Eco-Innovation and the Circular Economy in the Automotive Industry

Abstract

Purpose – Circular economy is emerging as a new sustainability paradigm. Similarly, eco-innovation is being recognized as one of the most important mechanisms that allow the transition from a linear to a circular economy in production processes, as there is a strong relationship between eco-innovation (eco-innovation of products, processes and management) and circular economy activities. However, the relationship between eco-innovation and circular economy is an issue that has been isolated and little analyzed in the academic literature. Therefore, this research fills this gap by exploring the interdependence between eco-innovation and circular economy.

Design/methodology/ approach – The research is conducted through an extensive literature review from where a research framework consisting of 2 measurement scales, 18 items and three hypotheses were developed. A self-administered questionnaire was distributed and 460 responses were obtained from companies in the automotive and auto parts industry in Mexico. The data obtained were analyzed through confirmatory factor analysis, descriptive statistics and Structural Equation Modelling.

Results – The results suggest that eco-innovation of products, process and management has a significant positive impact on the circular economy of companies in the automotive and auto parts industry.

Practical implications – The findings of this research can inform managers in the automotive sector and policy makers when formulating and deploying environmentally sustainable strategies.

Originality/value – This paper fills a research gap by expanding the limited body of knowledge that relates eco-innovation and circular economy and providing some evidence of their relationship. The research also allows the unique characteristics of eco-innovation and the circular economy to be understood within a particular context, growing in this manner the body of knowledge on this field.

Keywords: *Eco-innovation, circular economy, automotive industry.*

1. Introduction

Since the 1960s, the concept of circular economy has been adopted in various countries and industries (e.g. Korhonen *et al.*, 2018; Navarro Ferronato *et al.*, 2019; Talens Peiró *et al.*, 2019; Kumar *et al.*, 2019). This is because circular economy can generate a robust model that allows manufacturing firms, as is the case of companies in the automotive industry, to meet the requirements of sustainable development (Mishra *et al.*, 2019; EMF, 2015). However, the application of the activities that circular economy entails in the various areas of manufacturing companies has not generated the expected results to achieve a robust sustainability model (Ghisellini *et al.*, 2016).

On the other hand, eco-innovation is one of the strategies, in the form of a construct, which can be used to carry out a quantitative evaluation of the relationship between sustainable development and circular economy (Liu *et al.*, 2019). Eco-innovation is also considered as one of the most reliable quantitative methods for the analysis of the sustainability systems used by manufacturing firms (Kiefer *et al.*, 2019). Therefore, the essential objective of this empirical study is the analysis, evaluation and discussion of eco-innovation activities and their existing relationship with the circular economy of companies that comprise the automotive industry of Mexico. Thus, this study provides a significant contribution by addressing an existing gap in the academic literature that links eco-innovation and circular economy activities.

Eco-innovation generally emphasizes the changes that are required in the essential activities of firms, to transition to environmental sustainability (Durán-Romero and Urraca-Ruiz, 2015), and is commonly defined as innovation in all its forms (products, processes and management) (Diaz-Garcia *et al.*, 2015). In this sense, eco-innovation has been recognized in the current literature as one of the fundamental factors in the development of technological competitiveness and different forms of business (including new business models) (de Jesús *et al.*, 2018). Under this perspective and given that eco-innovation and the circular economy are a worldwide phenomenon, researchers and academics need to guide their studies in providing solid and robust empirical evidence to provide an initial overview, generalize significant inferences, and guide further and more detailed research.

Thus, the purpose of this study is to further understand the role of dynamic remanufacturing capability (DRC) in the relationship of eco-innovation and circular economy with the generation of new knowledge, in addition to complementing other works published in the literature (de Jesús *et al.*, 2018, 2019; Liu *et al.*, 2019). In this sense, the existing relationship between eco-innovation (eco-innovation of products, processes and management) and the circular economy is analyzed through the interaction of the DRC (Bag et al., 2018), with the purpose to identify the essential factors that influence the CRD, identify the dimensions of eco-innovation that have been most discussed in the literature and, finally, develop a conceptual model using a sample of companies in the automotive industry, since the relationship between eco-innovation and the circular economy can be considered inconclusive.

Therefore, to complement and expand the limited body of knowledge, this paper addresses the following research question: *What is the relationship between eco-innovation and circular economy within the context of the automotive industry?* The rest of the paper is structured as follows: Section 2 presents the literature review and hypothesis; Section 3 introduces the research methodology; the analysis and interpretation of results are included in Section 4; lastly, Section 5 provides derived conclusions, limitations and future research directions.

2. Literature Review

In the scientific literature, the remanufacturing of products is considered an essential process, through which components and/or raw materials are reused or used in the generation of new products, through a series of steps or sequences, e.g. disassembly of used components, cleaning, renovation, assembly, storage and packaging (Guide, 2000; Kim et al., 2006; Kin et al., 2014). Therefore, the remanufacturing capacity of any type of company, particularly those that make up the automotive industry, represents their ability to use remanufactured components or parts demanded by the market, and according to existing resources, the dynamics and existing capacity in organizations (Bag et al., 2018).

Likewise, the remanufacturing of products requires that companies not only improve their ability to adequately manage variation in their production lines but also reduce the processing times required for the incorporation of remanufactured components or parts in new products (Bag et al., 2018). Therefore, companies that implement remanufacturing activities should improve their dynamic capabilities and their ability to handle different sizes of components or parts safely, in addition to having safe storage for this type of materials, as well as have testing facilities and product packaging, in accordance with the recommendations of Fleischmann et al. (2000), Ferrer (2003) and Subramoniam et al. (2009).

In this sense, the current scientific literature establishes that the remanufacturing capacity of companies is directly influenced by a series of factors, among which are financial, management, innovation, market, technical, regulatory and process and environmental (Bag et al., 2018). In addition, the remanufacturing capacity of any type of company, including those that make up the automotive industry, must be designed in such a way that allows a level of production with products with high-quality content and with the shortest possible time for their production (Aljuneidi & Bulgak, 2016; Aydin et al., 2017).

On the other hand, the first decade of the current millennium was characterized by the high volatility of the prices of products and services (Dobbs *et al.*, 2011). From the second decade and until today, recycling, environmental sustainability and production with low levels of waste (Sellito & de Almeida, 2020), are becoming essential elements for both social living and economic development (WWF, 2014). However, the different actions and policies that have been implemented today in most countries, are considered simply a palliative to eradicate the problem of global warming, since global consumption of food and energy has increased exponentially in the last three decades, and is expected to triple by the year 2050 (Vanner *et al.*, 2014).

Fortunately, more and more new global trends are emerging, such as more restrictive environmental standards and consumer sensitivity to climate change, which are pressing companies to take more care of the environment (de Jesús *et al.*, 2018). In this sense, the concepts of new economic models (Cássia *et al.*, 2020), work in a circular economy and the adoption of eco-innovation activities are considered as excellent alternative solutions to minimize waste of materials and energy (Potocnik, 2014).

In addition, in the current literature researchers, academics and professionals in the field of innovation have recognized that circular economy has a too-close connection with the innovation activities carried out by companies, primarily manufacturing companies, including those belonging to the automotive industry, but in particular with the activities of eco-innovation (EC, 2017). In this line, there is theoretical and empirical evidence that makes it possible to argue that "*the adoption of systematic approaches to eco-innovation generates greater added value in the whole of the supply chain, because it practically involves all participating companies in the supply chain* " (EC, 2016).

In this sense, the current dynamics of an important part of companies around the world is the transformation of their production processes and routines and consumption habits (Ferro *et al.*, 2020), in such a way that it allows them to reduce material waste and generate products that do not damage the environment (EMF, 2013). Therefore, eco-innovation is considered in the current literature as one of the essential activities to achieve these objectives, since eco-innovation is based on the development of new products, processes and technology, as well as the development of new business models (de Jesús *et al.*, 2018). In addition, it also has a significant positive impact on the circular economy of business activities (de Jesús *et al.*, 2018, 2019).

Likewise, the connection between eco-innovation and the circular economy is essential that circular economy is oriented towards the design of products and processes, the minimization of negative impacts on the environment and society in general, the significant reduction of the use of non-renewable resources, the elimination of toxic materials and contaminants, the increase in the shelf life of products, and the maximization of the potential for reuse of materials and products (IAU, 2013). In addition, the concept of circular economy is inspired by natural ecosystems and the postulate of a departure from the notion of linear, or traditional, economics (which is essentially based on the unidirectionality of extraction, production, distribution and consumption), through a permanent regeneration of the economy (de Jesús *et al.*, 2018). Thus, considering the discussion presented above, it is possible to propose the first research hypothesis.

H1: Eco-innovation product has a significant positive influence on the circular economy

The circular economy is gaining increasing interest among researchers and academics since its results can be considered in the construction of public policies and in the development of business strategies (de Jesús *et al.*, 2019). Therefore, if corporate sustainability objectives have a circular approach and not a one-way approach, then circular economy is the best option for identifying business policy priorities (Kopnina, 2018). Thus, eco-innovation can be considered as the main variable for the development of new business policies, since it is strongly correlated with climate change, the efficiency of resources and the scarcity of resources energy (Kemp, 2011). Thus, future studies that are aimed at generating knowledge that explains how to direct innovation systems in circular economy practices will be essential (de Jesús *et al.*, 2019).

In this sense, sustainability and the circular economy are generally characterized by a multidisciplinary approach with a global emphasis, and with a long-term trajectory (de Jesús *et al*., 2019), whereby the integration of environmental aspects and elements that integrate sustainable development implicitly emphasizes eco-innovation as a vehicle for a transition to the circular economy (Kanger & Schol, 2018; Schol & Kanger, 2018). Therefore, eco-innovation activities are considered in the current literature not only as one of the most effective tools for achieving circular economy but also as the path through which a higher level of sustainability can be achieved (de Jesús *et al.*, 2019). Its implementation in the circular economy can be carried out at three essential levels (Ghisellini *et al*., 2016): at the micro level [i.e. private companies through business models (Pieroni *et al*., 2019)]; at the meso-level [i.e. relationship between companies through the management of green supply chains (Jabbour *et al*., 2015)]; and at the macro-level [i.e. at national or global level with emphasis on the legislation of products or services (Ghisellini *et al.*, 2016)].

At the micro-level, eco-innovation is directly related to the circular economy through the production of eco-products or eco-services, especially in terms of the increase and efficiency of the resources available to the organization (Adams & Ghaly, 2007), as well as their eco-design

(Sanyé-Mengual *et al.*, 2014). In addition, it is important to make radical changes in the processes and management systems of companies, particularly those belonging to the automotive industry. This would allow a transition to new forms of environmental sustainability, which implies a transformation in companies of its *status quo*, that is, the adoption and implementation of the mechanisms of technological and non-technological eco-innovation (de Jesús *et al*., 2018; Lazaretti *et al.*, 2020), which will allow organizations to streamline the activities of the circular economy.

With respect to the mechanisms of technological eco-innovation, they are generally established through the different tools that are used in the production of eco-products that allow improving their durability and quality, in the design of new eco-products or eco-services that have a more durable lifetime, and in the solution of those problems that reduce efficiency in production processes (Triguero *et al.*, 2015). However, the optimal design of the useful life of the eco-products requires both a knowledge of greater durability and the replacement of the damaged parts of the eco-products, so it is essential that companies (Ferro *et al.*, 2020), especially those that integrate the automotive industry, have constant updates of the parts that integrate the eco-products for replacement (Bakker *et al*., 2014). Thus, considering the discussion presented above, it is possible to propose the second research hypothesis.

H2: Eco-innovation process has a significant positive influence on the circular economy

Additionally, it is essential that manufacturing companies develop a program of reuse and re-manufacturing of products, since the costs of re-manufacturing of eco-products are usually much lower than production levels using virgin raw materials (de Jesús *et al.*, 2018). Likewise, companies are required to implement new ways to reduce transportation costs (economic and environmental). In addition, if companies use existing technology in the market, other types of eco-innovations will be necessary for these same activities that generate less negative impacts to the environment and less pollution of CO_2 (de Jesús *et al.*, 2018).

As for the mechanisms of non-technological eco-innovation, these include the promotion of new organizational models that facilitate the development of new schemes for the increase and intensive use of eco-products (de Jesús *et al.*, 2018; Cássia *et al.*, 2020). They also include innovations in marketing activities such as new forms of distribution, a new use, and perception of eco-products [e.g. a monthly payment for the use of the services of refrigerators, washing machines, concrete mixers, and other tools such as drills, saws, hammers, etc. (Mont, 2008; Ceschin, 2013; Bakker *et al*., 2014)]. This type of innovation can generate significant incentives for manufacturing companies for the development of longer-lasting eco-products (Ferro *et al.*, 2020), the replacement of existing eco-products with more efficient models and, in the long term, the development of eco-products with greater technological component (Mont, 2008).

In this sense, this type of innovation in marketing activities is an issue that has not been widely explored in the current eco-innovation literature, in addition to the role that consumers have in the eco-innovation of eco-products, as an innovative agent, it is also a topic that is under development (de Jesús *et al.*, 2018; Lazarotti *et al.*, 2020). This situation is paradoxical since consumers form an essential part of the circular economy, not only as actors that demand eco-products, but also as an essential part in the global supply chain of such eco-products, so the dynamics of the new business models (Choudhary & Singh, 2019), in which eco-innovation is directly related to the circular economy, are not only a fundamental part of the essential analysis at a micro level, but also one of the most important ways to operationalize and realize the congruence between clean production and a more efficient transition from eco-innovation to the circular economy (de Jesús *et al.*, 2018).

In addition, the circular economy is also directly related to genuine systematic innovation, which can be interpreted as green innovation or more commonly as eco-innovation, through the transition that manufacturing companies have to achieve clean production (de Jesús *et al.*, 2018). This is characterized not only by the improvement of the use of its resources, but also by the redesign of its production systems (Jabbour *et al.*, 2015; Kemp & Never, 2017; Kumar *et al.*, 2019). This leads, on one hand, to the migration of companies to a technological eco-innovation, that is, to a sensitive environmental innovation that improves their sustainable level and generates significant positive effects on ecology (Jabbour *et al.*, 2015; Steen & Njos, 2018; Colombo *et al.*, 2019).

On the other hand, the circular economy requires the redesign of social regimes in terms of the generation of official and tacit rules, as well as a change in collective and individual behavior, which favor the adoption and development of new business models (Geissdoerfer *et al.*, 2017; Pieroni *et al.*, 2019). In this sense, the relationship between eco-innovation and the circular economy can be considered as a new combination of *harder* (generation of products with greater investment and development processes, with cost reduction and technical solutions in the generation of cleaner products and processes), and *softer* (organizational reconfiguration, business models, and behavior patterns grouped in a circular organization and marketing solutions) elements (de Jesús *et al.*, 2018; Grillitsch *et al.*, 2019). Thus, considering the discussion presented above, it is possible to propose the third research hypothesis.

H3: Eco-innovation management has a significant positive influence on the circular economy

3. Methodology

In order to respond to the hypothesis proposed, an empirical study was carried out in the Mexican automotive industry, particularly analyzing the relationship between eco-innovation and the circular economy. In the first phase of the study, a qualitative investigation was applied in which in-depth interviews were conducted with three researchers from the innovation area and five businessmen from the automotive industry. The results obtained in this phase allowed the design of an information collection instrument, which was reviewed by four academics experts in the area of innovation and ten businessmen of the automotive industry, making minor adjustments in regards to the questionnaire's writing style, appearance and spelling. Pilot studies are essential to ensure validity when questionnaires are self-administered or contain self-developed scales (Hair *et al.*, 2016).

3.1. Sample Design and Data Collection

To collect empirical data, the directory of registered automotive companies of the Mexican Association of the Automotive Industry was consulted. The directory contained a registry of 909 companies producing cars and auto parts as for November 30, 2018. Additionally, it should be noted that the companies associated with the association belong to various organizations and local, regional and national business chambers, so the study did not focus on a particular group or business association.

Likewise, an instrument for the collection of data was designed to gather information relevant to the activities of eco-innovation in products, processes and management and the circular economy. The instrument was applied to a sample of 460 companies selected through a simple random sampling, with a maximum error of ±4% and a level of reliability of 95%. In this case, the sample represented 50.6% of the total population from January to March 2019. To help with the collection of data and to ensure a high response rate a professional and dedicated Marketing Agency was hired to collect the data. Finally, it should be noted that all of the managers interviewed were directly responsible for the adoption and implementation of eco-innovation practices in their respective companies, and they had been working in the automotive industry for several years. This allowed the interviewees to provide very valuable and knowledgeable information.

3.2. Development of Measures

As a preliminary step to the analysis of the reliability and validity of the measurement scales used in this paper, the measurement scales of the two variables used were determined. Therefore, for the measurement of product eco-innovation, process eco-innovation and management eco-innovation, an adaptation was made to the scales proposed by Hojnik *et al.* (2014) and Segarra-Oña *et al.* (2014), the first one being measured through 4 items, the second through 4 items and the third through 6 items. Regarding the circular economy, the scale proposed by Geissdoerfer *et al*. (2017), who considered that circular economy can be measured through 4 items (value propositions). A five-point Likert-type scale was used to strike a balance between complexity for respondents and accuracy for analysis (Hair *et al.*, 2016).

Please, insert Table 1 in Here

3.3. Reliability and Validity of Measurement Scales

The evaluation of the reliability and validity of the two measurement scales used in this paper was carried out through a Confirmatory Factor Analysis (CFA), using the maximum likelihood method and the EQS 6.2 software (Byrne, 2006). Therefore, Cronbach's alpha and the Composite Reliability Index (CRI) proposed by Bagozzi and Yi (1988) were used to measure reliability. In addition, according to the results obtained, all the values of the scales were greater than 0.7 for both indices (Cronbach's alpha and CRI), which provided evidence of the reliability of the two scales used and justified their internal reliability (Nunally & Bersntein, 1994; Hair *et al.*, 2014). As evidence of convergent validity, FCASO results indicated that all items of related factors were significant ($p < 0.001$), the size of all standardized factor loads was greater than 0.60 (Bagozzi & Yi, 1988), and the average of the standardized factor loads of each factor exceed the value of 0.70 (Hair *et al.*, 2014).

The results of the CFA are presented in Table 2 and suggest that the measurement model provides a good fit of the statistical data ($S\text{-}B\ X^2 = 571.696$; $df = 128$; $p = 0.000$; $NFI = 0.882$; $NNFI = 0.887$; $CFI = 0.906$; $RMSEA = 0.077$). Similarly, Table 2 shows a high internal consistency of the constructs, in each case, Cronbach's Alpha exceeded the value of 0.70 recommended by Nunally and Bernstein (1994). Compound reliability represents the variance extracted between the group of observed variables and the fundamental construct (Fornell & Larcker, 1981), so that a CRI greater than 0.60 is generally considered desirable (Bagozzi & Yi, 1988), in this empirical study this value was widely exceeded. The Extracted Variance Index (EVI) was calculated for each of the constructs, resulting in an EVI greater than 0.50 (Fornell & Larcker, 1981), in this investigation, 0.50 was exceeded in all factors.

Please, insert Table 2 in Here

Additionally, the discriminant validity of the theoretical model of eco-innovation of products, processes and management, and circular economy was measured by means of two tests, which are presented in Table 3. First, the *confidence interval test* was presented (Anderson & Gerbing, 1988), which established that with a 95% confidence interval, none of the individual elements of the latent factors of the correlation matrix had a value of 1. Second, the *extracted variance test* was presented (Fornell & Larcker, 1981), which suggested that the variance extracted from each pair of constructs of eco-innovation of products, process and management, and circular economy was lower than its corresponding EVI. Thus, according to the results obtained from the application of both tests, it is possible to conclude that both tests demonstrated sufficient evidence of the existence of discriminant validity.

Please, insert Table 3 in Here

4. Results

To test the hypothesis presented in this paper, a structural equation model (SEM) was applied with the support of the EQS 6.2 software (Byrne, 2006; Brown, 2006). The model analyzed the nomological validity of the theoretical model of eco-innovation of products, process and management, and circular economy through the Chi-square test, by means of which the results obtained between the theoretical model and the measurement model were compared, obtaining non-significant results, which allowed establishing an explanation of the relationships observed between latent constructs (Anderson & Gerbing, 1988; Hatcher, 1994). Table 4 shows in greater detail the results obtained from the application of the SEM.

Please, insert Table 4 in Here

Table 4 shows the results obtained from the application of the SEM and, with respect to **H1**, it can be seen that the results, $\beta = 0.420$ $p < 0.001$, indicate that product eco-innovation has a significant positive influence on the circular economy of companies in the automotive industry.
Regarding hypothesis **H2**, the results obtained $\beta = 0.262$ $p <0.001$, indicate that process eco-innovation has a significant positive influence on the circular economy of the firms in the

automotive industry. Finally, in relation to **H3**, the results ($\beta = 0.388$ $p < 0.001$), indicate that management eco-innovation has a significant positive influence on the circular economy. In summary, it can be corroborated that the activities of eco-innovation (eco-innovation of products, processes and management), carried out by companies that make up the Mexican automotive industry, have a strong influence on the activities that integrate the circular economy.

5. Discussion, Conclusions, Limitations And Future Investigations

Discussion and Conclusions

Several conclusions can be drawn from the results obtained from the present research, among which, in the first place, the theoretical model of the relationship between eco-innovation and the circular economy shows a high consistency, generating a high correlation between the two variables analyzed. This allowed the acceptance of the proposed research hypothesis. Secondly, this theoretical model also offers an overview that includes the three indicators of eco-innovation most cited in current literature (i.e. product eco-innovation, processes eco-innovation, and management eco-innovation). Likewise, the development of empirical studies that relate the activities of eco-innovation and the circular economy has received little attention from researchers, academics and professionals, compared to those studies that have been oriented towards the conceptualization and consequences of both constructs (Kemp, 2011).

In addition, even though the analysis and discussion of the relationship between eco-innovation and the circular economy is very incipient, it is also true that it is a topic that is gaining greater attention in the literature by researchers, academics and professionals from various fields, which allows us to conclude that the relationship between eco-innovation activities and the circular economy at the micro level is a topic that is open to discussion (de Jesús *et al.*, 2018, 2019; Liu *et al.*, 2019). Therefore, this study provides theoretical and empirical evidence of the relationship between eco-innovation activities and the circular economy in manufacturing companies, especially in those companies that make up the automotive industry of an emerging economy country, such as this is the case in Mexico, which is the most important industry for the development of the country's economy.

Likewise, the main objective of this study is to investigate the relationship between eco-innovation activities and the circular economy in companies in the automotive industry, using a sample of 460 companies in Mexico. However, it can be concluded that this study differs from other studies published in the current eco-innovation literature (e.g. Suddaby, 2014; Grillitsch *et al.*, 2019), since this empirical study considers three essential factors of eco-innovation activities for its measurement (eco-innovation in products, processes and management), which allows a broader measurement of the activities carried out by companies in the automotive industry, and the relationship that these eco-innovation activities have with the circular economy.

Additionally, it can also be concluded that the results obtained in this study are similar to those obtained by de Jesus *et al*. (2018), de Jesús *et al*. (2019), and Liu *et al*. (2019), which argue that eco-innovation activities not only induce manufacturing companies to continue improving, but also have significant positive effects on the circular economy. Therefore, it is possible to conclude that eco-innovation activities are not applied in the same way in companies in the automotive industry, since eco-innovation of products is the activity that companies are developing the most, followed by eco-innovation in management and eco-innovation in processes, i.e. eco-innovation in products has a higher level of importance.

Practical Implications

The results obtained in this paper have different implications for managers and organizations in general. The first implication is that the data obtained through the application of a survey, allowing a general analysis of the relationship between eco-innovation activities and the circular economy in a particular industry (automotive industry companies), therefore, in future studies it would be pertinent for researchers and academics to guide their studies in the discussion of these two same constructs in longitudinal studies or in cases of success. Likewise, this study incorporating a theoretical model that directly relates the activities of eco-innovation (eco-innovation of products, processes and management), with the circular economy provides a more holistic point of view that better explains the interrelation between the eco-innovation and the circular economy (de Jesús *et al.*, 2018).

In this sense, the development of the theory establishes the existence of a connection between eco-innovation and circular economy, which commonly generates a transformative innovation (Grillitsch *et al.*, 2019). In addition, this relationship also generates a transformation in the production systems of manufacturing companies, particularly those belonging to the automotive industry through the development of eco-product innovation activities, which are generally based on a change in the systematic integration of technological and non-technological activities developed by organizations, requiring for this the development of cooperation activities and greater integration of the companies that are its main business partners, in such a way that allows them to redirect their eco-innovation systems through the circular economy, that is an improvement in production practices and social activities (de Jesús *et al.*, 2019).

A second implication is that some studies published recently in the eco-innovation literature (e.g. de Jesús *et al.*, 2018, 2019; Liu *et al.*, 2019), they were oriented in an analysis of the literature review, in the analysis through the Delphi Method and in the analysis of a particular industrial sector. However, in this study, the approach has been practically oriented in the analysis and discussion of the effects that eco-innovation activities (measured through eco-innovation of products, processes and management), have on the circular economy in the companies that make up the automotive industry, which provides empirical evidence that establishes the existence of a significant positive relationship between eco-innovation in products, processes and management and circular economy. Therefore, by simultaneously analyzing the three types of eco-innovation as an essential part of the eco-innovation activities of manufacturing companies, it allows the managers of organizations the possibility of improving their eco-innovation practices which will facilitate the development of the quality of its eco-products (Huang *et al.*, 2018).

A third implication is that eco-innovation activities are strongly associated with the circular economy (EC, 2015), and are essential for the development of both the economy and the improvement of the sustainability of manufacturing companies (de Jesús *et al.*, 2019), mainly of those that make up the automotive industry. These results are consistent with those obtained by Guo *et al.* (2018), who considered that the development of the coal industry in China is closely related to economic efficiency and eco-innovation activities, so it is urgent and necessary that future studies be oriented in the analysis and discussion of the existing relationship between the eco-innovation in products, process and management, and the circular economy of manufacturing companies (Xu *et al.*, 2018), which can contribute to obtaining a higher level of business performance (Bonzanini *et al*., 2016), and contribute to the transformation of a more sustainable society (Carrillo-Hermosilla *et al.*, 2010).

Finally, a fourth implication of these results is that not only the decision-making of technology-oriented eco-innovation activities generate better results in the economy of manufacturing companies (Guo *et al.*, 2018), but also non-technological eco-innovation activities (de Jesús *et al*., 2018). Therefore, this empirical study enriches the discussion of the eco-innovation literature, by providing empirical evidence that determines that it is not only important for manufacturing companies, especially for those that make up the automotive industry, the adoption of technological activities (e.g. product eco-innovation and processes eco-innovation), but also non-technological activities (e.g. management eco-innovation), to generate both better business performance (Miroshnychenko *et al*., 2017), and greater significant positive effects on circular economy (Liu *et al.*, 2019).

Research Limitations and Future Research

This study has different limitations that are important to consider in the context of the interpretation and implications of the results obtained. Thus, the first limitation of this paper is related to the measurement scales of both eco-innovation (eco-innovation in products, processes and management) and of the circular economy, since these two constructs were measured with various subjective indicators through the survey. Therefore, in future studies it will be necessary to use objective data from manufacturing companies (e.g. percentage of use of renewable energy, percentage of use of treated water, percentage of recycling of raw materials), in order to verify whether the results obtained differ or not from those obtained in this study.

A second limitation is that the relationship between eco-innovation activities and the circular economy may have better results if an essential variable of the individual characteristics of managers and/or business owners is added (e.g. leadership, entrepreneurship, commitment, responsibility, management capacity). Therefore, in future studies it will be necessary to use some other variable that improves the relationship between eco-innovation and the circular economy, with the intention of corroborating whether the results obtained are similar or better than those obtained in this study. A third and final limitation is that in this empirical study the three types of eco-innovation most cited in the literature were considered (product eco-innovation, process eco-innovation and management eco-innovation) for the measurement of eco-innovation activities, and four items for the measurement of the circular economy, so in future studies it will be necessary to consider other types of eco-innovations (e.g. marketing, technology, systems), and others circular economy drivers, to corroborate the results obtained.

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Tables

Table 1. Eco-innovation and circular economy measures

Please, indicate if your company… (Eco-Product Innovation)		Totally Disagree				Totally Agree
PE1	It constantly improves the life cycle standards of its products and conducts studies on the life cycle of its products.	**1**	**2**	**3**	**4**	**5**
PE2	It uses or develops new energy sources with a tendency to reduce CO2 emissions.	**1**	**2**	**3**	**4**	**5**
PE3	It uses the eco-label system that each country requires for its products.	**1**	**2**	**3**	**4**	**5**
PE4	It uses and manufactures eco-innovative components and materials that are made from recycled raw materials.	**1**	**2**	**3**	**4**	**5**

Please, indicate if your company… (Eco-Process Innovation)		Totally Disagree				Totally Agree
RE1	Carries out a treatment of your wastewater	**1**	**2**	**3**	**4**	**5**
RE2	Uses sterilization methods for its components or technological devices	**1**	**2**	**3**	**4**	**5**
RE3	Produces or uses fabric components that utilize fabric sanitation technologies	**1**	**2**	**3**	**4**	**5**
RE4	Uses ecological or recyclable paper in your processes	**1**	**2**	**3**	**4**	**5**

Please, indicate if your company… (Eco-Organizational Innovation)		Totally Disagree				Totally Agree
ME1	Has a management system that reuses obsolete components and equipment.	**1**	**2**	**3**	**4**	**5**
ME2	Has an ISO 14001 Certification or similar.	**1**	**2**	**3**	**4**	**5**
ME3	Has constant audits of energy saving and ecology by the state and/or municipal authorities of your locality.	**1**	**2**	**3**	**4**	**5**
ME4	Constantly conducts seminars or training courses for staff related to Eco-innovation.	**1**	**2**	**3**	**4**	**5**
ME5	Has well-defined policies that encourage and support Eco-innovation activities throughout the organization.	**1**	**2**	**3**	**4**	**5**
ME6	Has a monitoring and control system for wastewater generated by the company.	**1**	**2**	**3**	**4**	**5**

Please, indicate if your company… (Circular Economy Practices)		Totally Disagree				Totally Agree
CE1	Has a recycling system for used and/or damaged products	**1**	**2**	**3**	**4**	**5**
CE2	Knows how to design products with components or materials from reuse or recycling of raw materials.	**1**	**2**	**3**	**4**	**5**
EC3	Has a program for the collection and recycling of products and materials.	**1**	**2**	**3**	**4**	**5**
EC4	Knows how to design products that significantly reduce the use of materials and/or energy, and generate greater eco-efficiency.	**1**	**2**	**3**	**4**	**5**

Table 2. Internal consistency and convergent validity of the theoretical model

Variable	Indicator	Factorial Loading	Robust t-Value	Cronbach's Alpha	CRI	EVI
Product Eco-innovation	PE1 PE2 PE3 PE4	0.667*** 0.799*** 0.894*** 0.820***	1.000[a] 14.827 15.994 15.124	0.900	0.901	0.639
Process Eco-innovation	RE1 RE2 RE3 RE4	0.859*** 0.884*** 0.878*** 0.809***	1.000[a] 24.772 24.517 21.387	0.917	0.918	0.736
Management Eco-innovation	ME1 ME2 ME3 ME4 ME5 ME6	0.777*** 0.759*** 0.864*** 0.887*** 0.885*** 0.768***	1.000[a] 17.472 20.556 21.284 21.214 17.725	0.926	0.927	0.681
Circular Economy	CE1 CE2 CE3 CE4	0.793*** 0.803*** 0.907*** 0.901***	1.000[a] 19.068 22.323 22.133	0.913	0.914	0.727
$S\text{-}BX^2$ (df = 128) = 571.696; p < 0.000; NFI = 0.882; NNFI = 0.887; CFI = 0.906; RMSEA = 0.077						

[a] = Constrained parameters to such value in the identification process

*** = p < 0.01

Table 3. Discriminant validity of the theoretical model

Variables	Product Eco-innovation	Processs Eco-innovation	Management Eco-innovation	Circular Economy
Product Eco-innovation	**0.639**	0.177	0.154	0.101
Processs Eco-innovation	0.345 – 0.497	**0.736**	0.446	0.151
Management Eco-innovation	0.335 – 0.451	0.546 – 0.790	**0.681**	0.145
Circular Economy	0.274 – 0.362	0.297 – 0.481	0.313 – 0.449	**0.727**

The diagonal represents the Extracted Variance Index (EVI), whereas above the diagonal the variance is presented (squared correlation). Below diagonal, the estimated correlation of factors is presented with 95% confidence interval.

Table 4. Results of the SEM

Hypothesis	Structural Relationship	Standardized Coefficient	Robust t-Value
H_1: Product eco-innovation has a significant positive influence in the circular economy.	Product Eco → CE	0.420***	6.450
H_2: Process eco-innovation has a significant positive influence in the circular economy.	Process Eco → CE	0.262***	3.952
H_3: Management eco-innovation has a significant positive influence in the circular economy.	Management Eco → CE	0.388***	5.730
$S\text{-}BX^2$ (df = 129) = 465.521; p < 0.000; NFI = 0.895; NNFI = 0.907; CFI = 0.921; RMSEA = 0.078			

*** = P < 0.01