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Collaboration, eco-innovation and economic performance in the automotive industry

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Abstract

Purpose – Eco-innovation is emerging as one of the most important constructs that improve environmental sustainability of firms. However, it has been shown that companies alone cannot adequately develop eco-innovation activities, which is why they require the implementation of external collaboration activities with intermediaries, suppliers and stakeholders to achieve a higher level of eco-innovation activities and improve business performance of manufacturing firms. Therefore, this research fills this gap by exploring the importance of the relationship between collaboration and eco-innovation.

Design/methodology/approach – The research is conducted through an extensive literature review with a research model consisting of 5 measurement scales, 24 items and 4 hypotheses. A self-administered questionnaire was distributed to a sample of 460 firms in Mexico, analyzing the data set through confirmatory factor analysis and structural equation models.

Findings – The results obtained from this study suggest that collaboration has significant positive effects both on the eco-innovation of products, processes and management, as well as on the business performance of companies in the automotive industry.

Practical implications – The findings of this study have important implications both for the public administration (e.g. development of policies to support companies and financing programs) and for the managers of companies in the automotive industry (e.g. training program for employees and collaboration with other firms).

Originality/value – This paper fills a research gap by expanding the limited body of knowledge that relates collaboration eco-innovation and business performance, which is why this research aims to fill this existing gap in the literature and explore the relationship between collaboration, eco-innovation and business performance.

Keywords Collaboration, Innovation, Eco-innovation, Economic performance

Paper type Research paper

1. Introduction

The deforestation of natural resources and climate change are generating strong social pressure on manufacturing companies to align their objectives of innovation and economic performance with sustainability (Schot and Steinmueller, 2018). The most appropriate approach to achieve this alignment is eco-innovation (Kanda *et al.*, 2022), since these types of activities are aligned with innovation adoption that improve both environmental and production performance and eco-products consumption (Geng *et al.*, 2021). However, eco-innovation activities require extensive collaboration with stakeholders, particularly in the automotive industry, through the combination of available resources in organizations (Kanda *et al.*, 2021), since collaboration facilitates the interaction, construction of synergies and resolution of conflicts between the participating companies, thereby improving not only

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the efficiency and effectiveness of eco-innovation but also its economic performance (Cramer, 2020; Kanda *et al.*, 2020; Janahi *et al.*, 2022).

Additionally, eco-innovation promotes solutions to environmental and sustainability problems, and is considered in the literature as an important strategy in manufacturing companies due to the environmental benefits it generates (Janahi *et al.*, 2021). However, there are few studies published in the literature that provide empirical evidence of the adoption and implementation of collaboration in eco-innovation activities (Janahi *et al.*, 2021), particularly in eco-innovation of products, processes and management that improve economic performance (Geng *et al.*, 2021). For this reason, a call is made for the scientific and academic community to guide their studies in the exploration of collaborative activities that allow the adoption and implementation of eco-innovation, not only in manufacturing companies in developed countries (Simms *et al.*, 2020), but also in emerging economy countries (Yi *et al.*, 2020).

The objective of this study is the analysis and discussion of the effects of collaboration on eco-innovation practices and economic performance. Thus, to achieve this objective, an empirical study was implemented in the context of companies in the automotive industry in Mexico, through a sample of 460 companies and estimating the model using structural equations with SmartPLS (Ringle *et al.*, 2022). This context is interesting for two reasons. On the one hand, not only because it is considered in the literature that the automotive industry is economically interested in reducing the consumption of energy and materials in its production process (Ceschin and Vezzoli, 2010), but also because it is the industry that generates the highest percentage of the GDP of the Mexican economy. On the other hand, because there is little empirical evidence in the literature that collaboration with suppliers, government authorities and customers facilitate both the implementation of eco-innovation practices and economic performance (Nikolaou *et al.*, 2016; Pacheco *et al.*, 2017; Kanda *et al.*, 2018).

The results obtained in this study show evidence of the existence of a positive effect of collaboration on eco-innovation practices (eco-innovation of products, processes and management) and economic performance. Therefore, this study contributes to the eco-innovation literature in two essential aspects. First, the existence of a limited number of empirical studies that have considered the role of collaboration in eco-innovation practices (Chen *et al.*, 2019), particularly the limited number of studies that analyze specific practices of eco-innovation (in products, processes and management) (Tumelero *et al.*, 2019) and its implication in economic performance (Di María *et al.*, 2019). Second, it contributes to the generation of knowledge about the effects and conditions in which collaboration affects eco-innovation practices and economic performance (Bossle *et al.*, 2016; He *et al.*, 2018), especially in developing countries, as is the case of Mexico (Bossle *et al.*, 2016; Aloise and Macke, 2017; Chen *et al.*, 2017; Sanni, 2018).

For these reasons, the overall effect of collaboration in eco-innovation practices and economic performance may still 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 collaboration, eco-innovation and economic performance in the automotive industry?* The rest of the paper is structured as follows: Section 2 presents the literature review and hypotheses; 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

Today, most manufacturing firms face various complex and multifaceted problems, which require collaboration with other companies for the integration of skills and knowledge that generate optimal and more holistic solutions (Budiarso *et al.*, 2021). Therefore, it is not uncommon to find in the literature that companies' ability to innovate successfully is through collaboration with other companies and organizations (West and Advisory, 2020; Nguyen *et al.*, 2020), particularly because collaboration it is a powerful business tool for manufacturing firms, regardless of their size, sector or industry to which they belong (Budiarso *et al.*, 2021). Thus, collaboration creates spaces and opportunities for companies to improve eco-innovation activities, through effective use of their resources (Cramer, 2020) and capabilities (Aspeteg and Bergek, 2020), which can substantially improve their level of economic performance (Kanda *et al.*, 2020).

This study is based on the theory of resources and capacities of firms (Barney, 1986; Wernerfelt, 1984), particularly because this theory explains how manufacturing firms can take advantage of resources and capacities of other companies and organizations (Calvo *et al.*, 2022). This theory argues that manufacturing firms that have certain types of resources (tangible or intangible) and capabilities that are valuable, rare, difficult to imitate and organized to generate value have a competitive advantage (Barney *et al.*, 2021), and that competitive advantage is increased through collaboration (Calvo *et al.*, 2022). Thus, from a business perspective, manufacturing firms relate the external activities of eco-innovation (consumer preferences, legal framework incentives and pressure from stakeholders), with internal activities, supported by an increase in efficiency of the business (reduction of internal consumption of energy and raw materials) (Calvo *et al.*, 2022).

2.1 Collaboration and products eco-innovation

The literature establishes the existence of several terms to designate eco-innovation such as green innovation, ecological innovation and environmental innovation (González-Moreno *et al.*, 2019), which are generally used to describe all those innovations that reduce negative impacts on the environment and that improve sustainability (Araújo and Franco, 2021). Regardless of the term used, the most important thing is to establish is that eco-innovation is emerging in the innovation literature not only as a need to manage the levels of pollution emitted by manufacturing firms, particularly those that make up the industry, but also as an essential variable that significantly improves economic performance (Kerdpitak *et al.*, 2019), especially when collaboration with other companies and public and private organizations (Niesten *et al.*, 2017) such as funders (Polzin *et al.*, 2016), universities (Kivamaa *et al.*, 2017), project developers (Aspeteg and Bergek, 2020) and business development organizations (Kanda *et al.*, 2020).

In this sense, Kemp and Pearson (2007) and Horbach (2008) considered that collaboration with other firms facilitates implementation of eco-innovation in manufacturing firms, particularly because of the technology for the development of products eco-innovation (Kishna *et al.*, 2017). However, since eco-innovation is considered in the literature to represent the technological frontier, in which manufacturing firms in general have very little experience (Tumelero *et al.*, 2018), it is not possible to accept that technology alone is the solution for the transition to a more sustainable society (Fisccher and Pascucci, 2017). Therefore, to achieve a more sustainable society, it is necessary to develop and increase products eco-innovation for which collaboration appears in the literature as a possible solution (De Giorgi *et al.*, 2015; Souto and Rodríguez, 2015), since through collaboration the use of resources is optimized (Burki *et al.*, 2019), and enabling the effective use of support systems resources (Cramer, 2020).

Likewise, collaboration with suppliers, intermediaries and stakeholders allow companies in the automotive industry to access their resources and skills, through different activities such as access to new markets (Polzin *et al.*, 2016), or the formation of supplier networks that facilitate the exchange of knowledge, skills, experiences and learning (Geels and Deuten, 2006), which allows substantially improving products eco-innovation (Kanda *et al.*, 2018).

In addition, collaboration with intermediaries and suppliers can directly support manufacturing firms in the development of their eco-innovation activities (Agogué *et al.*, 2017), since intermediaries are not only the ones with more information about tastes and consumer preferences but can also support companies in products eco-innovation (Hakkarainen and Hyysalo, 2016), improving business results (Melander and Pazirandeh, 2019) and supports with its resources and capabilities in the development of more environmentally friendly products (Ketelsen *et al.*, 2020).

Collaboration with other companies and organizations facilitates and improves the development of products eco-innovation in manufacturing companies (De Marchi, 2012), through access to financial resources and the integration of the vision of the companies that make up the supply chain (Garcés-Ayerbe *et al.*, 2019). Likewise, there is empirical evidence that establishes that collaboration has greater significant positive effects on the products eco-innovation when it works in isolation (Melander and Pazirandeh, 2019), since the heterogeneity of business partners, suppliers, clients, organizations, governments and universities generate a higher level of synergy (Becker and Dietz, 2004). The more or better collaboration will generate more benefits for firms, teams and organizations including better environmentally friendly products (Cronwell and Gardner, 2020). Therefore, considering the information presented in the previous paragraphs, it is possible to propose the following research hypothesis.

H1. Collaboration has significant positive effects on products eco-innovation.

2.2 Collaboration and processes eco-innovation

Collaboration refers to the activities carried out by firms with other companies and organizations for the use and exchange of information to creation of products, development of ideas, exchange of data, development of plans jointly and improvement of production processes (Garcés-Ayerbe *et al.*, 2019). In particular, the lack of resources and the limited existing knowledge within the manufacturing companies of the automotive industry, necessary for the development of processes eco-innovation, can be compensated through collaboration with suppliers, clients, centers of research and government agencies (Kobarg *et al.*, 2020), which can not only share their resources and knowledge, but also the technology for the development of eco-innovation of production processes (Tumelero *et al.*, 2019). Literature considers eco-innovation a result of collaborative knowledge exchanges, and includes a wide diversity of firms in conditions of interdependence that improves eco-innovation process (Saleh *et al.*, 2022).

In this sense, processes eco-innovation can be implemented more easily and in a faster way, working collaboratively with other firms and organizations than if the companies carry it out individually (Araújo and Franco, 2021), since the return investment and economic performance can be higher if firms share their resources and knowledge with other firms and organizations (González-Moreno *et al.*, 2019). In this sense, collaboration is becoming a fundamental activity not only for the significant improvement of environmental sustainability and the increase of competitive capacities in manufacturing companies (Burki and Dahlstrom, 2017), but also for the development of the process eco-innovation in the companies that make up the supply chain (Burki *et al.*, 2019). For this reason, literature establishes that processes eco-innovation can be considered as a dynamic capacity, which allows manufacturing firms to survive the changes demanded by the market in the short and long terms (Gil-Alana *et al.*, 2020; Hilmersson and Hilmersson, 2021).

Likewise, the literature on innovation shows that collaboration with suppliers, business partners and organizations can be effective both, in reducing negative environmental impacts and in recycling some components used in products eco-innovation (Tumelero *et al.*, 2019). In addition, the exchange of technology that reduces the level of CO_2 and greenhouse gases, significantly improves the internal processes of companies in the automotive industry, and allows compliance with environmental regulations and legislation (De Marchi, 2012). However, eco-innovation practices are not always available to all companies in the supply chain, so collaborative activities with major stakeholders will allow manufacturing firms to adopt and improve processes eco-innovation (Cainelli and Mazzanti, 2013; De Giorgi *et al.*, 2015). Therefore, social and stakeholder pressure is forcing manufacturing firms to improve processes innovation, and this can be achieved through collaboration with business partners and other actors (Shen *et al.*, 2021).

Based on collaboration point of view, researchers and academics argue that manufacturing firms can be more innovative in their processes, only when they can create an outstanding level of collaborative knowledge (Elia *et al.*, 2020). Therefore, processes eco-innovation that improve the environment and sustainability requires actions, involvement and change of roles of all the actors that participate in collaborative activities (e.g. managers, stakeholders, government, consumers, researchers, etc.) (Janahi *et al.*, 2021). Thus, collaboration demands greater proactivity on the part of manufacturing firms, in order to incorporate strategies that promote the adoption of eco-innovation practices (Tang *et al.*, 2020) such as participation of the different stakeholders in the production processes (Huiling and Dan, 2020; Arranz *et al.*, 2020). Thus, considering the information presented above, it is possible to propose the following research hypothesis.

H2. Collaboration has significant positive effects on processes eco-innovation.

2.3 Collaboration and management eco-innovation

In the innovation literature, it is established that eco-innovation is commonly oriented toward the management of a more sustainable future for manufacturing firms, through the development of various social, economic and, especially, environmental actions (Aboelmaged, 2018). In addition, there is a consensus among researchers and academics that eco-innovation generally refers to the products eco-innovation, that are not only more environmentally friendly, but also reduce the use of environmental resources and generate a lower level of industrial waste (Araújo and Franco, 2021), which could significantly reduce negative impact on both environment and global warming, emission of CO_2, greenhouse gases and industrial waste emitted in the process of industrialization of products (Kong *et al.*, 2016). In this sense, Bocken and Geradts (2020) emphasize the need for manufacturing firms to collaborate in eco-innovation activities, both to increase the dynamic capacities of organizations and improve environmental sustainability.

However, studies published in the literature indicate that management eco-innovation practices is an overly complex activity, which is why manufacturing companies, particularly those that make up the automotive industry, have to carry out collaborative activities with suppliers, business partners, universities and public and private organizations to facilitate the implementation of the different organizational changes that companies require to significantly improve the management eco-innovation (Hemmelskamp, 1999; Kemp and Pearson, 2007; Horbach, 2008; De Marchi, 2012; Cainelli and Mazzanti, 2013; De Giorgi *et al.*, 2015; Souto and Rodríguez, 2015), since collaboration with stakeholders that make up the supply chain not only facilitates the production of eco-products more friendly to the environment, but also the development of management eco-innovation activities (Tumelero *et al.*, 2019), since studies published in literature have shown that eco-innovation management is an elementary activity to achieve a higher level of business growth (Malmeström and Johansson, 2015; Mu *et al.*, 2019).

In this sense, in literature it is possible to find that eco-innovation management is a vital function in the survival of manufacturing firms, since this activity allows organizations to adopt activities of collaboration, reconstruction, growth and sustainability (Saleh *et al.*, 2022).

Lo *et al.* (2021) demonstrated the importance for organizations of the management capacity of eco-innovation in development of long-term sustainable value propositions, which allows manufacturing firms to respond as quickly as possible to the changes that current markets demand (Sakis, 2020; Ivanov, 2020; Correa *et al.*, 2021). Therefore, collaboration plays an essential role in eco-innovation management, since collaboration is usually considered in literature as a great facilitator of organizational agility that helps manufacturing firms to respond both to unforeseen emergencies and to short-term and long-term crises (Wang *et al.*, 2017; Saleh *et al.*, 2022).

Additionally, innovation has been considered in literature as a creative dynamic skill, which allows manufacturing firms to respond to unforeseen situations demanded by the market (Saleh *et al.*, 2022). Greco *et al.* (2021) showed that difference between successful and unsuccessful firms is eco-innovation activities, and even more efficiency in innovation management, for which literature has emphasized the importance of better manufacturing firms and their eco-innovation management skills, through collaboration with other companies and organizations, which will allow them to remain competitive (Steinmo and Rasmussen, 2018; Yesil and Dogan, 2019). However, few studies published in the literature have analyzed collaboration in eco-innovation, which not only improves business results but also long-term management of environmental sustainability (Laasch, 2019; Bocken and Geradts, 2020). Thus, considering the information presented above, it is possible to propose the following research hypothesis.

H3. Collaboration has significant positive effects on management eco-innovation.

2.4 Collaboration and economic performance

For a little over two decades, companies have been increasing their efforts to adopt more sustainable business practices (Sharma and Henriques, 2005), which is forcing them to modify their product portfolio, production processes and supply chain management in response to restrictive government regulations, changing consumer tastes and preferences and pressure from NGOs (Ahlström and Sjöström, 2005; Hoejmose *et al.*, 2012). In this sense, companies in the automotive industry must make substantial changes in their production processes to improve environmental conditions (Carroll and Shabana, 2010), for which they will require collaboration with other companies and organizations that help them to changes are made more quickly, in such a way that allows them to reduce production costs and increase the level of economic performance (Seuring and Gold, 2013).

Likewise, collaboration with suppliers, stakeholders and government agencies allow companies in the automotive industry, not only to focus investment and development on improving sustainability and the environment, but also on improving their production systems, which can generate a substantial increase in the level of economic performance (Chen *et al.*, 2019). Thus, manufacturing firms will be able to use the resources and knowledge of the stakeholders that participate in collaborative activities, to obtain more and better economic results (Tumelero *et al.*, 2019). Therefore, environmental efforts to introduce eco-innovation in manufacturing firms, and establish a sustainable relationship with the planet, is a recurring theme in current literature and even more so when it is directly related to the economic performance that companies can achieve (Cheng and Shiu, 2012; Cheng *et al.*, 2014; Hojnik *et al.*, 2018).

Additionally, the literature establishes that the influence of collaboration on the economic performance of firms in the automotive industry has generally been measured through indicators such as return on investment, sales, market share and profits or earnings (Im and Workman, 2004). In addition, some studies published in the innovation literature have found a significant positive influence of collaboration on economic performance, essentially when it has been related to the implementation of eco-innovation in manufacturing companies

(Cheng and Shiu, 2012; Cheng *et al.*, 2014; Hojnik *et al.*, 2018). Therefore, it is possible to establish that collaboration in eco-innovation activities of manufacturing companies could generate a higher level of economic performance (Belderbos *et al.*, 2004), since there is empirical evidence that demonstrates the existence of a significant positive relationship between collaboration and economic performance, only through the relationship with eco-innovation activities (Lee and Min, 2015).

Finally, the efforts of firms in the automotive industry to introduce eco-innovation in products, processes and management is one of the fundamental elements that stimulate collaboration with suppliers, stakeholders and government agencies, thereby generating greater level of economic performance (Tether, 2002; Chesbrough, 2003). However, the results obtained are not sufficient, which is why researchers, academics and professionals from the industry must guide their studies in providing more empirical evidence of the relationship between collaboration and economic performance, when they are directly related to eco-innovation practices (Tumelero *et al.*, 2019). Thus, considering the information presented above, it is possible to propose the following research hypothesis.

H4. Collaboration has significant positive effects on economic performance.

3. Methodology

To respond to the research hypotheses raised, an empirical study was carried out in the manufacturing firms of the automotive industry in Mexico, analyzing the relationship between collaboration, eco-innovation and economic performance. In a first phase of the study, a "Business Panel" was held in which five entrepreneurs from the automotive industry participated, two representatives of government agencies related to financial support to companies and three academics from innovation area who were given the survey that would be applied for analysis and discussion. The results obtained in this first phase allowed the design of a survey to collect information, which was applied to a pilot sample of 10 entrepreneurs from the automotive industry, making minor adjustments to writing, appearance and spelling. Pilot studies are essential to ensure validity when questionnaires are self-administered or contain self-developed scales (Bryman, 2016; Hair *et al.*, 2016).

3.1 Sample design and data collection

The reference framework used in this study was the directory of companies in the automotive industry in Mexico, which had 909 firms registered as of November 30, 2018, the companies belonging to various local, regional and national business organizations and chambers, therefore, the empirical study did not focus on a particular business group or association. In addition, the survey for the information collection was applied to a sample of 460 firms selected by means of a simple random sampling, with a maximum error of ±4% and a reliability level of 95%, representing 50.6% of the total of the population and applying the survey during the months of January to March 2019. Likewise, it should be noted that all the managers interviewed are directly responsible for the development of innovation in their respective companies, which allowed obtaining very valuable and interesting information for the deep knowledge and experience they have in the industry.

3.2 Measurement development

One of the most recurrent problems in the current literature on business sciences and innovation is how to measure innovation itself (Zhang *et al.*, 2019), which is why it is important to precisely define the measurement of innovation activities. Therefore, to measure collaboration, an adaptation of the scale proposed by Belderbos *et al.* (2004) and Eurostat (2012), who considered that the collaboration can be measured through four items. Likewise, Klewitz and Hansen (2014) extensively reviewed the literature on eco-innovation and found that it is commonly measured through three elements: *products eco-innovation, processes eco-innovation and management eco-innovation*. For this reason, in this empirical study the three most cited indicators in the literature for measuring eco-innovation will be used: eco-innovation in products, processes and management.

Thus, for the measurement of eco-innovation, an adaptation was made to the scales proposed by Hojnik *et al.* (2014) and Segarra-Oña *et al.* (2014), measuring products eco-innovation through four items, processes eco-innovation through four items and management eco-innovation through six items. Finally, to measure economic performance, the scale proposed by Bag (2014) was used, who measured this construct through six items. A five-point Likert-type scale was chosen to strike a balance between complexity for respondents and accuracy for analysis (Forza, 2016; Hair *et al.*, 2016). Table 1 shows the items and factorial loads of the four scales used in the theoretical model, and it is observed that all the values are greater than 0.6, as recommended by Hair *et al.* (2019).

In this study, the use of a composite model was considered pertinent, which is essential reason for use of partial least squares structural equation modeling (PLS-SEM) (Sarstedt *et al.*, 2016), using SmartPLS 4.0 software (Ringle *et al.*, 2022), since composite indicators are considered in literature as the operational definition of emergent construct that mediates all the effects of the model, and the composites measured through composite indicators do not have an error term (Hair *et al.*, 2021). For the estimation of path models, PLS-SEM generally uses Model A or Model B. Model A is related to correlation weights derived from bivariate correlations between each indicator and the construct, while Model B is relating to weights of the regression (Sarstedt *et al.*, 2016). The five constructs used in this empirical study are type A compounds, as shown in Table 1.

Additionally, given that data were collected using the same instrument applied to same informant (company manager), it can cause biases that alter responses that could lead to Type I (false positive) or Type II (false negative) errors, the evaluation of common method variance (CMV) was using, following the recommendations of Podsakoff *et al.* (2012). Traditionally, the method most used by researchers to verify the possible effect of CMV is Harman's one-factor test (Podsakoff *et al.*, 2003), which consists of subjecting practically all the items of the scales to exploratory factorial analysis (EFA), forcing extraction to a single factor (Andersson and Bateman, 1997; Mossholder *et al.*, 1998; Iverson and Maguire, 2000; Aulakh and Gencturk, 2000).

To verify the suitability of data and possible effect of CMV, an EFA was applied, through principal components method and with varimax rotation, calculating Kaiser–Meyer–Olkin coefficients (KMO) and Bartlett's sphericity test. Results that are obtained support the use of EFA with data of this sample, with a KMO value = 0.865 and Bartlett's test is statistically significant [X^2 (276) = 8972.77, $p < 0.000$]. If there is a CMV problem, common factor extracted should have a value greater than 50% of the variance (Podsakoff *et al.*, 2003), but the common factor extracted from data is 36.12%, which is lower than the recommended value, which suggests that CMV is not a threat to sample data of this study, and does not seem to significantly affect the relationships between variables of the research model (Podsakoff *et al.*, 2012).

4. Analysis and results

To respond to the four hypotheses proposed in this study, the use of PLS-SEM with the SmartPLS 4 software was considered pertinent; since PLS-SEM is considered, an approach based on composites that linearly combine indicators to form composite variables (Lohmöller, 1987), which generally serve as proxies for the concepts being evaluated (Rigdon, 2016). Likewise, PLS-SEM approach allows adjusting the estimates of the structural equation models, when common

Indicators	Constructs	Factor loads (p-value)
Collaboration (CO)		
Cronbach's alpha: 0.916; Dijkstra–Henseler's rho (ρA): 0.916; CRI (ρc): 0.940; AVE: 0.798		
CO1	Customers	0.884 (0.000)
CO2	Suppliers	0.892 (0.000)
CO3	Government offices to obtain information services from the sector (regulations, performance indicators, programs that promote innovation, protection of innovations, probable technological partners, etc.)	0.902 (0.000)
CO4	Higher Education Institutions (Universities, Technological Institutes, etc.)	0.896 (0.000)
Product Eco-innovation (PE)		
Cronbach's alpha: 0.927; Dijkstra–Henseler's rho (ρA): 0.933; CRI (ρc): 0.943; AVE: 0.733		
PE1	It constantly improves its product life cycle standards and conducts product life cycle studies	0.868 (0.000)
PE2	It uses or develops new energy sources with a tendency to reduce CO_2 emissions	0.894 (0.000)
PE3	It uses the eco-label system required by each destination country for its products	0.853 (0.000)
PE4	It uses and manufactures eco-innovative components and materials that are made from recycled raw materials	0.789 (0.000)
Process Eco-innovation (RE)		
Cronbach's alpha: 0.917; Dijkstra–Henseler's rho: 0.932; CRI: 0.941; AVE: 0.800		
RE1	Treat your wastewater	0.883 (0.000)
RE2	Uses sterilization methods for its components or technological devices	0.899 (0.000)
RE3	Produces or uses fabric components that use fabric sanitizing technologies	0.924 (0.000)
RE4	Use ecological or recyclable paper in its processes	0.870 (0.000)
Management Eco-innovation (ME)		
Cronbach's alpha: 0.873; Dijkstra–Henseler's rho (ρA): 0.876; CRI (ρc): 0.913; AVE: 0.726		
ME1	Has a management system that reuses obsolete components and equipment	0.830 (0.000)
ME2	Has an ISO 14001 Certification or similar	0.816 (0.000)
ME3	It has constant audits of energy saving and ecology by the state and/or municipal authorities of its locality	0.885 (0.000)
ME4	It constantly carries out seminars or training courses for staff related to eco-innovation	0.891 (0.000)
ME5	It has well-defined policies that promote and support eco-innovation activities throughout the organization	0.903 (0.000)
ME6	It has a monitoring and control system for wastewater generated by the company	0.807 (0.000)
Economic Performance (EP)		
Cronbach's alpha: 0.903; Dijkstra–Henseler's rho (ρA): 0.909; CRI (ρc): 0.925; AVE: 0.674		
EP1	Economic benefits have increased	0.748 (0.000)
EP2	The profit margin has increased	0.772 (0.000)
EP3	Return on assets has increased	0.823 (0.000)
EP4	Increased return on investment	0.828 (0.000)
EP5	Sales volume has increased	0.886 (0.000)
EP6	Sales performance has increased	0.860 (0.000)

Note(s): CRI: composite reliability index; AVE: averaged variance extracted

Table 1.
Measurement model assessment

factor models are estimated (Bentler and Huang, 2014; Dijkstra and Schermelleh-Engel, 2014; Dijkstra and Henseler, 2015; Hair *et al.*, 2021), as is the case of the model in this study.

4.1 Reliability and validity of measurement scales

The reliability and validity of the four measurement scales were assessed using Cronbach's alpha, composite reliability index (CRI), Dijkstra–Henseler rho and extracted variance index

(EVI), as suggested by Hair *et al.* (2019). In addition, the discriminant validity of the four measurement scales used was evaluated through three substantial elements: Fornell and Larcker criterion, cross loadings and, particularly, Heterotrait–Monotrait ratio (HTMT) of the correlations (Henseler *et al.*, 2015; Hair *et al.*, 2019). The results obtained show that Cronbach's alpha has values that oscillate between 0.873–0.927, the CRI has values between 0.913–0.943 and the Dijkstra–Henseler rho has values that oscillate between 0.876–0.933, which indicates that they are good values and are above the recommended values (Bagozzi and Yi, 1988; Hair *et al.*, 2014, 2019). Similarly, the EVI has values that oscillate between 0.674–0.800 that are above the levels recommended in the literature (Fornell and Larcker, 1981; Bagozzi and Yi, 1988).

Regarding discriminant validity, the obtained results show that the Fornell and Larcker criterion is fulfilled in such a way that the shared variance between pairs of constructs is less than the variance extracted for each individual construct. The most effective measure is the HTMT (Henseler *et al.*, 2015), since the HTMT is an estimate of what the real correlation between two constructs would be if they were measured in a perfect way. An HTML value lower than 0.85 is recommended (Henseler *et al.*, 2015). In our case, the HTMT ratio varies between 0.236 and 0.533, showing very satisfactory levels far from the recommended maximum of 0.8. Table 2 shows in greater detail the results obtained from the reliability and validity of the measurement scales.

4.2 Structural model

Table 3 shows the results obtained from PLS-SEM application, which generally satisfy the evaluation criteria, since the values of the SRMR, geodetic discrepancy (dG) and unweighted least squares discrepancy (dULS) are below HI 99%, which allows verifying the significance of the theoretical model (Dijkstra and Henseler, 2015). The estimation of the theoretical model verifies that collaboration has a significant positive effect both on products eco-innovation, processes eco-innovation and management eco-innovation, as well as on firms' economic performance in the automotive industry. In particular, the coefficient linked in the relationship between collaboration and products eco-innovation is 0.342 with a *p*-value of 0.000 is significant, as well as the coefficients of the relationship of collaboration with processes eco-innovation (0.258; *p*-value 0.000) and management eco-innovation (0.345; *p*-value 0.000). These results show empirical evidence in favor of hypotheses H1, H2 and H3, which allows us to establish that the adoption of collaboration generates a higher level of eco-innovation practices in companies.

Finally, the results obtained show that collaboration with suppliers, stakeholders, government agencies and universities generate a significant positive effect on economic performance of firms in the automotive industry (0.445; *p*-value 0.000), which provides empirical evidence in favor of hypothesis H4. Therefore, it is possible to establish that, on the one hand, evidence is provided that shows that collaboration plays a fundamental role in development of eco-innovation activities in companies in the automotive industry and, on the other hand, collaboration carried out by companies in automotive industry, not only generates an increase in eco-innovation practices (eco-innovation in products, processes and management), but also a significant increase in the level the economic performance of organizations.

5. Discussion

The results obtained support the relationship between collaboration and products eco-innovation in firms in automotive industry in Mexico, and are consistent with results obtained in studies published by De Marchi (2012), Hakkarainen and Hyysalo (2016) and

Panel A. Reliability and validity Variables	Cronbach's alpha	CRI	Dijkstra–Henseler rho	EVI
Collaboration	0.916	0.940	0.916	0.798
Product eco-innovation	0.927	0.943	0.933	0.733
Process eco-innovation	0.917	0.941	0.932	0.800
Management eco-innovation	0.873	0.913	0.876	0.726
Economic Performance	0.903	0.925	0.909	0.674

Panel B. Fornell–Larcker Criterio Variables	1	2	3	4	5	Heterotrait–Monotrait ratio (HTMT) 1	2	3	4
1. Collaboration	*0.893*								
2. Product eco-innovation	0.365	*0.856*				0.394			
3. Process eco-innovation	0.258	0.494	*0.894*			0.278	0.533		
4. Management eco-innovation	0.342	0.420	0.359	*0.852*		0.380	0.464	0.397	
5. Economic Performance	0.445	0.308	0.218	0.314	*0.821*	0.486	0.336	0.236	0.353

Panel C. Cross-loadings Variables	CEI	EPI	ERI	EOI	OPE	Variables	CEI	EPI	ERI	EOI	OPE
CEI1	*0.884*	0.323	0.180	0.350	0.381	EOI1	0.282	0.297	0.509	*0.830*	0.260
CEI2	*0.892*	0.325	0.246	0.351	0.400	EOI2	0.293	0.296	0.353	*0.816*	0.287
CEI3	*0.902*	0.269	0.261	0.292	0.410	EOI3	0.318	0.348	0.468	*0.885*	0.239
CEI4	*0.896*	0.302	0.234	0.310	0.398	EOI4	0.307	0.398	0.414	*0.891*	0.263
EPI1	0.280	*0.789*	0.217	0.307	0.261	EOI5	0.369	0.430	0.430	*0.903*	0.305
EPI2	0.271	*0.868*	0.298	0.381	0.227	EOI6	0.296	0.372	0.371	*0.807*	0.223
EPI3	0.294	*0.894*	0.330	0.390	0.280	OPE1	0.370	0.261	0.162	0.254	*0.748*
EPI4	0.315	*0.853*	0.368	0.353	0.296	OPE2	0.309	0.252	0.120	0.210	*0.772*
ERI1	0.206	0.277	*0.883*	0.374	0.161	OPE3	0.330	0.267	0.201	0.269	*0.823*
ERI2	0.208	0.314	*0.899*	0.393	0.183	OPE4	0.357	0.239	0.163	0.291	*0.828*
ERI3	0.274	0.326	*0.924*	0.483	0.211	OPE5	0.425	0.265	0.210	0.256	*0.886*
ERI4	0.222	0.364	*0.870*	0.504	0.221	OPE6	0.382	0.264	0.162	0.235	*0.860*

Note(s): CEI: Collaboration; EPI: Product eco-innovation; ERI: Process eco-innovation. EOI: Management eco-innovation. OPE: Economic performance. Panel A: Fornell–Larcker Criterion: Diagonal elements (italic) are the square root of the variance shared between the constructs and their measures (EVI). For discriminant validity, diagonal elements should be larger than off-diagonal elements. Panel B: Cross-loadings of the items for all the constructs

Table 2.
Measurement model. Reliability, validity and discriminant validity

Kanda *et al.* (2018), who found a significant positive relationship between collaboration and products eco-innovation (H1). One of the main reasons for this positive effect could be that stakeholders share with companies both, information collected on tastes and preferences of customers and consumers, as well as their resources and capabilities, which not only facilitates the development of eco-products that are friendlier to the environment, but also the preference for this type of product by consumers, which could substantially improve level of economic performance of companies.

The positive effects of collaboration in processes eco-innovation in firms in the automotive industry are in line with the studies published in literature by Garcés-Ayerbe *et al.* (2019), Tumelero *et al.* (2019) and Burki *et al.* (2019) establish a significant positive relationship between collaboration and processes eco-innovation and supports hypothesis H2. The reason for this positive effect could be that companies seek to improve efficiency both in the use of materials and energy, as well as a significant reduction in costs through production and processes innovation. Therefore, to achieve these goals, collaboration with other companies

Paths	Path (t-value; p-value)	95% confidence interval	f^2	Support
CEI → EPI (H1)	0.342 (7.320; 0.000)	[0.250–0.431]	0.132	Yes
CEI → ERI (H2)	0.258 (6.262; 0.000)	[0.181–0.344]	0.071	Yes
CEI → EOI (H3)	0.365 (8.003; 0.000)	[0.282–0.458]	0.154	Yes
CEI → OPE (H4)	0.445 (8.818; 0.000)	[0.345–0.454]	0.247	Yes
Endogenous variable	*Adjusted R^2*	*Model Fit*	*Value*	*HI99*
		SRMR	0.056	0.181
EPI	0.115	dULS	0.924	0.951
ERI	0.064	dG	0.679	0.696
EOI	0.132	NFI	0.799	
OPE	0.196	rms Theta	0.173	

Note(s): CEI: Collaboration; EPI: Product eco-innovation; ERI: Process eco-innovation; EOI: Management eco-innovation; OPE: Economic performance. One-tailed t-values and p-values in parentheses; bootstrapping 95% confidence intervals (based on n = 5,000 subsamples) SRMR: standardized root mean squared residual; dULS: unweighted least squares discrepancy; dG: geodesic discrepancy; NFI: normal fit index; HI99: bootstrap-based 99% percentiles

Table 3.
Structural model

and organizations, through the exchange of knowledge, skills and resources will substantially improve not only processes eco-innovation but also the level of economic performance of companies.

In addition, this study provides robust empirical evidence that supports the positive effect of collaboration on management eco-innovation in firms in the automotive industry, since the results found are consistent with the results obtained by De Giorgi *et al.* (2015), Souto and Rodriguez (2015) and Tumelero *et al.* (2019), provide empirical evidence in favor of H3, which indicates that collaboration has significant positive effects on management eco-innovation. One of the essential reasons that establishes this positive effect may be the strong social pressure to which firms in the automotive industry are exposed, due to changes in management systems that improve the sustainability and environmental conditions of the localities where they are located or established, as well as the pressure exerted by stakeholders to adapt their management systems to market demands.

Additionally, the positive effects of collaboration on the level of economic performance of firms in the automotive industry are in line with studies recently published in innovation literature such as the one by Hojnik *et al.* (2018), Chen *et al.* (2019) and Tumelero *et al.* (2019), provide empirical evidence like that of this study, which supports hypothesis H4. The reason for this positive effect may be that firms in the automotive industry seek not only to comply with existing government environmental regulations in the localities where they are located, but also that the exchange of resources and capacities that they carry out with their main stakeholders, through the various collaborative activities, are reflected in a substantial increase in its level of economic performance, thereby combining sustainability with financial aspects.

6. Conclusions, limitations and future research

In literature it is common to find that manufacturing firms, particularly those that make up the automotive industry, are seen as one of the largest sources of environmental pollution, especially in countries with emerging economies, such as Mexico. However, this view is at odds with the current view in literature that establishes the resurgence and reinvention of manufacturing firms as industrial networks, in which significant proactive and pragmatic efforts are being made beyond a traditional procurement-oriented industry of profits, as shown by the results of this study, by providing evidence of a significant positive relationship between collaboration and eco-innovation of products, processes and management, which allows us to conclude that sustainability and environmental issues are not in contrast with economic performance.

In this context, it can be concluded that this study contributes to the connection between eco-innovation activities and theory of resources and capabilities of firms, to identify collaborative activities that can accelerate or reduce the growth and development of the company's eco-innovation of products, processes and management systems in the automotive industry. This study opens the door to future research. First, previous studies that analyze the relationship between collaboration and eco-innovation are relatively scarce, compared to those studies that have focused on its conceptualization (Tumelero *et al.*, 2019), which from our point of view lack a substantial contribution Therefore, future studies should focus on the analysis of collaborative activities with other dimensions of eco-innovation and the level of economic performance to verify the results obtained.

Second, analysis of the relationship between collaboration, eco-innovation and economic performance is a relatively recent topic in the literature, but it is also true that this topic is recently gaining the attention of researchers, academic and professionals in the field industry, which allows us to conclude that the relationship between the three constructs is an unfinished topic that is currently open to discussion (Kanda *et al.*, 2018). For this reason, it would be pertinent that future studies focus on intrinsic aspects of collaborative activities such as the location of stakeholders, green technology used by stakeholders, and digitization of stakeholder information processes, which will allow firms in the automotive industry, not only substantially improve the eco-innovation of their products, processes and management systems, but also their level of economic performance.

Finally, regarding the methodology used in this study, it is possible to conclude that the development of successful case studies of firms in the automotive industry can help scientific and academic community to obtain a deeper understanding of why positive relationships were achieved among the above constructs. Additionally, regarding the use of PLS-SEM statistical technique used in this study, it is possible to conclude that in future studies other techniques could be used that consider both a greater amount of information and visibility, as well as a greater data efficiency, such as panel data analysis. However, the costs and time of collecting the information required by this type of statistical techniques should also be considered.

This empirical study has various limitations that are important to consider when interpreting and discussing the results obtained. Therefore, a first limitation of this study is related to the measurement scales of the collaboration, eco-innovation and economic performance, since these three constructs were measured through various subjective indicators obtained by applying a survey. Therefore, in future studies, the use of objective data from companies in the automotive industry (e.g. collaborations agreements, percentage of recycling of raw materials, percentage of cost reduction and percentage of profit margin) will be pertinent, in order to verify if the results obtained differ or not from those obtained in this research paper.

A second limitation of this study is that the relationship between collaboration, eco-innovation practices and economic performance may have better results if a moderating variable of the individual characteristics of the managers of manufacturing firms is integrated (e.g. leadership, commitment, managerial capacity and experience). Therefore, in future studies it would be pertinent to add some moderating variable that significantly improves the relationship between collaboration, eco-innovation and economic performance, in order to corroborate whether the results obtained are similar or better to those obtained in this study, or to replicate this same study in another sector or country to corroborate the results.

The third and final limitation of this study is that only four items were considered for the direct measurement of the collaboration, three constructs and fourteen items for the measurement of the eco-innovation practices, and six items for the measurement of the economic performance, which were the most cited in the scientific literature, but no type or dimension of the collaboration, eco-innovation and economic performance was considered, so in future studies it will be relevant to consider other types of measurement scales or some of the most cited dimensions in the scientific literature to corroborate the results obtained, or apply this same survey in other countries of Latin America and in other sectors of economic activity to verify whether the results are similar.

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