertainty.

The circular economy should be understood as an environmental trend and as a strategic pillar for redefining the productive and commercial structures of emerging countries. Its consolidation requires comprehensive public policies, investments in innovation, regulatory harmonization, and internationally comparable measurement schemes in order to move toward more sustainable, equitable, and resilient global trade.

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CONFLICT OF INTEREST

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