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# Circular economy and eco-innovation practices: a sustainable development approach

## *Prácticas de economía circular y eco-innovación: un enfoque del desarrollo sustentable*

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**Abstract:** the academic literature establishes that the integration and application of circular economic strategies encourage industrial enterprises to enhance their eco-innovation practices and sustainable performance, which helps drive the transition to a more sustainable economic system. However, the body of knowledge and evidence presented in the current academic literature on the effects of circular economic practices on eco-innovation and sustainable development presents fragmented and, in some cases, contradictory evidence and results. Therefore, this study seeks to fill this gap and contribute to addressing this deficiency by analyzing and discussing the effects of circular economic practices on eco-innovation and sustainable development practices of industrial enterprises. To this end, a paper survey was distributed to a sample of 410 industrial enterprises in Mexico, analyzing the data obtained through PLS-SEM. The findings suggest that circular economic practices have a notable beneficial influence on both eco-innovation practices and sustainable development activities, while eco-innovation practices do not exert a significant positive influence on sustainable development activities. In this context, the results led to the final inference that Mexican industrial enterprises are in an incipient stage of transition from a traditional linear model to a circular economic model, which is improving eco-innovation practices and sustainable development.

**Keywords:** circular economy, circularity, innovation, eco-innovation, sustainability, sustainable development, manufacturing firms, manufacturing industry.

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**Resumen:** la literatura académica establece que la integración y aplicación de estrategias de economía circular incentiva a las empresas industriales a mejorar sus prácticas de eco-innovación y su desempeño sustentable, lo cual ayuda a impulsar la transición hacia un sistema económico más sustentable. Sin embargo, el conjunto de conocimientos y evidencia presentados en la literatura académica actual sobre los efectos de las prácticas de la economía circular en la eco-innovación y el desarrollo sustentable presenta evidencia y resultados fragmentados y, en algunos casos, contradictorios. Por ello, este estudio busca llenar este vacío y contribuir a abordar esta deficiencia mediante el análisis y la discusión de los efectos de las prácticas de la economía circular en la eco-innovación y el desarrollo sustentable de las empresas industriales. Para este fin, se distribuyó una encuesta en papel a una muestra de 410 empresas industriales en México, analizando los datos obtenidos a través de PLS-SEM. Los hallazgos derivados sugieren que las prácticas de la economía circular tienen una notable influencia beneficiosa tanto en las prácticas de eco-innovación como en las actividades del desarrollo sustentable, mientras que las prácticas de eco-innovación no ejercen una influencia positiva significativa en las actividades del desarrollo sustentable. En este contexto, los resultados llevaron a la inferencia final de que las empresas industriales mexicanas se encuentran en una etapa incipiente de transición de un modelo lineal tradicional a un modelo económico circular, que está mejorando las prácticas de eco-innovación y el desarrollo sustentable.

**Palabras clave:** economía circular, circularidad, innovación, eco-innovación, sustentabilidad, desarrollo sustentable, empresas manufactureras, industria manufacturera.

## Introduction

The rise in environmental problems, such as water and air pollution, the depletion of natural resources, and ecological imbalance, is leading to greater consumer awareness and an increase in demand for environmentally friendly products (Le *et al.*, 2023). Furthermore, from a business perspective, the constant uncertainty regarding the availability of natural resources, coupled with the strong social pressure industrial companies are facing, is raising awareness within the business sector about the need to adopt and implement sustainable initiatives to minimize negative impacts on the environment (Le *et al.*, 2023). Therefore, industrial companies are seeking strategies that balance economic, social, and environmental benefits (Skalli *et al.*, 2024). However, most industrial companies worldwide continue to prioritize economic objectives over social and environmental benefits, rather than balancing the triple bottom line (Le *et al.*, 2023).

From this perspective, circular economy (CE) practices and eco-innovation (EI) practices are two of the most widely adopted strategies by industrial companies to address sustainability challenges. Wuyts *et al.* (2020) suggested that CE acts as a driver of innovation and sustainability, and thus CE and EI play an essential role in enhancing sustainable development (SD) activities in industrial firms. However, the current academic literature remains limited and lacks robust empirical evidence on the adoption of CE and EI that generates economic benefits while simultaneously respecting social and environmental standards (Skalli *et al.*, 2024), therefore, it is recommended to obtain future empirical evidence on the effects of CE and EI and their implications for the economic, social, and environmental performance of the manufacturing industry (Skalli *et al.*, 2024).

There are differences in the findings. For example, Cheng *et al.* (2021) did not observe significant effects of CE on sustainability performance, while Saha *et al.* (2021) found negative effects, and other studies have identified notable beneficial influences (e.g., Susanty *et al.*, 2020). Furthermore, the relationship between CE and EI requires further empirical testing in the manufacturing industry (Triguero *et al.*, 2023), especially since it remains unclear in the academic literature what types of EI practices should be promoted to support the adoption and implementation of CE in the industry, enabling not only the creation of competitive advantages for organizations but also an improvement in SD (Mora-Contreras *et al.*, 2025), such that these practices do not harm their reputation, image, credibility, and competitive advantage.

From this perspective, the objective of this research is to analyze and discuss the effects that CE has on EI and SD. To achieve this objective, an empirical study was conducted in Mexican industrial firms, using a sample of 410 observations and estimating the research model using the *P*artial Least Squares Structural Equation Modeling *(*PLS-SEM) statistical technique, with the support of SmartPLS 4.0 software (Ringle *et al.*, 2024). The manufacturing industry in

Mexico is essential for two basic reasons: first, because it is the industry least compatible with environmental protection and sustainability (Scur *et al.*, 2019); and second, because it is the industry that contributes the most to the national GDP (INEGI, 2020).

Finally, in line with the recommendations of Mora-Contreras *et al*. (2025) and Mora-Contreras and Carrillo-Hermosilla (2025), to conduct future studies that provide solid empirical evidence on the relationship between CE and EI that contribute to generating improvements in the economic, social, and environmental aspects of industrial companies, the main contribution of this study is to provide cutting-edge information on CE practices that impact EI practices and to integrate them into a coherent SD framework in industrial firms. Therefore, the effects of CE on EI and SD can be considered inconclusive and open to debate; thus, to complement and expand the limited existing knowledge in the academic literature, this study poses the following research question: *What are the effects of CE practices on EI practices and SD activities in industrial firms?*

## Circular Economy and Sustainable Development

The current environmental crisis facing the planet, known as the planetary emergency, demands a significant socioeconomic transformation of global society (De Angelis and Ianulardo, 2024), especially within companies, as they play a fundamental role in driving the transition toward sustainability (Schaltegger *et al.*, 2023). However, "to transform companies toward true sustainability and well-being for all, it is necessary to change the system itself" (Waddock, 2020, p. 9). This serious environmental crisis demands a profound restructuring of the intellectual frameworks through which sustainability is understood in the field of management (De Angelis and Ianulardo, 2024), hence the field of management studies, and more specifically that of corporate sustainability, is criticized in the academic literature for its inability to contribute effectively to SD and its management practices (Schaltegger *et al.*, 2023).

To address this issue, the CE emerges in the academic literature as one of the most effective and efficient strategies (De Angelis and Ianulardo, 2024); therefore, this study defines CE as "a transformative and systemic vision for a more ecologically effective economic system that operates within planetary boundaries and, consequently, maintains and rebuilds natural capital" (De Angelis and Ianulardo, 2024, p. 4862). Essentially, because recent studies have demonstrated in theory the relationship between CE and SD (e.g., Mora-Contreras and Carrillo-Hermosilla, 2025), and because CE is considered the most operational concept compared to others proposed in the academic literature for achieving a more sustainable economy (Mora-Contreras *et al.*, 2023).

However, although there are studies published in the academic literature that have demonstrated that CE significantly improves SD performance (e.g., Mora-Contreras *et al.*, 2023; Piyathanavong *et al.*, 2024), their results cannot be considered conclusive (Khan *et al.*, 2021). In particular, because some studies have found a positive influence between CE and economic and environmental performance, but not on social performance (e.g., Mora-Contreras *et al.*, 2025), while other studies have found a positive influence between CE and social and environmental performance (e.g., Khan *et al.*, 2021), and yet another study has found a positive influence between CE and economic, social, and environmental performance (e.g., Khan and Kabir, 2020), further studies are needed to provide robust empirical evidence on the relationship between CE and SD (Mora-Contreras and Carrillo-Hermosilla, 2025).

In order to provide empirical evidence supporting the relationship between CE and SD, recent studies such as that by Khan and Kabir (2020) have found that CE significantly increases SD, while the study by Priyadarshini and Abhilash (2020) has demonstrated the existence of a positive relationship between CE and SD. Similar results were obtained in the study by Sebestová and Sroka (2020), who found that small industrial firms that adopted and implemented CE practices significantly improved their SD activities. Therefore, it can be concluded that the application of CE helps industrial firms reduce negative environmental impacts and improve their SD through reduction, reuse, recycling (3Rs), recovery (4Rs), redesign, and remanufacturing (6Rs) of materials and raw materials in production processes (Mora-Contreras *et al.*, 2023). Thus, considering the information presented above, the following research hypothesis can be proposed.

*H1: The higher the level of the circular economy, the higher the level of sustainable development.*

## Circular Economy and Eco-Innovation

The concept of the CE has received significant attention from the scientific, academic, and business communities, as well as from policymakers and governments seeking to replace the current linear "take, make, and dispose" model of production and consumption with a more sustainable circular model (Al Halbusi *et al.*, 2025). The adoption and implementation of CE requires industrial companies to incorporate EI into their production and management systems, in order to achieve a shift that prevents the depletion of natural resources, closes energy cycles, and improves long-term economic, social, and environmental performance (Mora-Contreras *et al.*, 2025), to which end CE will help industrial companies repair, reuse, remanufacture, refurbish, and recycle materials, with EI playing an essential role (Mora-Contreras *et al.*, 2025).

From a business perspective, researchers and academics have recently focused their studies on analyzing the effects of CE on EI (e.g., Al Halbusi *et al.*, 2025), particularly from a SD perspective in the manufacturing industry (Mora-Contreras *et al.*, 2023; Mora-Contreras and Carrillo-Hermosilla, 2025). From this perspective, the effective adoption and implementation of CE in industrial firms depend, to a large extent, on systemic cooperation and integration among multiple stakeholders (Ramírez-Rodríguez *et al.*, 2024), with EI serving as a means to facilitate this transition (Schultz and Reinhardt, 2022), as it has been demonstrated in the academic literature that CE substantially improves EI in industrial firms, enabling them to enhance both sustainable performance and competitive advantages (Piyathanavong *et al.*, 2024; Mora-Contreras *et al.*, 2025).

Furthermore, it has been demonstrated in the academic literature that EI is consistent with CE (e.g., Kiefer *et al.*, 2021), especially if EI is defined as:

> The production, assimilation, or exploitation of a product, production process, service, management practice, or business method that is new to the organization and that results, throughout its life cycle, in a reduction of environmental risk, pollution, and other negative impacts of resource use (including energy use) compared to relevant alternatives. (Kemp and Pearson, 2007, p. 3)

Therefore, CE has a notable beneficial influence on EI, primarily because EI refers to any type of innovation implemented in industrial companies to reduce negative impacts on the environment (from changing conditions in supply, demand, or market regulation), whereas CE refers to the adoption and implementation of a set of EI explicitly designed to promote a more circular innovation system (Triguero *et al.*, 2023).

In this context, the adoption and application of CE demonstrate industrial firms' commitment to environmental sustainability, leading to improved SD (Le *et al.*, 2023). Therefore, all business practices of industrial firms revolve around improving resource efficiency and reducing raw material consumption to minimize environmental damage (Kiefer *et al.*, 2021). Thus, CE provides the ecological resource base necessary to promote the adoption of EI in companies and to enable them to address sustainability challenges by transitioning from a traditional linear model to a more sustainable one (Cherrafi *et al.*, 2022). According to Kiefer *et al.* (2021), the CE contributes to an increase in EI in a systematic way, as the relationship between the CE and EI is too close (Schultz and Reinhardt, 2022). Thus, considering the infor-


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mation presented above, it is possible to propose the following research hypothesis.

*H2: The higher the level of circular economy, the higher the level of eco-innovation.*

## Eco-innovation and sustainable development

Innovation is considered in the academic literature as one of the essential elements that increase business performance, improve people's standard of living, and have a strong influence on the development of economies. This idea is presented by Dima *et al.* (2020), who argue that innovation is a critical factor determining the development potential of industrial enterprises, national economies, and society in general. It demonstrates that innovation can be used to introduce environmentally friendly products, known as EI, which substantially reduce negative impacts on the environment and sustainability (Chien *et al.,* 2023). However, the positive effects of EI, both on industrial firms and on sustainability, are not immediate, as a prolonged period is required to achieve better business and sustainable development outcomes (Chen *et al.*, 2023).

Nevertheless, there is no doubt that EI significantly improves SD (Chien *et al.,* 2023), especially in the last two decades, during which environmental concerns related to natural resources have increased, requiring measures that lead to the achievement of ecological and long-term sustainability (Ahmad *et al.*, 2024). From this perspective, Chen *et al.* (2023) analyzed the influence of EI on green growth in BRICS countries during the 1993–2019 period and found that EI stimulates green growth and SD, while Suki *et al.* (2022) found that EI can significantly reduce both greenhouse gas and CO2 emissions and optimize resource utilization, which has a positive impact on both the green growth of countries and firms as well as on sustainable development.

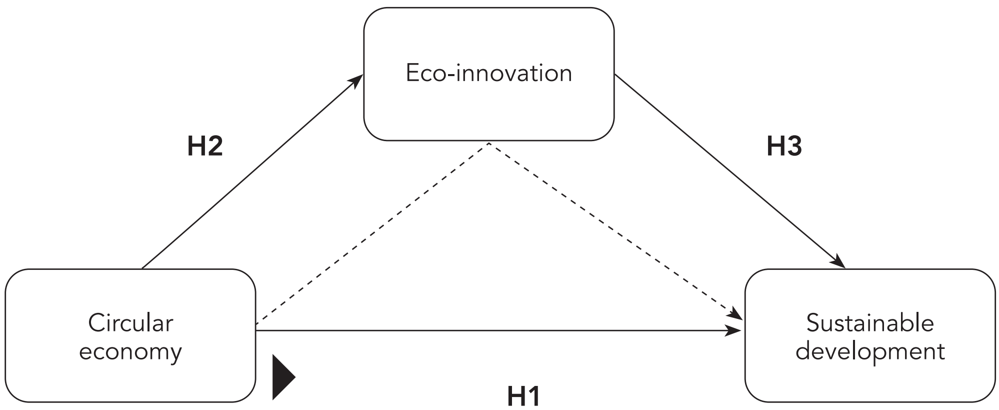
Mahmood *et al.* (2022) analyzed the effects of EI on corporate green growth and found that EI contributes positively to corporate green growth, primarily because EI contributes to the promotion and development of environmentally friendly products and technologies, which not only reduces levels of environmental pollution but also enables sustainable economic growth. Koseoglu *et al.* (2022) suggested that countries should transition toward green EI, as it is vital for enhancing sustainable development, given that EI is one of the fundamental ways to increase levels of sustainable development, while Sun *et al.* (2023) argued that EI can significantly improve resource efficiency by enhancing product design and production processes to make them more environmentally friendly, reducing industrial waste, and promoting the adoption of circular economy practices, thereby reducing the depletion of natural resources.

Furthermore, EI can help industrial companies develop environmentally friendly products and technologies, thereby reducing pollution levels, promoting the use of renewable energy, and lowering emissions of pollutants (Chien *et al.*, 2023). In this context, EI can help organizations increase their economic performance while minimizing the adverse effects of pollution and achieving social and environmental goals (Sun *et al.*, 2023). Consequently, an increasing number of countries worldwide are incorporating EI into their policies and programs, with the aim of significantly reducing greenhouse gas emissions in light of the catastrophic climate change caused by industrialization and the exponential demand for consumer goods (Chien *et al.*, 2023). Therefore, considering the information presented above, it is possible to propose the following research hypothesis.

*H3: The higher the level of eco-innovation, the higher the level of sustainable development*

In Figure 1 below, the three hypotheses proposed in the research model can be seen.

**Figure 1**
*Research Model*




## Materials and methods

To answer the questions established in the research model, an empirical study was conducted among industrial firms in Mexico, using the National Directory of Economic Units (DENUE), which, as of January 30, 2023, contained a registry of 32,541 industrial firms with more than ten employees (INEGI, 2023). It is important to note that industrial firms belong to various regional, national, and international chambers of commerce and business organizations; therefore, the study was not oriented toward any particular chamber or business organization. Additionally, a "Business Panel" was conducted, involving five business owners from industrial firms, two representatives from government agencies involved in financial support for businesses, and three academics in the field of innovation, who were provided with the survey to be used for analysis and discussion.

The results obtained from this Business Panel enabled the design of a survey to collect information, which was administered to a pilot sample of ten business leaders from industrial companies to verify that the questions were appropriate and that there were no incorrect responses from the executives of the surveyed manufacturing firms, with only minor adjustments made to the wording. Pilot studies are essential to ensure validity when questionnaires are self-administered or contain self-developed scales (Bryman, 2016; Hair *et al.*, 2016). The selection of industrial companies was carried out using simple random sampling, considering a margin of error of ±4% and a 95% confidence level, which resulted in a sample of 410 companies; the survey was sent to 600 industrial companies, and a total of 410 surveys were received. The paper survey was administered from February to June 2023 and distributed to executives at the industrial companies, who identified individuals within the organization with the appropriate experience and knowledge to answer the different sets of questions.

As a preliminary step to the reliability and validity analysis, a comprehensive review of the academic literature was conducted to identify the most appropriate measurement scales for the study. To measure CE, the scale developed by Ormazabal *et al.* (2018), consisting of eight items, was used. EI was assessed using the scale by Segarra-Oña *et al.* (2014), consisting of seven items. Finally, SD was measured using the scale proposed by D'Amato *et al.* (2019), consisting of nine items. All items on the three scales were assessed using a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). Table 1 presents the items of the scales used in this study and shows that all exceed the recommended value of 0.6 according to Hair *et al.* (2019).


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**Table 1**

*Evaluation of the measurement model*

| Indicators | Constructs | Factor loadings (p-value) |
|---|---|---|
| **Circular economy (CE)**<br>**Cronbach's alpha: 0.947; Dijkstra-Henseler's rho (ϱA): 0.949; CRI (ϱc): 0.955; AVE: 0.728** | | |
| CE1 | There is an environmental commitment on the part of senior management | 0.818 (0.000) |
| CE2 | There is support for environmental management from middle management. | 0.859 (0.000) |
| CE3 | There is cooperation among different departments or functional areas to improve the organization's environmental practices. | 0.874 (0.000) |
| CE4 | There is a training program for the organization's employees and workers on environmental topics. | 0.874 (0.000) |
| CE5 | There is a comprehensive environmental quality management program. | 0.842 (0.000) |
| CE6 | There are ongoing environmental audit programs for the organization, such as the ISO 14000 standard. | 0.873 (0.000) |
| CE7 | Eco-labels are used on most of the products produced by the organization. | 0.866 (0.000) |
| CE8 | There is a program to prevent pollution from waste generated by the organization, such as clean production. | 0.818 (0.000) |
| **Eco-innovation (EI)**<br>**Cronbach's alpha: 0.936; Dijkstra-Henseler's Rho (ϱA): 0.946; CRI (ϱc): 0.948; AVE: 0.723** | | |
| EI1 | Focuses its investment primarily on eco-innovation activities. | 0.858 (0.000) |
| EI2 | Raises awareness about eco-innovation | 0.869 (0.000) |
| EI3 | Distributes information on eco-innovation | 0.887 (0.000) |
| EI4 | Offers ongoing training in eco-innovation. | 0.858 (0.000) |
| EI5 | Participates in or develops research and development projects in eco-innovation. | 0.838 (0.000) |
| EI6 | Consistently supports the adoption and implementation of environmental standards. | 0.833 (0.000) |
| EI7 | Supports investments to improve the eco-innovation of its suppliers. | 0.804 (0.000) |
| **Sustainable Development (SD)**<br>**Cronbach's alpha: 0.935; Dijkstra-Henseler's rho (ϱA): 0.937; CRI (ϱc): 0.945; AVE: 0.659** | | |
| SD1 | Expands the economy's productive potential. | 0.815 (0.000) |
| SD2 | Promotes economic growth to facilitate the satisfaction of basic needs | 0.834 (0.000) |
| SD3 | Decouples economic growth from material consumption. | 0.829 (0.000) |
| SD4 | Stabilizes the economy's productive potential | 0.848 (0.000) |
| SD5 | Stabilizes economic growth to safeguard ecological thresholds and redistribute access. | 0.854 (0.000) |
| SD6 | Decouples economic growth from material consumption, taking rebound effects into account. | 0.837 (0.000) |

| | | |
|---|---|---|
| SD7 | Limits and transforms the economy's productive potential. | 0.768 (0.000) |
| SD8 | Reduces economic growth while simultaneously reducing inequalities and exploitation | 0.758 (0.000) |
| SD9 | It dematerializes society and the economy by emphasizing the role of self-sufficiency, happiness, and equity. | 0.755 (0.000) |

The analysis of the data derived from the survey of industrial firms was conducted using the PLS-SEM statistical technique with the support of SmartPLS 4.0 software (Ringle *et al.*, 2024), particularly because this study employs a composite indicator model, which is considered in the academic literature as the operational definition of the emerging construct that mediates all model effects, and concepts measured through composite indicators typically do not have an error term (Hair *et al.*, 2019).

The reliability and validity of the CE, EI, and SS measurement scales were assessed using Cronbach's Alpha, CRI, Dijkstra-Henseler rho, and AVE (Hair *et al.*, 2019). The Cronbach's Alpha, CRI, and Dijkstra-Henseler rho values exceed the recommended value of 0.70 (Hair *et al.*, 2019); while the AVE values are higher than the recommended value of 0.50 (Hair *et al.*, 2019), indicating, on the one hand, that the items effectively measure each of their variables and, on the other, the reliability of the data obtained. Regarding discriminant validity, it was assessed using the Fornell and Larcker criterion and the heterotrait-monotrait ratio (HTMT).

The results are shown in Table 2 and indicate that Cronbach's alpha ranges from 0.935 to 0.947, Dijkstra-Henseler's rho ranges from 0.937 to 0.949, and the CRI ranges from 0.945 to 0.955, indicating that these are good values and exceed the threshold of 0.70, while the AVE ranges from 0.659 to 0.728, which is higher than the 0.50 value recommended by Hair *et al.* (2019). The results obtained in this study show that the HTMT values range from 0.115 to 0.399, which are higher than the recommended value of 0.08, indicating the existence of discriminant validity for the CE, EI, and SD measurement scales.

**Table 2**

*Reliability, Validity, and Discriminant Validity*

| **PANEL A. Reliability and Validity** | | | | | |
|---|---|---|---|---|---|
| **Variables** | **Cronbach's Alpha** | **CRI** | **Dijkstra-Henseler Rho** | **AVE** | |
| Circular economy | 0.947 | 0.949 | 0.955 | 0.728 | |
| Eco-innovation | 0.936 | 0.946 | 0.948 | 0.723 | |
| Sustainable development | 0.935 | 0.937 | 0.945 | 0.659 | |
| **PANEL B. Fornell-Larcker criterion** | | | **Relación heterotrait-monotrait (HTMT)** | | |
| **Variables** | **1** | **2** | **3** | **1** | **2** | **3** |
| 1. Circular economy | **0.853** | | | | | |
| 2. Eco-innovation | 0.144 | **0.850** | | 0.148 | | |
| 3. Sustainable development | 0.381 | 0.114 | **0.812** | 0.399 | 0.115 | |

*Note.* CRI: Composite Reliability Index; AVE: Average Variance Extracted. PANEL B: Fornell-Larcker criterion: The diagonal elements (in bold) are the square root of the variance shared between the constructs and their measures (AVE). For discriminant validity, the diagonal elements must be greater than the non-diagonal elements.


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# Results and Discussion

## Results

To test the hypotheses proposed in the research model, the PLS-SEM statistical technique was used with the SmartPLS software (Ringle *et al.*, 2024), particularly because PLS-SEM is generally used in underdeveloped theories across various disciplines (Hair *et al.*, 2019). Furthermore, the use of PLS-SEM is essential, not only because it facilitates the explanation of measurement error in the variables—which gives this method greater potential than multiple linear regression (Hair *et al.*, 2019)—but also when the objective pursued through the application of the structural equation model is the prediction and explanation of the key constructs of the research model. Table 3 shows the results obtained from the application of PLS-SEM.

**Table 3**

*Structural Model*

| Paths | Path (t-value; p-value) | 95% confidence interval | $f^2$ | Support |
|---|---|---|---|---|
| EC → DS (H1) | 0.379 (7.498; 0.000) | [0.267 - 0.475] | 0.171 | Yes |
| EC → EI (H2) | 0.149 (2.843; 0.004) | [0.054 - 0.251] | 0.026 | Yes |
| EI → SD (H3) | 0.062 (1.283; 0.200) | [-0.032-0.151] | 0.007 | No |
| **Indirect effects** | | | | |
| EC → EI → DS | 0.323 (8.828; 0.000) | [0.251 - 0.395] | 0.182 | Sí |
| **Endogenous variable** | **Adjusted R ²** | **Model fit** | **Value** | **HI99** |
| | | SRMR | 0.034 | 0.040 |
| EI | 0.122 | dULS | 0.342 | 0.477 |
| DS | 0.154 | dG | 0.177 | 0.238 |

*Note.* CE: Circular Economy; EI: Eco-innovation; SD: Sustainable Development. One-tailed t-values and p-values in parentheses; 95% confidence intervals via bootstrapping (based on n = 10,000 subsamples); SRMR: standardized mean residual; dULS: unweighted least squares difference; dG: geodesic difference; NFI: normal fit index; HI99: 99% percentiles based on bootstrapping.

Table 3 shows the results obtained and indicates that they have acceptable statistical levels, with adjusted $R^2$ values greater than the recommended value of 0.10, an SRMR value (0.034) lower than the recommended value of 0.08 (Hair *et al.*, 2019), and unweighted least squares difference (dULS) (0.342), and geodesic difference (dG) values (0.177) lower than the HI99 values (Hair *et al.*, 2019), which allows for the verification of the research model's significance. In general terms, the results derived from the application of PLS-SEM allow us to establish that EC has significant beneficial influences on the SD of industrial firms (0.379; p-value 0.000), which provides empirical evidence in favor of hypothesis H1. Similarly, the results obtained also allow us to verify that EC has a significant positive influence on the IE of industrial firms (0.149; p-value 0.004), providing empirical evidence in favor of hypothesis H2. However, the results obtained establish that there is no positive relationship between IE and DS in industrial firms (0.062; p-value 0.200), which allows us to reject Hypothesis 3.

## Discussion

The results obtained support our argument that CE has a significant positive influence on SD in industrial firms, which is consistent with the findings of Khan and Kabir (2020), Priyadarshini and Abhilash (2020), and Sebestová and Sroka (2020). One possible explanation for this positive effect may be that a significant number of industrial firms in Mexico are transitioning from a traditional linear model to a circular economic model, which, through practices of recycling, reusing, and remanufacturing materials, is not only increasing firms' economic performance but also significantly reducing the level of industrial waste, greenhouse gas and CO2 emissions, leading to a substantial improvement in sustainable development.

Furthermore, the results also show the existence of a notable beneficial influence of CE on EI, which is similar to those found by Schultz and Reinhardt (2022), Mora-Contreras *et al.* (2023), and Mora-Contreras and Carrillo-Hermosilla (2025). One of the key reasons that could explain this result is that the adoption and application of CE promote the implementation of EI, since industrial companies, by incorporating recycled materials into new products, are manufacturing more environmentally friendly products. This not only generates a significant increase in their economic and financial performance but also substantially improves social and environmental performance levels—i.e., they are improving their level of SD.

However, the results obtained do not support our argument regarding the existence of a notable beneficial influence between EI and SD, which contradicts the evidence presented in the academic literature. Possible reasons for this result include, on the one hand, that industrial firms are in an early stage of adopting EI and, as established in the academic literature, results in organizations are long-term rather than immediate. On the other hand, industrial firms may be more focused on implementing CE than on EI, since organizations in Mexico, as in any other country with an emerging economy, are characterized by a scarcity of financial resources.

## Practical implications

The findings of our study are relevant to executives, policymakers, business professionals, and public administration officials. First, company executives who wish to adopt and implement CE that enhances their EI and SD activities can achieve substantial long-term improvements in their competitive advantages if they consider collaboration beyond their supply chain and proactively address legal, institutional, employee, and stakeholder pressures regarding environmental concerns for CE. According to the findings, CE helps companies foster a culture of environmental protection by promoting ecological values, disseminating EI practices, and favoring environmentally friendly products and eco-friendly circular packaging.

Second, company executives must align the adoption and implementation of CE practices with their business strategy, as this will enable them to achieve higher levels of circularity and sustainability. Therefore, business leaders must recognize that planning more in line with the realities of the business world and with the challenges and opportunities posed by the adoption and implementation of CE and CE practices in a globalized and highly competitive market generates greater chances of success. In this regard, policymakers should promote public initiatives aimed at expanding the use of recyclable materials across all industrial companies, as this will enable them to foster circularity that is viable from technical, economic, environmental, and social perspectives, in line with the guidelines of the Sustainable Development Goals.

Third, the results of this study suggest that to generalize the scope of its conclusions to all industrial firms, policymakers and public administrations should apply policies and tax incentives to industrial firms that adopt and implement CE and EI practices, since, as demonstrated in the literature, firms may require additional financial support to ensure their economic viability (e.g., Ranta *et al.*, 2018; Kirchherr *et al.*, 2018). This support is necessary in emerging economies, where resource and knowledge constraints are common among industrial firms (Rodríguez-Espíndola *et al.*, 2022), as they tend to be more sensitive to the additional financial costs arising from the adoption and implementation of CE and EI practices in a SD context (Triguero *et al.*, 2022).


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## Conclusions

It is possible to conclude, on the one hand, that although the research model offers a holistic view of CE, EI, and sustainable development—which includes the three most frequently cited activities in the academic literature (economic, social, and environmental)— the model does not exhibit high statistical consistency; therefore, it can be concluded that the adoption and implementation of CE, EI, and SD are in a starting phase in Mexico's industrial companies, and are in the initial phase of the transition from a linear production model to a circular production model, and require further work on the adoption and implementation of these types of practices across all production and marketing activities of the organizations.

On the other hand, it can also be concluded that the relationship between CE, EI, and SD remains a subject of active academic debate in the academic literature, therefore, it is necessary for researchers, academics, and industry professionals to direct their future studies toward providing solid empirical evidence, demonstrating a positive relationship between these three constructs, especially in emerging and developing economies in order to corroborate the results obtained and advance knowledge of EC, EI, and SD practices.

This study has several limitations that should be considered in future research. The first limitation concerns the generalizability of the results, particularly because the study focused solely on industrial firms in Mexico, which poses challenges for applying the findings to a broader group of firms in other sectors or countries. Therefore, to address this limitation, future research in other industries and countries could use this same survey to verify whether the results are similar. A second limitation is that this study adopted a research model analyzed using the PLS-SEM statistical technique; however, the use of other types of statistical techniques could broaden our understanding of the link between CE, EI, and SD. Therefore, it would be advisable for future studies to use neural networks or logistic regression to corroborate the results obtained.

A third limitation is that the literature has analyzed and discussed the various sustainable benefits that the joint adoption of CE and EI generates for industrial firms. However, further studies are needed to provide robust empirical evidence to better understand the implementation of CE practices by industrial firms, particularly in developing countries, as these countries generate the highest levels of pollution due to the lack of environmental policies and programs. Therefore, it would be advisable to conduct future studies in such countries to compare the results obtained.

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## Declaration of Authorship - CRediT Taxonomy

| Authors | Contributions |
|---|---|
| **Gonzalo Maldonado-Guzmán** | Conceptualization, formal analysis, research, methodology, supervision, writing, and original draft. |
| **Sandra Yesenia Pinzón-Castro** | Data curation, formal analysis, methodology, writing, review, and editing. |
| **Vianney Judith Robledo-Herrera** | Data analysis, formal analysis, research, writing, and editing. |

## Statement on the use of artificial intelligence

The authors **DECLARE** that in the preparation of the article titled: "Circular Economy Practices and Eco-Innovation: An Approach to Sustainable Development," artificial intelligence (AI) was not used at any stage of the process.


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